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Neuropsychologie fobické reakce na hady
Neuropsychology of phobic reaction to snakes

Vedoucí práce: doc. PhDr. Petr Kulišťák, Ph.D.

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Poděkování

Chtěl bych zde především poděkovat svému školiteli doc. PhDr. Petru Kulišťákovi, Ph.D. za jeho odvahu pustit se společně se mnou do psychologicky nepříliš tradičního tématu, za jeho osobitý laskavý přístup, nepředstíraný zájem o taje lidských i hadích duší, dlouholetou podporu a neposledně i inspirující široký (nejen neuropsychologický) přehled. Velké díky patří i Národnímu ústavu duševního zdraví v Klecanech, který poskytl nezbytné zázemí a zejména pokročilé přístrojové vybavení, bez kterého by tato práce nemohla vzniknout. Rovněž děkuji všem svým dobrovolníkům, kteří se ochotně a nebojácně vrhli do všech připravených výzkumů, aniž by z toho cokoliv měli. Na závěr chci poděkovat i své rodině, která to opět vše trpělivě snášela.

Prohlášení

Prohlašuji, že jsem dizertační práci napsal samostatně s využitím pouze uvedených a řádně citovaných pramenů a literatury a že práce nebyla využita v rámci jiného vysokoškolského studia či k získání jiného nebo stejného titulu.

Ve Štěchovicích, dne 31. 3. 2021 Mgr. Jakub Polák, Ph.D. v.r.

Abstrakt

Had je psychologicky velmi silný podnět vyvolávající u velké části populace intenzivní strach a zároveň způsobuje jednu z nejčastějších specifických fobií. Podle evoluční hypotézy je univerzální rozšíření strachu z hadů výsledkem selekčních tlaků, protože jedovatí hadi představovali v průběhu evoluce člověka zdroj smrtelného nebezpečí. Dosavadní psychologické výzkumy proto využívali hada jako archetypální spouštěč strachu. Hadi jsou však jako skupina velice variabilní z hlediska morfologie, zbarvení, jedovasti i chování. V této dizertační práci se tak pomocí řady nástrojů snažím ověřit hypotézu, že namísto strachu mohou některé druhy hadů vyvolávat v lidech spíše odpor. Celá práce je rozdělena do čtyř na sebe navazujících studií: 1) psychodiagnostika strachu z hadů a odporu pomocí standardních škál, 2) subjektivní hodnocení obrázků hadů vyvolávajících strach a odpor, 3) měření fyziologické odpovědi a 4) měření neurální aktivace pomocí fMRI. Pro každou ze čtyř výzkumných částí byl studován odlišný vzorek experimentálních osob, vždy se však jednalo o muže a ženy starší 18 let s odlišnou individuální mírou strachu z hadů a tendencí k prožívání odporu. Naprostou většinu tvořili zdraví dobrovolníci, pouze do fMRI experimentu byly zařazeny i osoby s fobií z hadů nebo pavouků. Z výsledků jednotlivých studií vyplývá, že 1) strach z hadů v české populaci je srovnatelný s ostatními zeměmi; 2) 2,6% osob dosahuje skóru typického pro pacienty s fobií z hadů; 3) had je v rámci plazů i ostatních zvířat hodnocen na škále strachu nejvýše; 4) mezi hady lze rozlišit dvě distinktní skupiny podle toho, zda vyvolávají převážně strach (zmijovití) nebo odpor (slepákovití), tyto dvě skupiny se od sebe liší tvarem těla, zbarvením, velikostí hlavy, jedovatostí i způsobem života; 5) na hodnocení strachu ze zmijovitých hadů existuje mezikulturní shoda; 6) obě skupiny hadů lze rozlišit i pomocí fyziologického záznamu, kdy hadi působící převážně strach vyvolávají intenzivnější galvanickou kožní reakci a srdeční tep a 7) obě skupiny hadů vyvolávají i odlišnou neurální odpověď, kdy hadi vzbuzující strach více aktivují primární zrakovou kůru a přilehlé oblasti zodpovědné za vizuální zpracování a udržování selektivní pozornosti. Závěrem je možné shrnout, že lidé i bez jakýchkoliv znalostí demonstrují schopnost rozpoznávat a specificky emočně reagovat na nebezpečné druhy jedovatých hadů.

Klíčová slova: evoluční psychologie; amygdala; neuropsychologie emocí; odpor; ofidiofobie; psychofyziologie; strach z hadů

Abstract

The snake is a psychologically very strong stimulus that triggers intense fear in a large part of the population and at the same time causes one of the most common specific phobias. According to an evolutionary hypothesis, universal snake fear is a result of selection pressures, because during evolution of the mankind, venomous snakes presented a deadly threat. Previous psychological research has therefore used the snake as a prototypical trigger of fear. However, snakes as a group are very variable in terms of morphology, colour, toxicity, and behaviour. In this dissertation, I have adopted several tools to verify the hypothesis that some species of snakes may elicit disgust rather than fear. The whole work is divided into four consecutive studies: 1) psychodiagnostics of fear of snakes and disgust using standard scales, 2) rating of snake images according to fear and disgust, 3) measurement of physiological response and 4) measurement of neural activation using fMRI. A different sample of subjects was studied in each of the four parts, however, men and women aged 18 or older with varying levels of fear of snakes and disgust propensity were included. They were mostly healthy subjects, only the fMRI experiment also included people with snake and spider phobia. The results of individual studies show that 1) fear of snakes in the Czech population is comparable to other countries; 2) 2.6% of people might be considered having snake phobia based on their score; 3) the snake is rated as the most frightening within reptiles and other animals; 4) two distinct groups of snakes can be distinguished based on whether they trigger mostly fear (vipers) or disgust (blind snakes), these two groups differ in body shape, colour, head size, toxicity, and behaviour; 5) fear of vipers is universal across different cultures; 6) both groups of snakes trigger a distinct physiological response as fear-eliciting snakes trigger a stronger galvanic skin response and a faster heart rate; 7) both groups of snakes also elicit a different neural response as fear-eliciting snakes trigger significantly stronger activation in the primary visual cortex and adjacent areas responsible for visual processing and sustained motivated attention. To conclude, humans even without any knowledge of snakes demonstrate an impressive ability to recognize and specifically respond emotionally to dangerous species of venomous snakes.

Keywords: amygdala; disgust; evolutionary psychology; fear of snakes; neuropsychology of emotions; ophidiophobia; psychophysiology

Obsah

I. Teoretická část

II. Výzkumná část

Předmluva

Nejchytřejší ze všech polních zvířat, která Hospodin Bůh učinil, byl had. (Genesis 3, 1)

Hospodin Bůh tehdy řekl hadovi: „Za to, cos udělal, budeš zlořečený mezi vším dobytkem i divokými zvířaty. Po všechny dny svého života polezeš po břiše a žrát budeš prach. Rozpoutám také nepřátelství mezi tebou a ženou i mezi tvým a jejím potomkem. On ti rozdrtí hlavu a ty mu rozdrtíš patu.“ (Genesis 3, 14-15)

Téma předkládané dizertační práce stálo dosud trochu stranou hlavního proudu psychologického výzkumného zájmu, ačkoliv s jistou neskromnou nadsázkou by se dalo říci, že se dotýká samotných evolučních kořenů lidské psychiky a principů, na jejichž základě se utvářela specifická část naší mysli. Zabývá se totiž základními emocemi, konkrétně mechanismy, jakými lidský mozek reaguje v situacích bezprostředního ohrožení. Pro studium tohoto fenoménu si vybírá prototypický, evolučně relevantní podnět, který je pravděpodobně jedním z nejstarších zdrojů nebezpečí, kterému museli předci moderního člověka pravidelně čelit ve svém každodenním životě a se kterým se často setkává i velká část současné civilizace. Člověk se po dobu několika miliónů let vyvíjel vedle celé řady různých druhů zvířat. Množství a pestrost fauny, se kterou přicházel do častého kontaktu, bylo ve srovnání s dnešní dobou pravděpodobně nepoměrně větší (Serpell, 1996). Člověk se musel naučit jednotlivá zvířata rozpoznávat a adekvátně na jejich přítomnost reagovat. Řada zvířat se pro prehistorického člověka stala nezbytným zdrojem utilitárních požitků v podobě potravy (maso, kostní dřeň, vejce, později v době neolitické revoluce mléko a v některých lidských kulturách i krev), ošacení (kůže a srst), materiálu k výrobě nástrojů (kůže, kosti, rohy a parohy). Vedle našich fyziologických potřeb však zvířata naplňovala i ty psychologické, jelikož se pro nás stala zdrojem radosti spojené s estetickým vnímáním jejich krásy (Boyd & Silk, 2017). Části zvířecích těl pak také sloužily jako ozdoby či symboly společenského statutu (kosti, zuby, kožešiny, ptačí peří apod.). Nakonec s nástupem domestikace jsme začali zvířata využívat i jako levnou pracovní sílu či rodinné společníky. Především dnes zvířata plní důležitou společenskou, estetickou a terapeutickou funkci, a proto by se současná psychologie měla více zabývat vzájemným vztahem lidí a zvířat.

Vedle druhů, ze kterých člověk profitoval, existovalo i množství dalších zvířat, která pro něj představovala značné nebezpečí, jelikož mu mohla způsobit vážná zranění, otravu, či být zdrojem různých parazitárních infekcí, což v tehdejších predindustriálních podmínkách mělo pro lidi často fatální následky (Barrett, 2005). Přestože v dnešním světě se lidský druh považuje za tzv. super-predátora stojícího na špici potravního řetězce a zcela dominujícího celému ekosystému (Darimont, Fox, Bryan, & Reimchen, 2015), ještě v pozdním paleolitu (před 10 000 lety) tomu tak rozhodně nebylo. Zatímco nejpravděpodobnější příčinou smrti moderních lidí je infarkt, mozková příhoda či rakovina, v evoluční minulosti jsme nejčastěji umírali jako kořist ostatních predátorů. Ve světě obývaném velkými kočkovitými a psovitými šelmami, dravými ptáky, či mohutnými plazy bylo poměrně snadné stát se potravou (Hart & Sussman, 2005).

Ve východní Africe, kolébce lidstva, patřili hadi mezi jedny z nejnebezpečnějších zvířat. Smrt lidem nezpůsobovali pouze uštknutím při vlastní obraně, ale řada větších škrtičů byla aktivními predátory lovícími tehdejší předky člověka i další primáty (McGrew, 2015). Tak významný selekční tlak vedl k tomu, že setkání s hadem bylo doprovázeno intenzivními prožitky strachu. Navíc strach z hadů je velmi pravděpodobně mnohem starší než lidstvo samo. Můžeme ho totiž pozorovat u množství živočichů, a tak je velmi pravděpodobné, že člověk ho pouze zdědil od svých savčích předků (Öhman & Mineka, 2003). Strach z hadů posléze přečkal veškeré změny spojené s vývojem lidského druhu a v takřka nezměněné formě se dodnes vyskytuje i u moderních lidí napříč společnostmi a stupni kulturního vývoje. I v současném moderním světě pravděpodobně nenajdeme zvíře (snad kromě pavouků), které by v lidech vyvolávalo větší strach a způsobovalo v takové míře klinicky diagnostikovanou specifickou fobii (Davey, 1994). Strach však není to jediné, co v nás had vyvolává. Had má důležité postavení nejenom z hlediska biologického přežití našeho druhu, ale zastává i podstatnou roli v kulturním vývoji. Je totiž nositelem celé řady často protikladných antropomorfizovaných vlastností či symbolů a těžko budeme hledat jiné zvíře, které by bylo srovnatelné z hlediska mytologické, náboženské a psychologické významnosti. Jak se pokusím ukázat v následující teoretické části, had provází člověka již od dávné minulosti, je zdrojem jeho nočních můr, ale i určité fascinace, uměleckým objektem, silným emočním stimulem s bohatou psychologickou symbolikou, do kterého si projikujeme světlé i stinné stránky vlastní mysli a zároveň i zvířetem, kterému vděčíme za řadu schopností, které se natrvalo staly součástí naší psychické výbavy.

I. Teoretická část

1. Biologická charakteristika stimulu

Současná zoologická taxonomie[1] rozeznává 3 709 druhů hadů z 25 čeledí, počet popsaných druhů přitom rok od roku mírně vzrůstá, ať už s objevem dříve zcela neznámých druhů anebo díky pokročilým metodám molekulární fylogenetiky[2], která některé poddruhy nově klasifikuje jako samostatné druhy (Uetz & Hošek, 2019). Z hlediska taxonomického zařazení patří hadi (Serpentes) mezi obratlovce (Vertebrata), konkrétně do řádu šupinatých plazů (Reptilia: Squamata). Jedná se o zvířata velmi dobře přizpůsobená svému prostředí a způsobu života. Celá skupina je charakteristická tvarem těla, kdy u nich došlo k sekundární ztrátě končetin, což je v rámci suchozemských obratlovců poměrně unikátní tělní plán[3]. I přes tento zdánlivý hendikep jsou hadi schopni často rychlého pohybu na souši i ve vodě a beznohé tělo jim usnadňuje pohyb i v hustém lesním porostu či pod zemí. Právě adaptace na podzemní (subteránní) prostředí a tendence zde vyhledávat úkryt před predátory pravděpodobně stála za jejich ztrátou končetin před zhruba 100 milióny let (Yi & Norell, 2015), původní formy s ještě dobře vyvinutými končetinami se na Zemi objevili o již 50 miliónů let dříve.

Hadi postupně úspěšně obydleli téměř všechny typy biotopů od pouští, přes savany a lesy, až po hornatou krajinu, svým rozšířením zasahují na pevnině i ve vodě od rovníku až k polárnímu kruhu, ten však už nepřekročili (viz Obr. 1). To je samozřejmě do značné míry způsobeno typem termoregulace, kdy se jedná o ektotermní živočichy s tělesnou teplotou závislou na okolním prostředí. Proto, stejně jako ostatní chladnokrevná zvířata, hadi nikdy nedokázali kolonizovat arktické oblasti a jediným kontinentem zcela bez hadů je tak Antarktida.

Ačkoliv ektotermní způsob termoregulace tělesné teploty do určité míry omezuje rozšíření a životaschopnost hadů, kdy naprostá většina všech známých druhů žije v tropickém a subtropickém pásmu, toto fyziologické nastavení jim přináší i některé výhody. Při poklesu okolních teplot totiž dochází ke zpomalení metabolismu a základních životních pochodů až do

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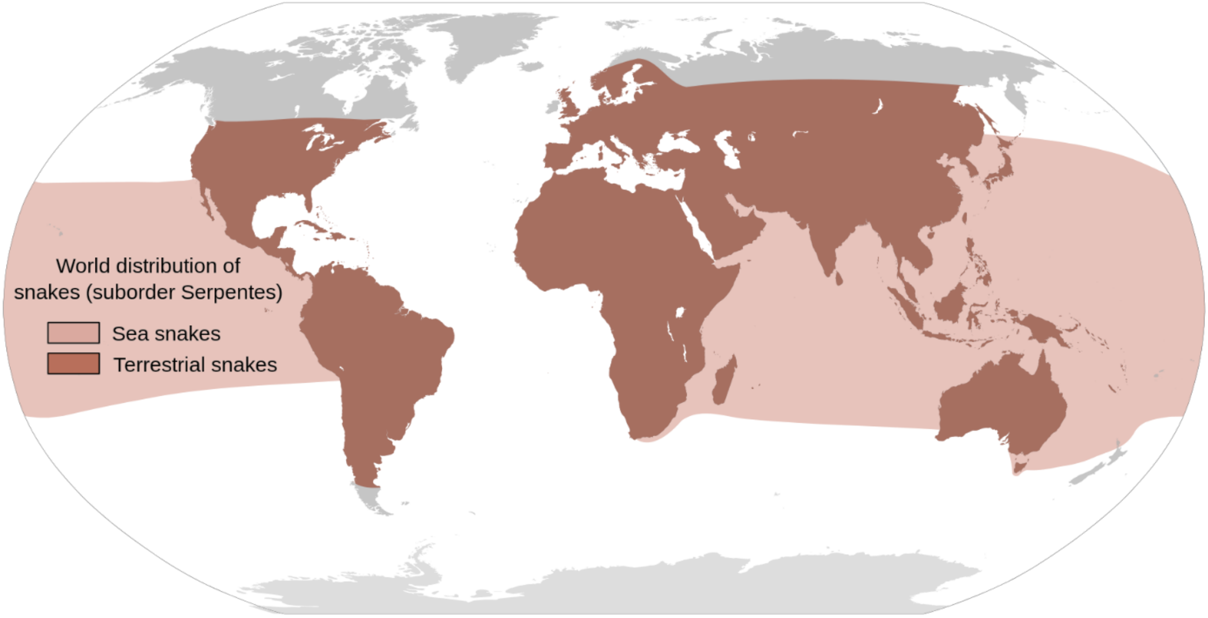
[1] Obor, který se snaží se katalogizovat biodiverzitu a uspořádat ji do systému obvykle hierarchicky řazených skupin.

[2] Podle většinového názoru taxonomů je nejlepším přirozeným systémem organizmů ten, který odráží průběh jejich fylogeneze, tedy vznik a vývoj jednotlivých linií. Molekulární fylogenetika k rekonstrukci těchto vývojových stromů využívá molekulárně biologické znaky, tedy především sekvence DNA.

[3] Hadi však rozhodně nejsou jedinými čtyřnožci (Tetrapoda) s nevyvinutými končetinami. K této specifické adaptaci došlo v evoluci obratlovců, kteří vystoupili na souš, několikrát nezávisle na sobě v různých linií. Z plazů je známý příklad beznohých ještěrek (slepýš, blavor atd.), u obojživelníků jsou to červoři. Ačkoliv mezi ptáky a savci nikdy k úplné ztrátě končetin nedošlo, najdeme zde alespoň druhy s částečnou ztrátou či redukcí (např. moa, kiwi, kytovci a sirény).

stavu strnulosti, např. zmije obecná (*Vipera berus*) tráví zimní období v úkrytu ve stavu hibernace. Schopnost snížit rychlost bazálního metabolismu na minimum pak v případě nedostatku potravy hadům pomáhá přečkat dlouhá období zcela o hladu, větší druhy krajt a hroznýšů takto dokážou vydržet i rok bez toho, aby přijali jakoukoliv potravu (Lillywhite, 2014).

Obrázek 1. Současné celosvětové rozšíření suchozemských a vodních hadů (převzato z en.wikipedia.org/wiki/Snake).



Z hlediska potravní ekologie se jedná o dokonalé lovce. Vyhlédnutou kořist hadi aktivně nepronásledují, ale přepadávají ze zálohy, k čemuž jim často dopomáhá i kryptické zbarvení, kterým napodobují okolní prostředí a jsou tak snadno přehlédnutelní (viz Obr. 2.). Velká část hadů svou kořist uchopí do čelistí a zaživa spolkne (asi 38% všech druhů), zbývající skupina svou kořist nejdříve usmrtí, a to buďto škrcením (11%), vstříknutím jedu pomocí jedových zubů (35%), či oběma způsoby najednou (6%)[4]. Hadí jed, což je v podstatě směs toxinů vzniklých chemickou přeměnou slin[5], má přitom velice starobylý původ a podle jedné uznávané a

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[4] Procentuální zastoupení jednotlivých loveckých strategií jsou pouze hrubé odhady na základě známých druhů hadů, u dalších 10% druhů zatím netušíme, jakým způsobem loví svou kořist ((Durso, 2017)

[5] Obecně se rozlišují dvě hlavní skupiny hadích jedů: 1) neurotoxiny napadající nervovou soustavu a zabraňující šíření akčního potenciálu, oběť umírá poměrně rychle na udušení díky ochrnutí dýchacích svalů (vyskytuje se u korálovcovitých hadů, kam patří kobry, mamby, korálovci apod.) a 2) hemotoxiny rozkládající krevní buňky, což po nějaké době vede k silnému krvácení a nekróze tkáně (produkují ho jedové žlázy zmijovitých hadů (zmije, chřestýši, ploskolebci).

empiricky podložené evoluční hypotézy vznikl dávno před tím, než se na Zemi objevila samotná skupina hadů (a to dokonce až o 100 miliónů let dříve u jejich společného předka s ještěrkami (Zimmer, 2005; Fry et al., 2006). Podle nejnovějších odhadů disponuje jedem až 2000[6] druhů hadů, z nichž více než 200 je člověku velmi nebezpečných (WHO, 2010). Vysoce toxický jed a efektivní jedový aparát mají především zástupci čeledi korálovcovití (Elapidae) a zmijovití (Viperidae), kteří se poprvé objevili na začátku třetihor před zhruba 60 milióny let současně s recentními řády savců.

Obrázek 2. Zmije gabunská (*Bitis gabonica*) skrytá v lesním podrostu (převzato z commons.wikimedia.org/wiki/File:Bitis_gabonica_rhinoceros.JPG, autor: Tim Vickers).

K lovu využívají hadi i pokročilých smyslů. Vzhledem k tomu, že se původně vyvinuli ve zvířata vyhledávající podzemní úkryty, mají hadi většinou nedostatečně vyvinutý zrak i špatný sluch. To však kompenzují především chemorecepcí, kdy pomocí typického rozeklaného jazyku neustále transportují pachové molekuly rozptýlené ve vzduchu do vomeronasálního (Jacobsonova) orgánu umístěného v horním patře ústní dutiny, který tyto signály vyhodnocuje. Spodní strana těla pak obsahuje velké množství hmatových receptorů citlivých na vibrace podkladu. Had tedy dokáže zaregistrovat blížící se zvíře i pomocí nepatrných otřesů

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[6] Až donedávna se počet jedovatých druhů hadů udával okolo 600. Podrobnou analýzou se však zjistilo, že i druhy dosud považované za nejedovaté mohou ve slinách produkovat malé množství toxinů, které se do kořisti dostávají při kousnutí (Fry et al., 2006).

půdy. Nakonec chřestýšovití hadi, krajty a někteří hroznýši mají pod očima zvláštní jamky, ve kterých jsou uloženy receptory reagující na infračervené záření. To jim umožňuje registrovat změny teploty v prostředí, a především vidět tělesné teplo vyzařované teplokrevnou kořistí (Lillywhite, 2014)

Vzhledem k vysokému počtu žijících druhů hadů je pochopitelné, že v rámci celého podřádu existuje vysoká mezidruhová variabilita, co se týče velikosti těla a zbarvení. Hadi mohou dorůstat od několika málo centimetrů[7] až po několik metrů[8]. Najdeme zde druhy s kontrastním (výstražným, aposematickým) zbarvením, kdy se na těle hada pravidelně střídají výrazné barevné vzory (černé, červené, žluté a bílé proužky u korálovců a jim podobných korálovek, tmavá klikatá čára u zmijí, sytě zelené zbarvení u chřestýšovců apod.), či naopak nenápadně zbarvené hady (světle hnědá zmije pouštní, šedé zbarvení mamby černé či některých kober apod.). A právě morfologická variabilita této skupiny a lidské reakce na různé podoby hada budou jedním z hlavních předmětů mé dizertační práce.

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[7] Nejmenším hadem na světě je druh *Tetracheilostoma carlae* z čeledi slepanovití, který dorůstá 10,4 cm.

[8] Nejdelším hadem světa je krajta mřížkovaná (*Malayopython reticulatus*), která může údajně dorůstat délky až 10 m a vážit až 160 kg, největší doložená délka u tohoto druhu byla 9,75 m u jedince pocházejícího z ostrova Sulawesi (Kořínek, nedatováno). Nejtěžším hadem světa je pak anakonda, kdy největší doložený exemplář měřil 9,15 m při váze 250 kg.

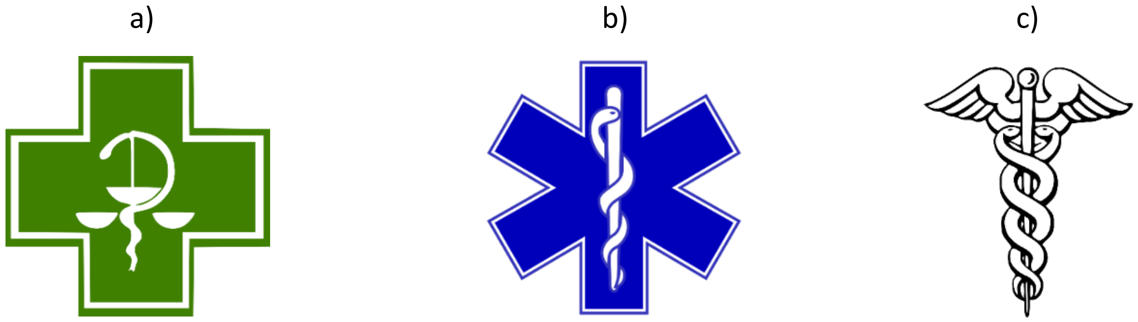
2. Had jako kulturní symbol

Hadi provází člověka po celou jeho evoluční historii a již od počátku přitahovali naši pozornost, vyvolávali v nás silné reakce od hrůzy či opovržení až po obsesivní fascinaci a zároveň se stali významným objektem našich mentálních reprezentací. To ostatně dokládá i rané prehistorické umění doby kamenné, kdy had byl častým motivem zobrazovaným na jeskynních malbách i rytinách do dřeva a kamene (Morgan, 2008). Had je namalovaný i na skalních úkrytech Bhimbetka v Indii ve státě Madhjapradéš. Tento komplex paleolitických nástěnných maleb přitom patří k nejstarším na světě, jejich stáří se odhaduje na 30 000 let (Mathpal, 1984). Had také patří mezi jeden z nejsilnějších, nejstarších a nejrozšířenějších mytologických a posléze i náboženských symbolů spojených s ancestrálními rituály, se kterým se setkáváme napříč různými kulturami po celém světě, od Afriky a Blízkého Východu, přes antické Řecko až po předkolumbovskou Ameriku. Nedávno byl objeven vůbec nejstarší lidstvu známý rituál, kterým již před 70 000 lety uctívali v jedné jeskyni v botswanských horách krajtu (Vogt, 2012). Symbolika hada je přitom duální, reprezentující často protikladné charakteristiky, had je tak obecně ztělesněním dobra i zla zároveň.

V mnoha kulturách, např. u severoamerických indiánů z kmene Hopi, byl had symbolem plodnosti a živí hadi byli po rituálních tancích vypouštěni na pole, aby lidem zajistili bohatou úrodu. Had je i symbolem znovuzrození, životní energie, nesmrtelnosti, věčnosti a neustálého cyklu obnovy života, který je zobrazen jako ouroboros, had požírající vlastní ocas. Tento symbol, původem ze starověkého Egypta, nakonec získal významné místo i v gnostickém myšlení a alchymii. Lidé se při asociaci hadů s regenerací a znovuzrozením pravděpodobně inspirovali způsobem, jakým se hadi zbavují staré kůže, která je pravidelně svlékána v celku, tím si znovuobnovují tu část těla, která je ve styku s okolním světem. S fertilitou navíc souvisí i symbolika erotické energie a sexuální touhy, která je rovněž hadům přisuzována. I v moderní době je had často využíván v reklamách jako erotický symbol (Morgan, 2008).

Díky přítomnosti jedových žláz u řady druhů se had samozřejmě stal také symbolem otravy, ale i zdraví a léčení. Had byl považován za nejchytřejší ze všech zvířat s božskými vlastnostmi, za ztělesnění posmrtného života a věřilo se, že z hadího jedu je možné připravit elixír nesmrtelnosti. Od starověku až do dnešní doby se dochovaly tři nejdůležitější symboly léčení zobrazující hada, které jsou stále běžně užívány: Hygieina miska[9] (pohár, ze kterého pije had, znak lékárnictví), Aeskupalova neboli Asklépiova hůl[10] (hůl obtočená hadem, znak lékařů) a kaduceus (okřídlená berla obtočený dvěma hady směřujícími vzhůru, alchymický archetyp poznání, moudrosti a služby, nesoucí i umění uzdravovat a obnovovat život (Wilcox & Whitham, 2003; viz Obr. 3).

Obrázek 3. Tři moderní znaky lékařství zobrazující hada: (a) Hygieina miska, (b) Aeskulapova hůl a (c) kaduceus (převzato z en.wikipedia.org/wiki/Bowl_of_Hygieia, en.wikipedia.org/wiki/Rod_of_Asclepius a en.wikipedia.org/wiki/Caduceus).



Je zajímavé, že až do vzniku židovsko-křesťanské kultury byl had uctíván v řadě náboženství jako božská bytost s řadou kladných vlastností. Hadí kult měl významné postavení v Mezopotámii, kobra byla ztělesněním bohyně Wadjet ve starověkém Egyptě a její stylizace ve vztyčené pozici (Uraeus) dokonce zdobila i faraónovu korunu, jeden z nejvýznamnějších mezoamerických bohů Quetzalcóatl měl zase podobu okřídleného hada a na rozdíl od většiny aztéckých bohů byl považovaný za dobrého (Stanley, 2008). Tuto tradici však narušila kniha Genesis, která naopak hada popisuje jako zlomyslné, zrádné a pomstychtivé stvoření, skrze nějž promlouval Satan, aby v Rajské zahradě oklamal Evu. Had se tak stal hlavně symbolem pokušení, zla a destrukce, zároveň ale přivedl člověka k vědomí/poznání. Ostatně celá Bible

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[9] Hygieia byla v řecké mytologii dcera boha Asklépia, sama se stala bohyní zdraví a čistoty. Je zobrazována s hadem omotávajícím její tělo. Z jejího jména se odvozuje slovo hygiena.

[10] Asklépion byl údajný řecký léčitel ve 13. století př. n. l., který prý dokázal léčit každou chorobu a přivádět mrtvé k životu. Navrhl systém léčení, při kterém užíval účinků bylin. Za své zásluhy byl později zbožštěn jako bůh lékařství. Existuje však také hypotéza, podle které není kolem Aeskulapovy hole obtočen had, ale parazitický červ vlasovec medinský, jehož dospělé samice žijí po kůží napadeného člověka. Drakunkulóza, jak se tato parazitární infekce nazývá, se ve starověku léčila tak, že se červ pomalu namotával v průběhu i několika týdnů na tenkou dřevěnou tyčku. Podobným způsobem se ostatně červ vytahuje i v současnosti (Hinek & Backstein, 2004).

věnuje hadům značnou pozornost, když je zmiňuje ve více než 80 případech, většinou jako odporné, zavrženíhodné bytosti (“Serpents in the Bible“, 2019). Hadí pověsti v křesťanském světě rozhodně neprospěla řada smrtelně jedovatých druhů rozšířených v daném regionu (tedy především oblast Předního východu) a jejich tendence útočit nečekaně ze zálohy, stali se tak symbolem nebezpečí a smrti.

Had má významné postavení i v psychoanalýze, jeho význam však různé směry interpretují odlišně. Podle Freuda, stejně jako řada jiných podnětů, představuje had typický falický symbol, sexualitu spojovanou s mužstvím či mužskou energii v psychice ženy. Sny o hadech[11] pak vysvětloval jako odraz potlačené sexuální touhy či vnitřní konflikt související s vyjadřováním a prožíváním vlastní sexuality. Carl G. Jung zase vnímal hada jako symbol moudrosti Přírody a v jeho plazivém pohybu viděl způsob dosažení cíle, který může být často lepší než nejkratší přímá cesta. Sny o hadech potom měly znamenat vnitřní konflikt (diskrepanci) mezi postoji vědomé mysli a instinkty a had měl symbolizovat ohrožení vznikající z tohoto konfliktu (Gabbard, Litowitz, & Williams, 2012).

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[11] Až 50% lidí se někdy zdálo o hadovi.

3. Hypotézy vzniku strachu z hadů: vrozený vs. naučený

Strach z hadů je u lidí univerzálně rozšířený po celém světě napříč různými etniky bez ohledu na stupeň kulturního a technologického vývoje (Seligman, 1971; Merckelbach, Van den Hout, & Van der Molen, 1987; Ware, Jain, Burgess, & Davey, 1994; Davey et al., 1998). Agras, Sylvester a Oliveau (1969) provedli ve státě Vermont epidemiologickou studii zaměřenou na rozšíření různých strachů v obecné populaci. Na základě rozhovorů s 325 respondenty došli jednoznačně k závěru, že had byl jako obávaný podnět zmíněn vůbec nejčastěji, a to u 39% dotázaných. Intenzivní míru strachu z hadů pak zmínilo 38% žen a 12% mužů . Dokonce i na britských ostrovech, které jsou z hlediska četnosti výskytu i druhové diverzity hadů velmi chudou oblastí[12], nejvíce lidí uvedlo, že ze všech tamních zvířat se nejvíce bojí právě hadů (téměř 60% žen a zhruba 45% mužů). Hadi jsou také předmětem jedné z nejčastějších specifických fobií, v obecné populaci má klinický strach z hadů prevalenci 2-3% (Klorman, Weerts, Hastings, Melamed, & Lang, 1974; Fredrikson, 1983; Klieger, 1987).

K vysvětlení vzniku a všeobecného rozšíření strachu z hadů vznikly tři hlavní teorie lišící se především na základě toho, zda hlavní roli přisuzují vlivu učení či působení vrozených (genetických) faktorů. Nejstarším je model klasického učení, který předpokládá, že pro vznik strachové reakce na konkrétní podnět je nejprve nezbytný výskyt přímé podmiňující traumatické zkušenosti. Mnohé laboratorní experimenty prokázaly, že u člověka je takto možné i v umělých podmínkách navodit intenzivní strach z jakéhokoliv podnětu (McNally, 1987). Jedním z nejznámnějších pokusů se stal případ „Malého Alberta“, 9-měsíčního chlapce, u kterého se J. B. Watsonovi podařilo navodit fobii z laboratorních potkanů pomocí asociace s averzivním hlasitým zvukem (Watson & Rayner, 1920). Rachman (1977) poté teorii klasického podmiňování rozšířil o dvě nepřímé cesty asociativního učení strachu: pozorováním a slovním předáním informace. Bylo např. potvrzeno, že batolata se naučí vyhýbat hračce hada, pavouka, květiny nebo houby na základě pozorování negativního výrazu tváře matky (Gerull & Rappe, 2002). Další studie naopak ukázala, že pozorováním pozitivního modelového

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[12] Ve Velké Británii žijí pouze čtyři druhy hadů, z nichž jediná zmije obecná je mírně jedovatá, pro zdravého dospělého člověka však nepředstavuje žádné významné riziko (Valenta, 2008). V přírodě sousedního Irska hadi chybí úplně.

chování matky lze u batolat navodit pozitivní reakce na hračku hada a pavouka (Egliston & Rapee, 2007).

Ačkoliv existuje řada důkazů podporujících teorii přímého či zprostředkovaného učení při vzniku strachu z různých podnětů, konkrétně v případě hadů se příliš neosvědčila. Podle retrospektivních studií si naprostá většina lidí trpících intenzivním strachem z těchto zvířat nedokáže vybavit žádnou negativní zkušenost (napadení, kousnutí hadem), která by tomu předcházela. Doctor, Kahn, a Adamec (2008) dokonce uvádí, že až 85% lidí projevujících hrůzu z hadů nikdy žádného živého hada ani nevidělo. Navíc v případě vysoce nebezpečných podnětů, které mohou již při prvním setkání člověka zabít (jako celá řada prudce jedovatých hadů), by cesta klasického podmiňování naivnímu (nezkušenému) jedinci samozřejmě nijak nepomohla v budoucím přežití. Proto byl vytvořen model neasociativní vzniku strachu, podle kterého reakce na vybrané podněty nevyžaduje žadnou předchozí negativní zkušenost. Strach je tedy vrozený, zakódovaný do genetické výbavy člověka a měl by být aktivován okamžitě při prvním vystavení se podnětu (Poulton & Menzies, 2002). Podpůrné důkazy pro neasociativní hypotézu pocházejí především z již zmíněných retrospektivních výpovědí lidí s fobií, kteří většinou nejsou schopni úvest žádný prvotní spouštěč takové reakce v podobě traumatického zážitku. Dalším důkazem může být částečně i zjištění, že specifické fobie ze zvířat se často vyskytují v rámci rodiny (tedy jejich prevalence u geneticky příbuzných jedinců je signifikantně vyšší než odpovídá obecné populaci: Davey, Forster, & Mayhew, 1993; Lichtenstein & Annas, 2000) a fobie jsou tak pravděpodobně výsledkem společného působení genetických faktorů a individuálních zkušeností (Kendler, Neale, Kessler, Heath, & Eaves, 1992), ačkoliv rozlišit v takových případech vliv dědičnosti a prostředí je velmi obtížné. Stejně tak někteří autoři kritizovali hypotézu, která se do značné míry opírá o retrospektivní výpovědi jedinců postižených iracionálním strachem, které mohou být velmi nespolehlivé. Jak argumentuje Mineka a Öhman (2002), neschopnost rozpomenout se na negativní zkušenost vedoucí k rozvoji fobie ještě nemusí nutně znamenat, že taková zkušenost nikdy nenastala.

Vzhledem k nedostatkům obou uvedených teorií proto Martin Seligman, amerických psycholog známý především pro svůj výzkum naučené bezmocnosti při rozvoji deprese, koncipoval v roce 1971 model biologické připravenosti učení, který je ve skutečnosti propojením asociativního a neasociativního modelu. Seligman (1971) si totiž všiml, že zatímco v laboratorních podmínkách je možné pomocí klasického podmiňování navodit strach téměř z jakéhokoliv podnětu, naprostou většinu klinických případů fobií z realného života vyvolává pouze velmi omezený počet podnětů: výšky, otevřená postranství, skupina lidí a zvířata, a to především hadi a pavouci[13]. Tedy distribuce strachu v populaci je z hlediska jeho spouštěčů nenáhodná a jednotlivé obávané objekty či situace se liší ve svém potenciálu strach vyvolat. Ve všech zmíněných případech se jedná o zdroje nebezpečí, které se opakovaně vyskytovaly v průběhu evoluce člověka, a proto musel vzniknout kognitivní mechanismus, který upřednostňoval rychlé učení se reagovat na takové podněty strachem (často již po jediné expozici), což mohlo zajistit budoucí přežití jedince. Takový geneticky předávaný mechanismus připravenosti učení tedy zajistí, že člověk má vrozenou tendenci přednostně asociovat hrozbu s evolučně relevantními nebezpečnými stimuly. Již během velmi krátké zkušenosti u něj dojde k rozvoji intenzivního strachu, který je navíc trvalý. Přitom není podstatné, zda je tato prvotní zkušenost přímá či pouze zprostředkovaná pozorováním reakcí ostatních členů skupiny, stále se tedy i v tomto případě uplatňují tři cesty učení, jak je definoval Rachman (1977). Je však zcela nezbytné, aby výskyt daného podnětu byl doprovázen negativní asociací (ať už přímým averzivním podnětem či pozorováním výrazu strachu u druhých). Díky tomuto mechanismu je tedy mnohem pravděpodobnější, že člověk bude trpět fobií z hadů či pavouků a ne např. ze zbraní, elektrických zásuvek či automobilů, což jsou z hlediska evoluce zcela neznámé a tedy nevýznamné hrozby, ačkoliv v moderním světě každým rokem zabijí nespočetně více lidí[14]. Seligman (1971) na základě své teorie následně vyvodil tři hlavní předpoklady: 1) i v laboratoři by mělo být mnohem snazší a rychlejší (často během jediné expozice) vyvolat strach z hadů a pavouků než z jiných podnětů, 2) tento strach by měl být intenzivnější a 3) navíc i mnohem trvalejší díky větší odolnosti vůči vyhasínání. Zároveň také předpoklídal, že takto předpřipravený strach z ancestrálních zdrojů nebezpečí bude "méně kognitivní" (tedy pod menší kontrolou rozumu) a bude zprostředkovaný spíše evolučně staršími oblastmi mozku.

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[13] Öhman, Dimberg, & Öst (1985) rozkategorizovali strach u lidí do tří hlavních skupin: 1) z fyzických objektů nebo událostí (např. výšky, bouřka,…), 2) z ostatních lidí a 3) strach ze zvířat, což odpovídá třem nejdůležitějším kategoriím fobických objektů uvedených i v pátém vydání Diagnostického a statistického manuálu duševních poruch (DSM-5: Raboch, Hrdlička, Mohr, Pavlovský Pavel, & Ptáček, 2015): příroda, sociální prostředí a zvířata.

[14] Podle nejnovějších odhadů Světové zdravotnické organizace zabije hadí uštknutí ročně 81 000 až 138 000 lidí (WHO, 2019a), zatímco v automobilových nehodách zahynulo v roce 2018 1 350 000 lidí (WHO, 2019b).

Seligmanova teorie od svého zveřejnění inspirovala intenzivní experimentální výzkum a dodnes je považována za jednu z nejvlivnějších teorií vzniku fobií. Za posledních více než 40 let získala i poměrně přesvědčivou podporu, především pak její poslední předpoklad o větší odolnosti strachu z evolučních hrozeb vůči vyhasínání (pro přehled viz McNally, 2016). Stala se i základem pro dvě novější vlivné teorie původu strachu z hadů, které do značné míry čerpají i z poznatků evoluční neuropsychologie, a to tzv. modul strachu (Öhman & Mineka, 2001) a teorie detekce hada (Isbell, 2006, 2009), které budou detailněji popsány v kapitole 7.

4. Fylogeneze a ontogeneze strachu z hadů

Hadi samozřejmě nevyvolávají strach pouze u člověka, ale i u celé řady dalších druhů zvířat, zejména pak mezi primáty. Ačkoliv zdokumentovaných přímých pozorování interakce primátů s hady v divoké přírodě není příliš mnoho, King (1997) ve svém přehledu všech publikovaných prací uvádí, že alespoň u 11 rodů primátů z 5 různých čeledí byly zaznamenány behaviorální reakce související s pocitem ohrožení. Opice v takovém případě na přítomnost hada reagovaly zvýšenou pozorností (ostražitým chováním), vyhýbáním, poplašným voláním a gestikulací, mobbingem[15] a někdy i jeho zabitím. Klíčovou roli pravděpodobně hraje velikost hada, přičemž kritickou hranicí pro zvýšený strach se zdá být délka 1,8 m. Tu překonávají hlavně krajty, hroznýši a anakondy, tedy velcí škrtiči, kteří primáty aktivně loví. Menší hadi, pokud jsou nejedovatí, vyvolávají u primátů mnohem variabilnější reakce od chladného nezájmu, přes zvědavost a hru až po konzumaci. Podle Kinga (1997) však velikost není rozhodující v případě strachu z jedovatých hadů, což předpokládá schopnost primátů tyto nebezpečné druhy rozpoznávat, což bylo potvrzeno např. u malpy pruhohřbeté (*Cebus libidinosus*; Falótico et al., 2018).

Všeobecné rozšíření strachu z hadů napříč lidskou populací i výskyt tohoto fenoménů u blízce příbuzných druhů již od začátku vyvolávalo otázku, jaký má taková reakce původ. Tedy zda je strach z hadů vrozený, anebo se ho jedinec naučí až v průběhu života na základě vlastních negativních zkušeností s hady (traumatických zážitků) či zprostředkovaně od ostatních členů skupiny skrze sociální učení. Pro psychologii charakteristický dlouhodobý myšlenkový střet o zásadním vlivu dědičnosti vs. výchovy (nature vs. nurture) tak ovlivnil i teoretické pojetí a vědecký výzkum tohoto fenoménu (Tierney & Connolly, 2013; Baynes-Rock, 2017).

Primatologické studie se hlavně zaměřily na porovnání reakcí divoce žijících a laboratorních (z hlediska zkušeností s hady tedy naivních) opic. Nejzásadnější a tedy i nejcitovanější práce vznikly pod vedením Susan Mineky působící na katedře psychologie Wisconsinské univerzity a posléze Northwestern University. Mineka, Keir a Price (1980) zjistili, že zatímco opice odchycené z divoké přírody reagovaly intenzivním strachem na živého hada i neživé předměty hada připomínající (gumová hračka anebo model), reakce opic chovaných od narození

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[15] Mobbing je typem antipredačního chování, kdy skupina jedinců stejného druhu (kořisti) obklopí predátora, vydává varovné zvuky a může dojít i k fyzickým útokům na predátora s cílem ho zahnat a ochránit tak mláďata.

v laboratoři byly naproti tomu velmi nevýrazné. Navazující studie pak potvrdila, že k navození intenzivního strachu z hadů u původně nebojácných mláďat makaka rhesus (*Macaca mulatta*) narozených v laboratoři stačí, aby krátce (učení dosáhlo maxima již po 8 minutách) pozorovala reakci svých (původně divoce žijících) rodičů na živého hada, hračku i jeho model (Mineka, Davidson, Cook, & Keir, 1984). Tento efekt observačního učení se projeví i v případě, kdy mláďata pozorují reakce zcela nepříbuzných opic (Cook, Mineka, Wolkenstein, & Laitsch, 1985).

Průlomovým z hlediska porozumění původu strachu z hadů u primátů se však stal až výzkum z konce 80. let. Cook a Mineka (1989) v důmyslném experimentu pouštěli laboratorním makakům bez jakékoliv předchozí zkušenosti s hady film, ve kterém dospělá opice reagovala strachem na hračku hada. Pouhé sledování tohoto záznamu stačilo k tomu, aby se i makak sedící před televizní obrazovkou začal hračky hada bát, což se projevilo i 3 měsíce po experimentu. Autoři poté sestříháním vyrobili další film, ve kterém ta samá modelová opice projevovala stejnou hrůzu při setkání s umělou květinou, k navození strachu z květin u pozorující opice to však nestačilo[16]. Dále se prokázalo, že podobně lze nepřímou zkušeností zprostředkovanou pozorováním filmu napodmiňovat u makaků i strach z hraček v podobě krokodýlů, nikoliv však králíků[17].

Výsledky dosavadních výzkumů tak ukazují, že primátům scie není vrozený přímo strach z hadů (v takovém případě by se totiž i naivní opice narozené a vychovávané v laboratoři bez jakékoliv předchozí zkušenosti bály při setkání s hadem), existuje však vrozená tendence přednostně asociovat hady s nebezpečím a rychle se strachu z nich naučit. K tomu většinou dochází pozorováním reakcí ostatních opic ve skupině a i velmi krátká expozice stačí k rozvoji silné celoživotní averze. Tento selektivní mechanismus observačního napodmiňování se uplatní pouze v případě evolučně relevantní hrozby v podobě hadů či krokodýlů, tedy dlouhodobých predátorů primátů, nefunguje však v případě neutrálních podnětů, jako jsou květiny nebo i zvířata, která primáty nikdy nelovila (např. králíci). Podle jedné z nejnovějších studií hadi

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[16] Stejného výsledku bylo dosaženo i v další studii obou autorů, kdy jedna skupina laboratorních opic sledovala film s dospělcem makaka reagujícího strachem na hada a neutrálně na květinu a druhá skupina viděla dospělou opici reagující neutrálně na hada a strachem na květinu. Opět se potvrdilo, že pouze jedinci z první skupiny po zhlédnutí záznamu projevovaly strach z hadů, na rozdíl od opic z druhé skupiny, které se nezačaly bát květin (Cook & Mineka, 1990).

[17] V tomto kontextu je důležité, že s žádným z testovaných stimulů (tedy had, květina, krokodýl a králík) se experimentální opice před tím nikdy nesetkaly.

vyvolávají u primátů strach nejenom skrze vizuální percepci, ale podobné reakce způsobí i hadí pach u naivních opic (Weiss, Brandl, & Frynta, 2015).

Vedle zvířecích modelů se výzkum zaměřil i na ontogenezi strachu z hadů u lidí ve snaze objasnit, zda se jedná o vrozenou reakci či naopak vlastnost získanou až v průběhu života. Ideálním experimentálním subjektem k tomu jsou předevevším děti, u kterých předpokládáme nulový či alespoň do určité míry omezený vliv zkušenosti s daným podnětem. Četná pozorování však napovídala tomu, že velmi malé děti se hadů většinou nebojí. V roce 1928 dva američtí psychologové H. E. Jones a M. C. Jones v rámci jednoho experimentu zavírali děti různého věku do místnosti s velikým, avšak zcela neškodným hadem a pozorovali, jaké budou jejich reakce. Zatímco děti mladší 2 let neprojevovaly žádný strach, 3-4leté už byly ostražité, ale jasné známky strachu byly pozorovatelné až u dětí starších 4 let (Doctor et al., 2008). Podobně i Morris a Morris (1965) uvádějí, že strach z hadů je u britských dětí nejvyšší mezi 4. a 6. rokem, kdy jím trpí až třetina dětské populace (Muris, Merckelbach, & Collaris, 1997), poté postupně klesá až do 14 let (viz také Prokop, Özel, & Uşak, 2009).[18]

Evoluční hypotézu o vzniku strachu z hadů se rozhodly studovat i americké psycholožky DeLoache a LoBue (2009), jejichž publikace výzkum tohoto fenoménu výrazně posunula. V sérii několika experimentů se především snažily prokázat, zda strach z těchto zvířat je lidem vrozený a nepotřebují tedy k jeho navození žádný podmiňovací stimulus či zkušenost (tzv. neasociativní pohled na vznik strachů a fobií, viz Menzies & Clarke, 1995), anebo je vrozená spíše tendence spojovat si hady se strachem (tedy asociativní pohled na etiologii, viz Seligman, 1971; Öhman & Mineka, 2001). Vybraly si k tomu velmi malé děti ve věku 9-10 měsíců, u kterých nepředpokládaly žádnou dřívější zkušenost s hady. V prvním experimentu jim pouštěly krátká videa hadů a dalších exotických zvířat a sledovaly, zda filmy zobrazující plazícího se hada přitáhnou větší pozornost nemluvňat a budou se na ně dívat déle v porovnání s ostatními zvířaty (nosorožec, slon, žirafa, hroch, atd.) To se však nepotvrdilo a autorky tím tedy zavrhly hypotézu, že i ve velmi nízkém věku je bez dalšího emocionální zarámování reakce na hady odlišná, tedy zamítly neasociativní vysvětlení.

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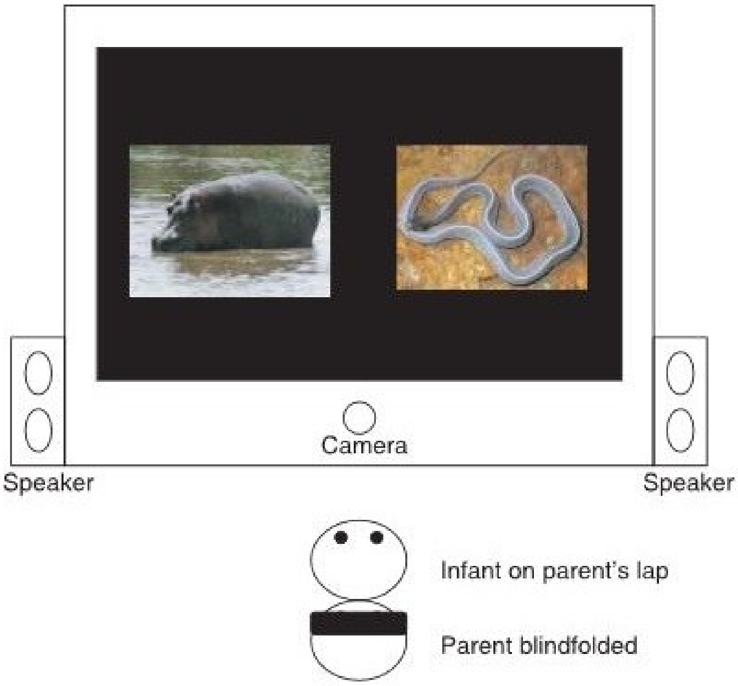
[18] Jedna velká mezikulturní srovnávací studie provedená na 2570 dětech ve věku 7-14 let z 10 zemí světa dokonce zjistila, že řada dětí v tomto věku má hady v oblibě a většina z nich by je chtěla i chránit (Ballouard et al., 2013)

V navazujícím experimentu tedy ke stejným filmovým ukázkám různých zvířat včetně hadů ještě přidaly další podnět, a to nahrávku ženského či mužského hlasu, který v neexistujícím jazyce říkal větu buďto vyděšeným, nebo naopak šťastným výrazem. Dítě ve věku 9-18 měsíců tedy sedělo na klíně rodiči (který měl zavázané oči, aby ho nemohl nijak ovlivňovat) a na plátně se mu promítala vždy náhodná dvojice videí, z nichž jedno zobrazovalo plazícího se hada a na druhém bylo jiné zvíře pohybující se zhruba stejnou rychlostí. Zároveň s tím byl z reproduktorů pouštěn vyděšený či šťastný hlas, opět náhodně přiřazený (viz Obr. 4.). Opět se měřil čas, jaký dítě věnovalo oběma filmovým ukázkám.

Obrázek 4. Design experimentu použitý při výzkumu strachu z hadů u malých dětí (převzato z DeLoache & LoBue, 2009) .



Z výsledků vyplývá, že děti sledovaly hada signifikantně delší dobu v případě, že poslouchaly vyděšený hlas v porovnání se šťastným hlasem, zatímco u jiného zvířete se efekt typu pouštěného hlasu neprojevil. V posledním experimentu ještě otestovaly stejný design, pouze s tím rozdílem, že místo videí použily statické fotky. Tentokrát však žádný rozdíl v době sledování hada při poslouchání různých hlasů nevyšel. To je tedy možné interpretovat tak, že už velmi malé děti bez jakékoliv zkušenosti mají vrozenou tendenci asociovat hady jako evolučně relevantní hrozbu s projevy strachu někoho jiného (modelu), ačkoliv samy žádný strach při sledování hada neprojevují (LoBue, Rakison, & DeLoache, 2010). Had se však musí plazit, asociace funguje jen v situaci, kdy dítě vidí vlnivý pohyb, který je pro hady charakteristický (žádné jiné známé zvíře se takto nepohybuje), u statických obrázků tento signál ztrácí hodnotu (DeLoache & LoBue, 2009).

Přestože se v této studii nepodařilo objevit žádné mezipohlavní rozdíly v reakcích nemluvňat na hady, v podobném experimentu s 11měsíčními dětmi snáze asociovaly obrázek hada či pavouka (ve srovnání s obrázkem květiny nebo houby) se strachem (tentokrát v podobě vyděšené tváře) pouze dívky, zatímco u chlapců se žádný efekt neprokázal (Rakison, 2009). Z toho vyplývá, že vrozená tendence rychlého učení se strachu z hadů je spíše charakteristická pro ženy, což by mohlo vysvětlit i fakt, proč prevalence normativního i klinického strachu z hadů (fobie) má mnohonásobně vyšší prevalenci právě u žen než u mužů (8,3% vs 2,4%: Fredrikson, Annas, Fischer, & Wik, 1996).[19]

V dalších letech se výzkum spíše zaměřil na fyziologické reakce autonomního nervového systému nemluvňat při setkání s hadem. Např. Erlich, Lipp, & Slaughter (2013) měřili fyziologickou (srdeční tep, elektromyografie (EMG) kruhového oční svalu zaznamenávající úlekové mrkání) a behaviorální (vizuální orientace směrem ke zdroji stimulu či k pečující osobě) odpověď na různé druhy zvuků. Potvrdili tak, že 6-9měsíční děti odlišně reagují na syčení hadů (a další evolučně relevantní zvuky ohrožení jako jsou agresivní hlasy, pláč, praskání ohně, či hrom) v porovnání se zvuky moderní hrozby (exploze výbušniny, tříštění skla, hluk sirény, skřípění pneumatik) a příjemnými zvuky (dětský smích, Beethovenova hudba, řehtání koně, zvuk oceánu). Zvuky související s dávnou evoluční hrozbu vedly k výraznějšímu zpomalení srdečního tepu (značící zaměření pozornosti, zrychlení tepu by naopak bylo známkou vyššího strachu), častějšímu mrkání (úleková reakce) a větší vizuální orientaci směrem ke zdrojům zvuku či blízké osobě.

Tyto závěry se částečně potvrdily i v jiném experimentu, kdy děti stejného věku jako v předchozí studii opět sledovaly filmy s hadem či slonem při současném přehrávání

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[19] Zbývá ovšem zodpovědět otázku, jaký by pro mezipohlavní rozdíly měl být důvod. Např. podle jedné evoluční hypotézy byl na ženské předky dnešních lidí mnohem vyšší selekční tlak, aby se hadů bály. Byly to především ony, kdo zůstával v blízkosti obydlí a sbíral různou potravu. Při této činnosti, jako bylo vyhrabávání hlíz, sběr ovoce, hub apod. se s daleko větší pravděpodobností setkávaly s nebezpečnými hady. Navíc musely chránit nejenom sebe, ale i své současné i dosud nenarozené potomky. Naproti tomu muži byli často daleko na lovu a příliš velký strach z hadů by jim bránil v úspěšném pronásledování a zabití kořisti (Buss, 2008).

vyděšeného nebo šťastného hlasu (design studie viz DeLoache & LoBue, 2009). Přitom byl zaznamenáván jejich srdeční tep a velikost a latence úlekové reakce (EMG kruhového očního svalu). K největšímu zpomalení srdečního tepu došlo při prezentaci hada s vyděšeným hlasem, což opět svědčí pro zvýšenou pozornost, nikoliv však pocit strachu. Film s hadem bez ohledu na typ hlasového doprovodu byl současně dětmi zaznamenán nejrychleji (měl nejmenší latenci úlekové reakci), paradoxně byl však rozsah úlekové reakce nejmenší při podmínce had-vyděšený hlas (Thrasher & LoBue, 2016). Autorky z toho tedy vyvozují, že hadi představují pro malé děti specifický podnět, který v porovnání s jinými zvířaty přednostně přitahuje jejich pozornost, nevyvolává však u nich strach ani averzi.

Další studie zase prokázala, že 6měsíční kojenci reagují na obrázky hadů a pavouků větším rozšířením zorničky ve srovnání s kontrolními obrázky květů a ryb, což autoři interpretují jako známku většího emočního vzrušení. To je podle nich důkazem, že ancetrální hrozby v podobě např. jedovatých hadů a pavouků vyvolávají i bez jakékoliv předchozí negativní zkušenosti v dětech stres a člověk je tak díky evolučnímu vývoji připraven k rychlému navození strachu z těchto podnětů (Hoehl, Hellmer, Johansson, & Gredebäck, 2017)[20].

Reakce malých dětí na hady byla nakonec zkoumána i pomocí pokročilých neurozobrazovacích metod, konkrétně měřením elektrofyziologické mozkové aktivity elektroencefalogramem (EEG). Ve studii zaměřující se na evokované potenciály sledovaly děti obrázky hadů nebo ryb, které byly v předchozí fázi náhodně spárovány s fotografií lidského obličeje s vyděšeným či neutrálním výrazem (emoční výraz ve tváři tedy v tomto případě fungoval jako nepodmíněný podnět poskytující dítěti sociální vodítko k hodnocení dosud neznámého stimulu). Amplituda negativní centrální komponenty, která odpovídá zvýšené pozornosti, byla vyšší v případě hada ve srovnání s rybou, a to bez ohledu na kontext, tedy typ přidruženého emočního výrazu (Hoehl & Pauen, 2017)[21]. Tyto výsledky by proto spíše svědčily pro neasociativní mechanismus vzniku strachu z hadů, tedy automatickou, vrozenou reakci bez nutné přítomnosti jiného (nepodmíněného) podnětu, což zcela neodpovídá závěrům předchozích studií.

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[20] Tento výzkum byl však následně kritizován, především z důvodu špatné interpretace výsledků. Rozšíření zorničky totiž nemusí být nutně známkou negativních emocí, ale může souviset i s vnímáním komplexity podnětu, která byla v případě pavouků větší než u květin. U hadů zase požadované výsledky vyšly až při mezisubjektovém srovnání, ne však při vnitrosubjektovém designu (Denzer, 2017).

[21] Je přitom zajímavé, že zvýšená reakce na obrázky pavouků (nikoliv však květin) byla pouze tehdy, když byl pavouk spojen s vyděšenou tváří, neutrální obličej však žádný efekt neměl (Hoehl & Pauen, 2017). To by mohlo poukazovat na odlišný mechanismus vzniku strachu z pavouků oproti hadům.

Ačkoliv dosavadní výsledky týkající se ontogeneze strachu z hadů nejsou příliš jednotné, dá se nejspíš shrnout, že velmi malé děti strach při setkání s hadem nepociťují. Hadi však již v raných stádiích ontogenetického vývoje přitahují dětskou pozornost, a to především tehdy, když jsou jsou prezentováni s jiným nepodmíněných podnětem (tváří či hlasem) odkazujícím k emoci strachu. Tato přednostní vizuální pozornost věnovaná vybraným evolučně relevantním zdrojům hrozby, jako jsou např. hadi a pavouci, a jejich snadná asociace se strachem či něčím nepříjemným pravděpodobně posléze vede k tomu, že děti se v průběhu dalšího vývoje rychle naučí se hadů bát. To platí především pro dívky, pro které bylo rychlé učení se strachu z hadů v evoluci výhodnější. Je přitom zajímavé, že tento mechanismus funguje i opačným směrem, kdy negativní zkušenosti s určitým stimulem a strach z něj následně ovliňují naši percepci a zvyšují jemu věnovanou pozornost (Lobue, 2010; pro shrnutí viz LoBue, 2013; LoBue & Rakison, 2013).

5. Prioritizace pozornosti

Člověk se po několik miliónů let vyvíjel v prostředí, ve kterém potenciální zdroje nebezpečí byly nepravidelně rozmístěné v čase i prostoru. V takových podmínkách, kdy především přítomnost nebezpečných zvířat, jakými byli například skrytě žijící jedovatí hadi a pavouci, nebylo nikdy možné dopředu věrohodně odhadnout, hrála podstatnou adaptivní roli nezáměrná, pasivní pozornost. Ta je oproti pozornosti záměrné aktivována automaticky (bez nutnosti vyvinutí určitého úsilí) na základě specifických charakteristik daného podnětu a funguje především pro objekty vyskytující se na periferii zorného pole. Detekce hrozby nacházející se mimo střed záměrné (vědomé) pozornosti tedy předpokládá, že u člověka existují mimovolní percepční procesy, které neustále automaticky prohledávají a analyzují veškeré percepční pole. V případě, že zaznamenají potenciální nebezpečí, tak k danému zdroji ohrožení následně nasměrují aktivní pozornost (New & German, 2015)[22].

Je tedy mořné předpokládat, že ancestrální zdroje nebezpečí v podobě smrtelně jedovatých hadů ohrožujících přežití předků dnešního člověka, byly prioritizované z hlediska pozornosti a dalšího zpracování, a proto mohly být i v nepřehledném prostředí (navíc mající často kryptické zbarvení) přednostně zaregistrovány, což následně umožnilo i rychlou a adekvátní odpověď. Experimentálně se schopnost určitých stimulů automaticky zaujmout pozornost nejčastěji studuje pomocí prezentace matice 9 obrázků (uspořádaných ve formě 3x3), které buďto všechny patří do stejné kategorie (zobrazují evolučně relevantní podnět, např. hada či pavouka, nebo irelevantní, neutrální podnět, např. květinu či houbu), anebo jeden z obrázků je diskrepantní a patří do odlišné kategorie (tedy např. obrázek hada či pavouka mezi 8 obrázky květin či hub nebo naopak, obrázek květiny/houby mezi 8 obrázky hada/pavouka, viz Obr. 5). Testovaná osoba má v každé ruce jedno tlačítko a instrukci co nejrychleji zmáčknout to v nedominantní (nejčastěji tedy levé) ruce, pokud jsou všechny obrázky ze stejné kategorie podnětů (např. když jsou v matici pouze obrázky hadů nebo pouze obrázky květin). Pokud je však v matici jeden obrázek diskrepantní (ten má za úkol experiemntální subjekt vyhledat,

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[22] Někteří autoři pro stejný psychologický fenomén používají koncept tzv. předpozornostní a popozornostní zrakové pozornosti či percepčního zpracování (v anglické literatuře je zavedený termín pre-attentive and post-attentive visual attention). V prvním případě se jedná o rychlou, automatickou, paralelní pozornost, která pracuje se základními vlastnostmi stimulu a jejím primárním úkolem je zaregistrovat objekty v okolním prostoru. Druhý typ pozornosti je naopak pomalý, úmyslný, pracující seriálně a zaměřující se na složitější vyhodnocení a interpretaci objektů vstupujících do percepčního vědomí.

proto se označuje jako cílový, zbylých 8 obrázků pak působí jako distraktory pozornosti) musí daná osoba zmáčknout tlačítko v druhé ruce[23]. Jednotlivé matice se od sebe liší nejenom tím, zda obsahují diskrepantní obrázek či jsou složené z identických podnětů, ale i pozicí diskrepantního obrázku v matici. Po zmáčknutí jednoho z tlačítek se zobrazí další matice, celkem je takto různě uspořádaných matic prezentováno každému subjektu několik desítek až stovek. Hlavní měřenou veličinou (závislou proměnou) je potom reakční čas a chybovost (tedy zda participant správně určil, že matice obsahuje diskrepantní stimulus či je složena pouze z jedné kategorie podnětů).

Obrázek 5. Ukázka matice používané při výzkumu prioritizace pozornosti. Úkolem subjektu je najít diskrepantní obrázek mezi mezi distraktory z druhé kategorie (převzato z Hayakawa, Kawai, & Masataka, 2011).

a) cílový obrázkem je had

b) cílovým obrázkem je květina

Jako první použil tuto metodu Hansen & Hansen (1988) při výzkumu percepce lidských obličejů. Lidé mnohem rychleji a s menším počtem chyb našli v „davu“ veselých obličejů naštvaný obličej než opačně, rychlejší i přesnější detekce zlostného výrazu se projevila i na pozadí neutrálních obličejů, a dokonce i v případě, kdy obrázky tváří byly otočené vzhůru nohama. Schopnost přednostně upoutat pozornost přitom měly pouze nepřátelské výrazy agrese (další významná hrozba z naší evoluční minulosti), u exprese jiné negativní emoce, jako je smutek, se takový efekt neprojevil (Öhman, Lundqvist, & Esteves, 2001).

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[23] Pro takové experimentální paradigma se vžilo označení „had v trávě“, protože má do jisté míry simulovat reálné podmínky, kdy je had ukryt na pozadí komplexního prostředí.

Přelomový psychologický experiment, věnovaný tendenci podnětů zobrazujících evolučně relevantní hrozbu přednostně přitahovat automatickou pozornost, provedli Öhman, Flykt a Esteves (2001)[24]. V maticích složených z obrázků zvířat vzbuzujících strach (had nebo pavouk) nebo neutrálních podnětů (květina či houba) našli participanti diskrepantní cílový obrázek mnohem rychleji, když se jednalo o hada či pavouka mezi obrázky květin nebo hub než pokud měli najít květinu či houbu mezi obrázky hadů či pavouků. Je přitom zajímavé, že v případě hada a pavouka jako cílového podnětu nijak nezáleželo na jeho pozici v matici. I pokud byl diskrepantní obrázek strach vzbuzujícího stimulu na periferiích prezentovaného čtverce, rychlost jeho detekce to příliš neovlivnilo. Naproti tomu neutrální podnět mezi hady či pavouky v roli distraktorů byl zaznamenán nejrychleji, pokud byl v prostředním řádku, tedy centru zrakového pole. Podstatně déle (tedy s nejdelší latencí mezi zobrazením matice a zmáčknutím tlačítka) však lidem trvalo objevit neutrální diskrepantní podnět, když se nacházel na okrajích matice v prvním a třetím řádku. I v případě, kdy matice byla složena pouze z jednoho typu stimulu a neobsahovala tedy cílový obrázek, se potvrdil kratší reakční čas a tedy rychlejší percepční zpracování matice unikátně zobrazující strachové, nikoliv neutrální podněty (Öhman et al., 2001).

V dalším experimentu autoři zmenšili prezentovanou matici na 2x2, což se projevilo signifikantním snížením reakčního času u detekce neutrálních podnětů, rychlost nalezení hada či pavouka zůstala stejná jako u větší matice 3x3. To tedy znamená, že zvětšení počtu distraktorů ze 3 na 8 podstatně prodlouží latenci odpovědi v případě neutrálních podnětů, osamoceného hada či pavouka mezi distraktory si ale všimneme stále stejně rychle bez ohledu na množství obrázků, které při tom musíme prohledat. V posledním experimentu pak potvrdili, že lidé se zvýšeným strachem z hadů či pavouků (určeným na základě skóru v dotaznících) najdou nebezpečný podnět ještě podstatně rychleji, než kontrolní osoby s nízkým strachem[25]. Rychlejší detekce u těchto lidí (potenciálních fobiků) ve srovnání s kontrolami se však

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[24] Podle databáze Google Scholar tento článek dodnes citovalo 2382 prací. Pro srovnání, jeden vůbec z nejznámějších dosud publikovaných psychologických experimentů, výzkum poslušnosti vůči autoritě Stanleyho Milgrama, nasbíral celkem 5940 citací, ten je však také o téměř 40 let starší (článek s názvem Behavioral study of obedience vyšel v roce 1963 v časopise The Journal of Abnormal and Social Psychology).

[25] To může být vysvětlením známého fenoménu, kdy lidé s fobií z pavouků (arachnofobií) si často po vstupu do místnosti ihned všimnou i malého pavouka na zdi, jedinci s fobií z hadů (ofidiofobií) se zase leknou i kusu provázku či zkroucené větve na zemi. Zdá se totiž, že vysoký strach u těchto jedinců je předurčuje k tomu, aby neustále a s ještě větší intenzitou a efektivitou prohledávali okolní prostředí pro možný výskyt obávaného objektu.

specificky projeví pouze u obávaného zvířete, tedy lidé bojící se hadů si dříve než kontroly všimnou hada, nikoliv však pavouka a naopak (Öhman et al., 2001)[26].

Výše zmíněné výsledky tedy poskytují poměrně přesvědčivý a konzistetní doklad o tom, že lidé dokáží rychleji nalézt nebezpečné zvíře vzbuzující strach na pozadí neutrálních podnětů než naopak. Hadi či pavouci jako relevantní zdroje hrozby z naší evoluční minulosti tak dokáží přednostně přitáhnout pozornost, což je pravděpodobně výsledkem dávných selekčních tlaků, kdy právě rychlost detekce nebezpečí v nepřehledném prostředí byla klíčová pro přežití. K rychlé registraci možného zdroje ohrožení přitom stačí, aby scéna byla prezentována na velice krátkou dobu 150-300ms (Soares & Esteves, 2013).

Skutečnost, že rychlost nalezení hada či pavouka neovlivní pozice v matice, ani množství distraktorů na pozadí (zatímco reakční čas při hledání neutrálního podnětu se výrazně prodlouží na periferiích zorného pole i s příbývajícím počtem obrázků, které je potřeba zpracovat), je důkazem existence dvou různých stylů pozornosti či percepčního vyhledávání. V prvním případě se jedná o paralelní styl fungující ještě v tzv. předpozornostním stádiu percepčního zpracování[27], který je mnohem rychlejší a je vyladěn na detekci podnětů představujících možné ohrožení, ke kterým rychleji nasměruje aktivní pozornost pro další zpracování. Často se v této souvislosti mluví o tzv. pop-up efektu, kdy se zdroj strachu při prvním pohledu na matici vynoří z pozadí distraktorů. Seriální styl uplatňovaný při vyhledávání neutrálních stimulů je naopak mnohem pomalejší a náročnější, protože člověk při něm prohledává jeden podnět za druhým[28]. K registraci podnětu pomocí tohotu pozornostní stylu

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[26] Vztah mezi ofidiofobií/arachnofobií a rychlejší detekcí fobického podnětu byla potvrzena i v řadě navazujících studiích (Flykt & Caldara, 2006; Soares, Esteves, Lundqvist, & Öhman, 2009; Soares, Esteves, & Flykt, 2009). Jiní autoři však zpochybnili vliv strachu na lepší detekci fobického zvířete. Namísto toho ukázali, že úspěšnost rekognice hada či pavouka více korelovala s individuální tendencí subjektů pociťovat odpor, zatímco strach občas vedl k falešně pozitivní detekci (Wiens, Peira, Golkar, & Öhman, 2008) Flykt & Caldara (2006) zase měřili i fyziologické (srdeční tep) a neurofyziologické (evokované potenciály) koreláty prioritizace pozornosti. Přestože byla u participantů s vysokým strachem z hadů či pavouků při detekci fobického zvířete pomocí EEG naměřena větší amplituda pozdního pozitivního potenciál (late positive potential) v porovnání s reakcemi na nefobické zvíře (pavouk u ofidiofobiků a had u arachnofobiků) a neutrální stimulus, žadný signifikaktní rozdíl nebyl naměřen ani v srdečním tepu, a dokonce ani v časných komponentách evokovaných potenciálů, což nepodporuje hypotézu o časnějším vizuálním zpracování.

[27] Předpozornostní stádium percepčního zpracování je definováno jako podvědomé shromáždění a zpracování informací z prostředí ještě před vstupem signálu do vědomí a účastní se ho tedy podkorové oblasti mozku. V tomto stádiu dochází především k prvotní filtraci důležitých informací, které je potřeba dále vědomě zpracovat.

[28] Začíná přitom v prostředním řádku matice zleva a postupuje doprava, poté na spodní řádek a jako poslední prohledá horní řádek zprava doleva. Neutrální podněty umístěné v levém horním rohu tak najdeme nejpozději. V této pozici byl rozdíl v rychlosti nalezení hada/pavouka a neutrálního podnětu v průměru více než 300ms, což už je doba, která může rozhodnout o přežití.

dojde až poté, co je na něj přenesena aktivní vědomá pozornost, tedy v tzv. postpozornostním stádiu percepčního zprácování (Öhman et al., 2001).

Výzkum priorotizované pozornosti směrem k evolučně relevantním zdrojům ohrožení vyvolal v následujících letech zvýšenou vlnu zájmu. Schopnost rychlejší detekce hadů ve srovnání s květinami byla potvrzena i u 3-5letých předškoláků (LoBue & DeLoache, 2008), 8-14měsíčních batolat (LoBue & DeLoache, 2010) anebo laboratorních makaků červenolících (*Macaca fuscata*: Shibasaki & Kawai, 2009; Masataka, Koda, Atsumi, Satoh, & Lipp, 2018), existuje tedy poměrně konzistentí empirický důkaz o tom, že se jedná o vrozenou tendenci. Had byl nalezen rychleji i v případě, kdy namísto květin byly jako distraktory použity obrázky žab nebo housenek, tedy tvarově podobných, avšak neškodných zvířat (LoBue & DeLoache, 2008; LoBue & DeLoache, 2010). Rychlost detekce hada oproti květině se u malých dětí i dospělých osob ještě dále zvýší, pokud je zobrazen v útočné pozici se zdvihnutou hlavou a esovitě prohnutým krkem, což ve srovnání s klidnou pozicí zintenzivní hrozící nebezpečí (Masataka, Hayakawa, & Kawai, 2010). Stále nejasnou roli má přitom barevnost podnětů v detekci hrozby. Zatímco kratší reakční laboratorních opic (Shibasaki & Kawai, 2009) nebo dospělých lidí (Flykt, 2005) při hledání hada nebyl ovlivněn tím, zda byly obrázky barevné či černobílé, 4-6leté děti si hada mezi květinami všimly mnohem rychleji, pokud se dívaly na barevné obrázky (Hayakawa, Kawai, & Masataka, 2011)[29].

Öhman, Soares, Juth, Lindström a Esteves (2012) následně ukázali, že had je nalezen ještě rychleji než pavouk, což vysvětlují tím, že hadi byli v evoluci i současnosti pro člověka mnohem nebezpečnější. Výhoda hada oproti pavoukovi i jiným zvířatům z hlediska schopnosti zaujmout pozornost se projeví zejména v komplexních vizuálních podmínkách ztěžujících detekci (Soares, 2012; Soares & Esteves, 2013; Soares, Lindström, Esteves, & Öhman, 2014; Kawai & He, 2016). I laboratorní makaci červenolící dokáží najít rychleji hada než neutrální koalu, u pavouka už to však neplatí a čas pro jeho nalezení se nijak neliší od koaly. Nakonec se tedy výzkumníci kloní k názoru, že přednostní detekce se výlučně vztahuje na hady (Kawai & Koda, 2016).

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[29] Naproti tomu 10-15letí školáci hodnotili míru strachu vyvolaného barevnými a černobílými fotkami hadů stejně, aposematické (výstražné) zbarvení tedy nemělo na vnímanou hladinu strachu žádný podstatný vliv (Prokop, Fančovičová, & Kučerová, 2018).

LoBue a DeLoache (2011) provedly sérii pěti experimentů, které měly detailněji prozkoumat jednotlivé percepční charakteristiky hadích stimulů zodpovědné za jejich rychlejší detekci. Tříleté děti i jejich dospělý doprovod opět dokázaly najít hada rychleji než žábu i v případě, když 1) byly obrázky umístěny na bílém pozadí, 2) pro cílový obrázek hada nebo žáby byly použity stejné typy distraktorů (kůň, jelen, králík,…) anebo když 3) byly použity černobílé obrázky[30]. V posledních dvou experimentech pak autorky prokázaly, že klíčovým pro rychlost detekce hadů je jejich stočený tvar těla. Malé děti i dospělí totiž rychleji našli stočený drát mezi obrázky květin, už však nebyl žádný rozdíl v času nutném k nalezení hada mezi stočenými dráty vs. stočeného drátu mezi hady. Stejně tak, když použily v experimentu obrázky natažených hadů, výhoda rychlejší detekce stimulu mezi květinami se tím ztratila, a konečně ani obrázky hadích hlav bez těla nebyly nalezeny rychleji než hlavy žab. Bez typicky stočeného těla si tedy hada rychleji nevšimneme (LoBue & DeLoache, 2011). To potvrzují i výsledky navazující studie, kdy lidé našli rychleji oblé vlnky než klikaté čáry s ostrými hranami mezi distraktory, kterými byly rovné linky nebo kolečka. Určitou roli v tom hraje i kognice, pokud před participanty označíme oblé vlnky za „hada“, mírně tím usnadníme jejich detekci, zatímco označení za „housenku“ žádný efekt nemá a oblé vlnky jsou nalezeny se stejnou rychlostí jako hranaté čáry. Stejně tak funguje i emoční naladění, lidé sledující hororovou scénu následně mnohem rychleji našli oblé linky, pokud však před úkolem sledovali neutrální scénu, žadný rozdíl mezi oběma tipy podnětů se neprojevil (LoBue, 2014).

Další studie prioritní detekce evolučně relevantních podnětů např. ukázaly, že 3-8leté děti i dospělí najdou rychleji nejenom hada mezi ještěrkami, ale i lva mezi antilopami než naopak (Penkunas & Coss, 2013), tedy že lidská vizuální orientace byla specificky vyladěna na nebezpečná zvířata, která byla v minulosti predátory předků člověka a dodnes přednostně přitahují naši pozornost (Yorzinski, Penkunas, Platt, & Coss, 2014). Přitom nehrají žádnou roli rozdílné zkušenosti s těmito zvířaty, reakční časy indických dětí vyrůstajících v městské zástavbě či na venkově se od sebe nijak neliší (Penkunas & Richard, 2013).

Hypotézu, že naše pozornost byla během milionů let lidské evoluce vyladěna na rychlé nalezení nebezpečných zvířat a dalších zdrojů ohrožení, dokazují i experimenty založené na paradigmatu detekce změny. Ten spočívá v tom, že participantům je na krátkou dobu

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[30] Podle další studie stačí k rychlejší detekci i pouhé siluety hadů (Forbes, Purkis, & Lipp, 2011).

promítnut obrázek s určitou komplexní scénou (např. fotografie krajiny, městské ulice, zátiší na stole), ten je následně překryt bílou obrazovkou a poté se objeví ve stejné podobě znovu, ovšem se změnou v jednom z objektů (do obrázku může být přidán či z něj odstraněn jakýkoliv prvek, např. budova, strom, zvíře, postava, předmět, apod.). Úkolem člověk je pak určit, k jaké změně v obrázku došlo. Sekvence originálního a změněného obrázku se může několikrát opakovat do té doby, než participant správně neodpoví. New, Cosmides a Tooby (2007) prokázali, že lidé takto mnohem rychleji a s větší přesností detekují změny, které se týkají zvířat nebo člověka než neživého předmětu, a to i v případě, kdy by objektivně jejich nalezení mělo být mnohem obtížnější (tj. jsou méně kontrastní, více splývají pozadím nebo jsou v porovnání s ostatními objekty v obrázku menší). Konkrétně postava muže a slon měli 100% úspěšnost detekce, holub 91%, zatímco velké obilné silo 76% a minivan pouze 67%.

Autoři studie toto zjištění interpretují jako důsledek ancestrální architektury vizuálního systému primátů, který byl zkonstruován tak, aby si přednostně všímal možné hrozby, která v naší minulosti pocházela především od zvířat či jiných příslušníků vlastního druhu[31]. Jedoucí auta, která jsou v současném světě pro člověka mnohem nebezpečnější než téměř cokoliv jiného, však zůstanou často nepovšimnuta, protože vizuální systém neměl dostatek času na to, aby se na ně vyladil (Öhman, 2007)[32]. Podle ekologické hypotézy vizuální percepce totiž úkolem zraku primárně není vytvořit věrnou reprezentaci okolního světa, ale spíše zachytit odrazy světla z informačně salientních podnětů, které nesou pro příjemce instrukci o tom, jak by se měl zachovat (Gibson, 2015).

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[31] Rychlost detekce v tomto experimentálním designu opět, stejně jako v úlohách vyhledávání cílového obrázku, ovlivní míra strachu subjektu z daného podnětu. Ženy s arachnofobií si tak pavouka přidaného do schematické scény všimnou rychleji než ženy, které se pavouků nebojí (Peira, Golkar, Larsson, & Wiens, 2010).

[32] Z hlediska rychlosti detekce se však specifický efekt fylogeneticky ancestrálních hrozeb (hadi, pavouci, agresivní obličeje atd.) oproti ontogenetickým moderním hrozbám (auta, zbraně, jehly, atd.) neprokázal. V dosud provedených experimentech buďto nebyl nalezený žádný signifikantní rozdíl mezi oběma typy ohrožení (Fox, Griggs, & Mouchlianitis, 2007; Carlson, Fee, & Reinke, 2009), anebo zbraně přitahovaly dokonce ještě větší pozornost než hadi nebo pavouci (Blanchette, 2006; Zsido, Deak, & Bernath, 2018; Subra, Muller, Fourgassie, Chauvin, & Alexopulos).

6. Mimovědomé vnímání a had jako specifický zdroj strachu

Podstatnou složkou jakékoliv emoční odpovědi je fyziologická reakce organismu spuštěná aktivací autonomního nervového systému (sympatikus či parasympatikus), která je automatická, tedy mimo volní kontrolu. V případě setkání s nebezpečným podnětem způsobujícím strach tak sympatická nervová větev okamžitě vyvolá výrazné tělesné změny, především zrychlení srdečního tepu a dechu a současně periferní vazokonstrikci vedoucí ke zvýšení krevního tlaku a napětí ve svalech (přesunem většího množství krve k příčně pruhovanému svalstvu). Tyto fyziologické změny, které dosáhnou vrcholu do 5-10 vteřin od začátku působení stimulu, mají za cíl připravit organismus na rychlou a adekvátní úlekovou reakci, která po následném kognitivním vyhodnocení může vést k útěku nebo naopak fyzické konfrontaci v závislosti na situaci a hrozícím nebezpečí[33]. Při tak intenzivní fyzické zátěži však zároveň dochází i k velké produkci tepla ve svalech, které by mohlo vést k přehřátí organismu. Proto se zvyšuje i aktivita potních žláz, což vede i k nárustu kožní vodivosti (tedy k poklesu elektrického odporu kůže; Mendes, 2016). Tato fyziologická odpověď typická pro prožívání strachu je pravděpodobně ještě výraznější u lidí trpících fobií (Fredrikson, 1981).

Právě rychlost, s jakou k fyziologickým změnám u fobiků dochází, a zároveň jejich nepřístupnost vědomé kontrole, se snažila vysvětlit již řada teorií. Psychoanalýza považovala fobie za nevědomý obranný mechanismus pro vyrovnání se s úzkostí tím, že se úzkost přeorientuje na externí podnět, kterému se lze vyhnout. Öhman, Dimberg a Esteves (1989) zase předpokládali, že existuje předpozornostní analytický systém, stejný, jaký má úlohu při prioritizaci pozornosti popsané v předchozí kapitole, který na nevědomé úrovni automaticky vyhodnocuje informace z prostředí a spouští příslušnou reakci, pokud emočně relevantní podnět interpretuje jako možnou hrozbu. To vše proběhne ještě dříve, než signál o daném podnětu doputuje do vědomí, kde je dále a detailněji zpracován. Právě z toho důvodu, že dochází k zaregistrování fobického stimulu až na pozadí silné tělesné odezvy, která byla nastartováno o zlomek vteřiny dříve, mají podle těchto autorů fobičtí pacienti v přítomnosti konkrétního stimulu pocit zahlcení silnou a nekontrolovatelnou úzkostí, která je rezistentní

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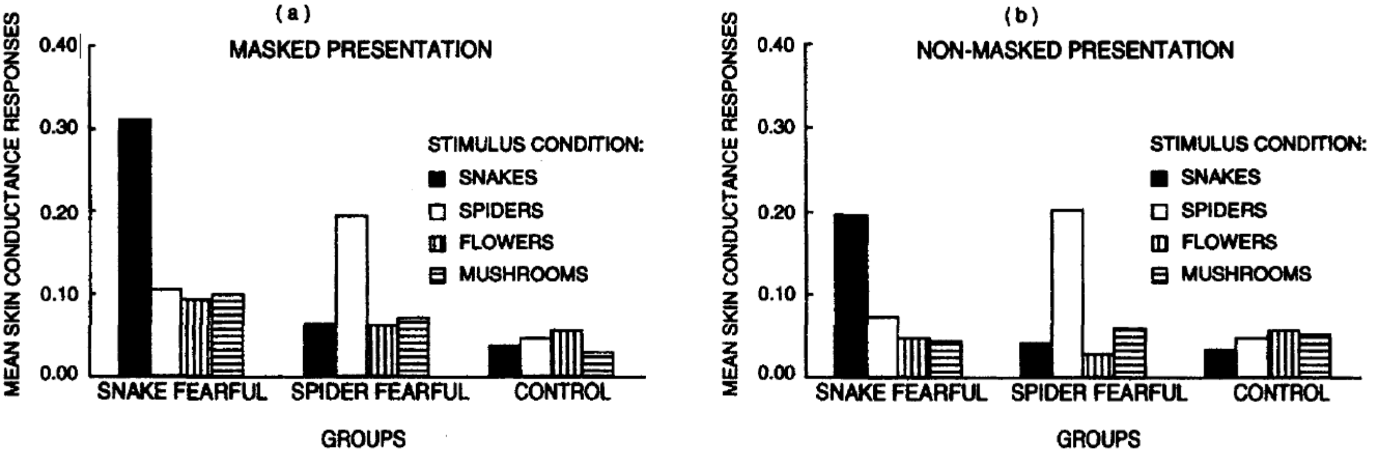
[33] Častou reakcí na nebezpečí je u člověka i zvířat strnulost (freezing), tedy neschopnost pohybu, což může být úspěšnou antipredační strategií.

vůči jakékoliv kognitivní snaze o regulaci. V takové situaci je pak jediným východiskem vyhýbání se danému fobickému stimulu, což pouze dále posiluje úzkostnou reakci.

Pro ověření této hypotézy provedli Öhman a Soares (1994) experiment, ve kterém použili metodu tzv. zpětného maskování. Při ní je cílový podnět, který má vyvolat sledovanou reakci, prezentován jen po dobu nutnou k tomu, aby byl vůbec zrakovým systémem zaznamenán, ale současně příliš krátkou na to, aby se signál mohl dostat do vizuální zrakové kůry a byl tedy vědomě zaregistrován. Na základě experimentálních dat se zjistilo, že takovou vhodnou dobou je 30ms, po kterých je cílový podnět překryt neutrálním obrázkem (Öhman & Soares, 1993, 1994; Soares & Öhman, 1993a,b). Zpětné maskování je tedy druhem podprahové (subliminální prezentace), která umožní zaregistrování podnětu na podvědomé úrovni, avšak zabrání jeho vědomému zpracování. Je přitom zásadní, že tímto způsobem zároveň dojde k disociaci vědomého rozpoznání stimulu od fyziologické reakce, která by měla být díky předpozornostnímu systému zachována.

Původní hypotéza se skutečně následně potvrdila ve zmíněném experimentu, kdy Öhman a Soares (1994) prezentovali skupině subjektů s pravděpodobnou fobií z hadů nebo pavouků (stanovenou na základě dosaženého skorů v dotaznících) maskované i nemaskované obrázky hadů, pavouků a kontrolních podnětů, květin a hub. Pro srovnání rekrutovali také kontrolní skupinu zdravých dobrovolníků. Během prezentace zároveň experimentálním osobám měřili kožní galvanickou odpověď, tedy změny v kožní vodivosti, které doprovázejí prožívání strachu. Prokázalo se, že hadí i pavoučí fobici reagovali oproti zdravým kontrolám zvýšenou kožní vodivostí, pokud viděli obrázek svého fobického objektu, ne však při prezentaci nefobického zvířete (tedy lidé s fobií z hadů reagovali na hada, nikoliv však na pavouka či kontrolní stimuly, arachnofobici zase fyziologicky reagovali pouze na pavouka). Nejzajímavější však bylo zjištění, že k fyziologické odpovědi dochází u fobiků i v případě, kdy je daný podnět prezentován maskovaně, tedy bez účasti vědomého zpracování. V tomto případě byla změna kožní vodivosti dokonce ještě vyšší, než když byl podnět nemaskovaný (viz Obr. 6).

Obrázek 6. Kožní galvanická odpověď na maskované a nemaskované obrázky hada, pavouka, květiny, nebo houby u lidí se zvýšeným a normálním strachem z hadů či pavouků (převzato z Öhman & Soares, 1994).



Z toho vyplývá, že zkoumané osoby při prezentaci fobického podnětu prožívaly zvýšený strach (na základě fyziologické reakce i vlastní výpovědi), aniž by si uvědomovaly přesnou příčinu, nikdo z nich totiž nedokázal poznat, co skutečně viděl před maskujícím obrázkem. Fyziologická odpověď organismu tedy může vzniknout na základě podprahové zkušenosti ještě před vědomým emočním prožitkem. Při vědomé registraci fobického podnětu tak už má mozek k dispozici zpětnovazebné signály o probíhajících tělesných změnách, které mohou pomoci interpretovat emoční zkušenost, jak ostatně předpokládá i James-Langeova teorie emocí. Proto mají podle Öhmana a Soarese (1994) fobici pocit, že jsou při setkání s obávaným objektem zcela paralyzováni automatickým, pohlcujícím, nevyhnutelným strachem, který nemohou nijak kontrolovat vlastní vůlí.

K podobným závěrům dospěly i paralelní studie provedené začátkem 90. let, které měly za cíl popsat rozdílnou roli podvědomého zpracování strachu z evolučně relevantních (hadi a pavouci) vs. neutrálních podnětů (květiny a houby) u zdravých dobrovolníků (Soares & Öhman, 1993b). K navození emoční reakce používali metodu diskriminačního Pavlovova klasického podmiňování, kdy některé z podmíněných podnětů, kterými byly obrázky různých objektů, byly následovány nepodmíněným podnětem, jemným elektrickým šokem individuálně nastaveným tak, aby byl člověku nepříjemný, nikoliv však bolestivý. Sledovanou závislou proměnou pak byl rozdíl v kožní galvanické reakci na podmíněný podnět. Tyto pokusy prokázaly, že tak jako je tomu u fobiků, i u zdravých jedinců je možné navodit fyziologickou reakci podprahovou stimulací obrázkem hada či pavouka, nikoliv však květiny nebo houby. Experimentální subjekty napodmiňované elektrickou ránou na prožívání strachu z hadů či pavouků vykazovaly během fáze vyhasínání (kdy už zobrazení obrázku nebylo doprovázeno averzivním stimulem) vyšší fyziologickou reakci na podmíněný podnět i v případě, že byl obrázek po 30ms maskován. Naproti tomu maskování zcela vyrušilo rozdílnou tělesnou odpověd na neutrální obrázky (Öhman & Soares, 1993)[34]. Podobně i instrukce experimentátora, že už zkoumaná osoba nedostane žádné elektrické rány, stačila k eliminaci vyšší fyziologické odpovědi na neutrální obrázky, neměla však žádný efekt v případě hadů či pavouků (Soares & Öhman, 1993a).

Stejná skupina experimentální psychologie vedená Arne Öhmanem působícím na Univerzitě v Uppsale[35] navíc již dříve testovala hypotézu, že v laboratorních podmínkách je snazší navodit strach z hadů a pavouků jako zdrojů ancestrální hrozby než z evolučně irelevantních, živých či neživých objektů (jedná se o fenomén selektivních asociací, kdy se jednotlivé kategorie podnětů liší v rychlosti učení i intenzitě podmíněné odpovědi). V sérii publikovaných studiíí prokázali, že pokud je subjekt napodmiňován jemnými elektrickými šoky na obrázky hadů, jeho kožně galvanická reakce (pocení dlaní značící emoční aktivaci) je významně silnější a delší, než pokud je stejným způsobem naučen reagovat na obrázky květin nebo hub[36]. Změna v kožní vodivosti v případě hadů a pavouků jako podmíněných podnětů je navíc i mnohem odolnější

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[34] V pozdějším experimentu se zase prokázalo, že u lidí je možné pomocí averzivního podnětu napodmiňovat strach ze stimulů, které jsou již během fáze učení (akvizice) prezentovány maskovaně, tedy i bez toho, že by byl podmíněný podnět vědomě rozpoznán (a bez možnosti vědomé asociace mezi podmíněným a nepodmíněným podnětem). To však opět platí pouze v případě hadů a pavouků, nelze tak naučit strachu z květin či hub. Dokonce se ukázalo, že při maskované prezentaci podnětů, po kterých má následovat elektrická rána, mají lidé signifikantně vyšší očekávání nadcházejícího averzivního stimulu. Zdá se tedy, že i při mimovědomém vnímání má člověk částečný přístup k mentálnímu obsahu, na kterém může založit toto negativní očekávání (Öhman & Soares, 1998). Tento fenomén je pravděpodobně založen na schopnosti percepce autonomní fyziologické reakce (srdeční tep), která může subjektu poskytnout informace o emoční valenci nevědomého stimulu (Katkin, Wiens, & Öhman, 2001).

[35] Přestože se jedná o nejznámější a pravděpodobně i nejproduktivnější experimentálně psychologickou laboratoř studující napodmiňování strachu u evolučně relevantních stimulů, jejich výsledky potvrzují i práce nejméně 6 dalších týmů z celého světa (pro přehled viz McNally, 1987 a Öhman & Mineka, 2001).

[36] Autonomní fyziologická reakce organismu je v případě hadů i kvalitativně odlišná. Zatímco hadi vyvolávají zrychlení srdečního tepu (známka strachu), člověk napodmiňovaný na obrázky květin a hub reaguje zpomalením srdečního tepu (doprovází orientační reflex, zvýšenou pozornost vyvolanou podmíněným podnětem při očekávání elektrické rány).

vůči vyhasínání a přetrvává tak po dlouhou dobu i v nepřítomnosti posilujícího averzivního podnětu[37]. Naproti tomu podmíněná tělesná reakce na květiny a houby, ale dokonce i na podněty související s moderní hrozbou, jako jsou elektrické zásuvky nebo zbraně, bez posilování rychle vymizí (e.g., Hugdahl & Kärker, 1981; pro přehled viz McNally, 1987; Öhman et al., 1989; Öhman & Mineka, 2001)[38].

Výlučnost hadů, resp. pavouků, jako specifických podnětů vzbuzujících strach dokazuje i další studie, která u nich potvrdila existenci fenoménu tzv. iluzorní korelace (kovariačního zkreselení). Tomarken, Mineka a Cook (1989) pouštěli experimentálním osobám prezentaci sestavenou z obrázků hadů, pavouků, květin a hub. Zcela náhodně pak po každém obrázku následoval jeden ze tří typů podnětů: elektrická rána, zvukový tón, nebo nic (nulový stimulus). Po skončení experimentu pak měli lidé větší tendenci spojovat elektrickou ránu s hady nebo pavouky, spíše než s květinami či houbami (ačkoliv různé kombinace obrázků a následných podnětů měly naprosto shodnou distribuci), a to především ti, u nichž byl na začátku pomocí dotazníků naměřen vyšší strach z těchto zvířat[39]. Přitom respondenti byli schopni poměrně přesně odhadnout frekvenci jednotlivých typů obrázků a následných stimulů, takže sklon k iluzorní korelaci mezi hadem/pavoukem a elektrických šokem nemohl být výsledkem sklonu k nadhodnocování výskytu hada/pavouka a elektrické rány[40]. Je zajímavé, že tato iluzorní korelace se neprojeví při zobrazení technologických/ontogenetických zdrojů ohrožení, jako jsou rozbité či odkryté elektrické zásuvky. I v tomto případě mají lidé větší sklon vidět souvislost mezi elektrickým šokem a obrázkem hada spíše než zásuvkou, ačkoliv si jasně uvědomují bližší sémantický vztah elektrického šoku k poškozeným zásuvkám než hadům (Tomarken, Sutton, & Mineka, 1995).

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[37] Stejného efektu je možné dosáhnout i při použití sociálních stimulů, jako jsou rozzlobené lidské obličeje, což je jiný typ evolučně relevantního zdroje ohrožení. I v jejich případě platí, že po napodmiňování pomocí elektrické rány tyto podněty vyvolávají kvalitativně odlišnou a intenzivnější fyziologickou odpověď ve srovnání s neutrálními či šťastnými obličeji a zároveň je tato autonomní reakce i mnohem odolnější vůči vyhasínání (pro přehled viz Dimberg & Öhman, 1996).

[38] Pokud je ovšem had spárován s elektrickým šokem a zbraň s hlasitým zvukem, tak se míra napodmiňování u obou podnětů nijak neliší (Hugdahl & Johnsen, 1989).

[39] Toto může být experimentálním vysvětlením známého fenoménu, kdy fobičtí pacienti mají silný iracionální sklon k přehánění nebezpečí plynoucí z jejich fobického objektu.

[40] Fenomén iluzorní korelace funguje stejně dobře i pro další evoluční hrozby, jako jsou obrázky krve, zohavení těla, otevřených ran či nebezpečí plynoucí ze sociálního prostředí v podobě rozzlobených lidských obličejů.

V jiné studii pak výzkumné osoby před začátkem experimentu předpokládaly zvýšenou pravděpodobnost elektrických šoků po zobrazení hadů i rozbitých elektrických zásuvek a přístrojů (tzv. apriorní kovariační zkreslení), avšak po jeho skončení se opět projevila tendence přeceňovat korelaci mezi averzivním a strachovým podnětem jen pro fylogenetické (evoluční) zdroje hrozby, tedy hady (tzv. aposteriorní kovariační zkreslení; Kennedy, Rapee, & Mazurski, 1997)[41]. Öhman a Mineka (2003) proto shrnují, že u lidí existuje kognitivní sklon spojovat hady s něčím averzivním a nebezpečným a tato afinita je navíc zcela odolná vůči zkušenosti[42]. To do jisté míry doplňuje dříve uvedená zjištění o zvýšené rezistenci napodmiňovaného strachu z fylogeneticky významných podnětů vůči vyhasínání (Mineka & Öhman, 2002).

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[41] Kovariační zkreslení pro společný výskyt obrázků poškozené zásuvky a následujícího elektrické šoku se dokonce neprojevila ani u lidí, kteří měli před začátkem experimentu z rozbitých nebo nechráněných zásuvek zvýšený strach.

[42] Je třeba také zmínit, že selektivní asociace, zvýhodňující učení se strachu z evolučně relevantních, předpřipravených hrozeb oproti ostatním stimulům, však byla řadou autorů kritizována a existuje množství studií, kterým se nepodařilo replikovat výsledky Öhmanova týmu, především co se týče rychlejší akvizice reakce strachu a intenzivnější fyziologické odpovědi (pro přehled viz McNally, 1987).

7. Neurální mechanismus: modul strachu

Od té doby, co Seligman (1971) publikoval svou vlivnou teorii biologické připravenosti vysvětlující zvýšený výskyt určitých typů fobií, zaměřila se pozornost mnoha vědců především na působení hadů a pavouků na lidskou psychiku. Tento výběr nebyl nijak náhodný. Jednak proto, že se i v současné době stále jedná o jedny z nejobávanějších zvířat (a i veškerých podnětů) v obecné populaci, ale i z toho důvodu, že jsou několikrát explicitně zmíněny i v původní Seligmanově práci jako modelové příklady relevantní hrozby z naší evoluční minulosti. Od poloviny 70. let bylo provedeno několik desítek psychologických experimentů mapujících charakteristiku lidské emoční odpovědi při setkání s hadem či pavoukem, jakým způsobem ovlivňují naše kognitivní (především percepční, ale i exekutivní) schopnosti a do jaké míry je tento vliv specifický ve srovnání s ostatními podněty (Öhman, 1986, 2009). Množství dosažených výsledků (z nichž ty nejdůležitější shrnuje předchozí text této práce) ukazovalo psychologický fenomén příliš komplexní na to, aby ho dokázala zcela pojmout původní Seligmanova teorie stojící v začátcích. Proto bylo potřeba vyvinout novou sjednocující teorii podstaty strachu, která by byla schopna propojit řadu dílčích a kvalitativně odlišných dat do smysluplného obrazu vzájemně propojených jevů. O to se snaží teoretický koncept nazvaný modul strachu poprvé představený Öhmanem a Minekou (2001), který podle autorů nejlépe vysvětluje a vzájemně propojuje komplexní vzorec poznatků z posledních 30 let a jež následně dominoval v rámci psychologického výzkumu emocí.

Öhman a Mineka (2001) při formulaci svého konceptu vycházejí především z předpokladů Seligmanovy teorie, kterou dále výrazně rozpracovávají a pomocí evolučně psychologických přístupů se snaží interpretovat velké množství dat výzkumu trvajícího tři desetiletí. Domnívají se, že v lidské psychické výbavě existuje jako součást obranného systému komplexní soubor behaviorální, mentální a neurální odpovědi aktivované v případě ohrožení, který označují jako modul strachu[43]. Tento modul je relativně nezávislý na ostatních složkách psychiky a jeho hlavním úkolem je řešit adaptivní problémy související s přežitím, konkrétně ochránit jedince

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[43] Modul je v evoluční psychologii základní jednotkou při popisu lidské psychiky. Tento relativně nový obor je založen na předpokladu, že lidská mysl je ve skutečnosti souborem jednotlivých mentálních nástrojů, neboli modulů, sloužících k řešení nejrůznějších problémů od shánění potravy po hledání vhodného partnera či fungování v sociální skupině. Zásadní přitom je, že stejně jako lidské tělo se i mysl postupně vyvíjela po milióny let evoluce. Proto tyto mentální moduly jsou výsledkem adaptace na původní prostředí hominidů a původních lovců sběračů, které se od moderního prostředí v mnoha ohledech dramaticky změnilo (Gerrans, 2002).

proti nejrůznějším hrozbám, jakými jsou např. nebezpeční hadi. Existence modulu strachu je založena na čtyřech základních předpokladech či charakteristikách, které ho definují.

Za prvé, modul strachu nereaguje na jakoukoliv hrozbu, ale je selektivně aktivován pouze vybranými podněty, které představovaly smrtelné nebezpečí pro dávné předky moderních lidí. Autoři se domnívají, že modul se vyvinul už u prvních savců před téměř 100 miliony let. V tehdejším prostředí byli pro primitivní drobné savce největší hrozbou velcí plazi, kteří dominovali suchozemské fauně a řada plazích predátorů byla na vrcholu potravního řetězce. Modul strachu tedy původně vznikl jako reakce na život ve stínu dravých ještěrů a postupně se vyvíjel v závislosti na okolním prostředí s nově se objevujícíme se hrozbami tak, aby přednostně reagoval i na hady a další nebezpečná zvířata z naší evoluční minulosti. Had je tedy vedle pavouka prototypickým stimulem, který má k modulu přednostní přístup a dokáže ho spustit, dalším jsou např. lidské tváře vyjadřující agresi (Öhman, 2009). Citlivost modulu na hady jako prototypické spouštěcí podněty strachu dokazují již dříve zmíněné studie reakcí malých dětí či laboratorních opic (kapitola 4), předvědomé prioritizované pozornosti při detekci hrozby v prostředí (kapitola 5), ale fenomén kovariačního zkreslení či početné výzkumy fyziologických reakcí při klasickém podmiňování (kapitola 6).

Druhou charakteristikou navrženého modulu je, že jeho aktivace specifickými podněty je automatická, může tedy proběhnout i na nevědomé úrovni bez nutnosti zapojení vyšších vědomých procesů. Z hlediska evoluce nervového systému lze takovou vlastnost modulu očekávat, musel totiž vzniknout v době, kdy savci měli v porovnání s dnešním stavem ještě velmi primitivní mozky, které pravděpodobně nebyly schopné pokročilejších kognitivních procesů zodpovědných za vznik vědomí. I v takovém případě však adekvátní reakce obranného systému[44] v případě ohrožení znamenala podstatnou selektivní výhodu konkrétního jedince. I přes postupující vývoj mozku a jeho rostoucí komplexitu bylo i později stále přínosné, aby si modul zachoval schopnost rychlé reflexivní odpovědi na základě hrubé analýzy signálu nezávisle na pokročilejších, detailnějších, ale zároveň pomalejších vědomých procesech probíhajících v neokortexu. Proto je možné předpokládat, že vyšší kognitivní funkce spojené s vědomím nejsou nezbytně nutné pro vyvolání pocitu strachu spolu s příslušnou fyziologickou

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[44] Evoluční počátky obranného systému, jehož je strach nedílnou součástí, se pravděpodobně datují stovky miliónů let do minulosti u primitivních organismů (Allman, 1999).

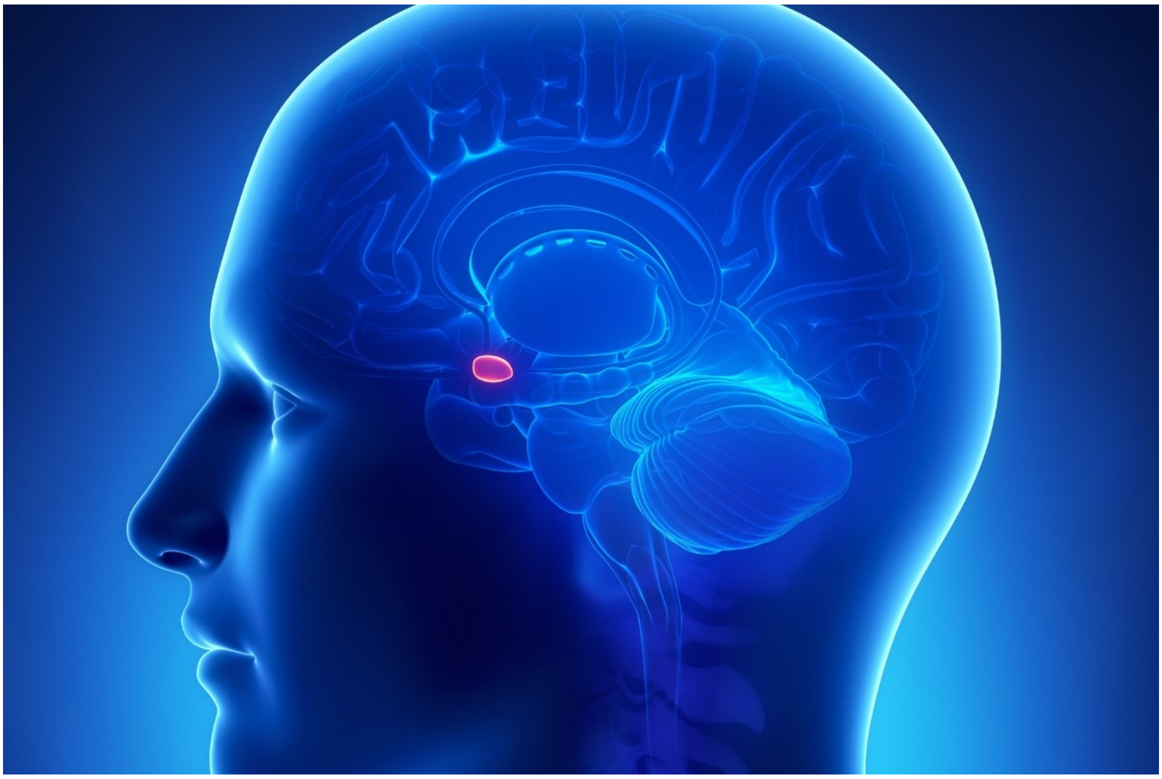
a behaviorální odpovědí. Schopnost hadů a dalších evolučně relevantních podnětů aktivovat modul a tím vyvolat u jedince strach i na mimovědomé úrovni dokazují experimenty s podprahovou stimulací (kapitola 6).

S nezávislostí modulu strachu na vědomí úzce souvisí i jeho třetí vlastnost, a to je relativní zapouzdření a nepřístupnost vůči kognitivní kontrole. Typickým znakem lidí trpících fobií (nejenom z hadů) je, že si dobře uvědomují přehnanost až absurditu svého strachu vzhledem k reálné nebezpečnosti obávaného podnětu. I přesto nejsou schopni tento strach rozumově potlačit (Doctor et al., 2008). To je podle Öhmana a Mineky (2001) potvrzením, že modul strachu není ovlivněn vyššími kognitivními procesy jako jsou různá přesvědčení a očekávání, ani množstvím objektivních informací o podnětu, a proto není možné vyvolaný strach kontrolovat rozumem. Pro relativní nezávislost modulu na kognici svědčí poměrně dobrá experimentální evidence z řady studií. Schopnost výzkumníků napodmiňovat strach na maskované (nevědomé, podprahové) stimuly, vylučující možnost vědomé znalosti vztahu mezi nepodmíněným a podmíněným podnětem, ukazuje, že lidé se mohou naučit asociovat i nerozpoznaný podnět vzbuzující strach (hada) s averzivním následkem. Naproti tomu kontrolní stimuly tuto vlastnost nemají a pro vytvoření asociací musí být prezentovány vědomě (nadprahově). Podobně ani informace podaná probandovi, že sledované obrázky už nebudou následovány averzivním stimulem v podobě elektrické rány, způsobí rychlé vyhasnutí reakce na kontrolní podněty, v případě napodmiňování strachu z hadů však nemá žádný efekt (a to ani tehdy, když je obrázek hada prezentován podprahově, (Soares & Öhman, 1993a, viz kapitola 6).

Čtvrtou, poslední charakteristikou modulu strachu je podle autorů tohoto konceptu existence specializovaného neurálního okruhu, který řídí jeho funkci. Öhman a Mineka (2001) se domnívají, že takový neurální okruh by měl být zřetelně odlišný od jiných oblastí zabezpečujících ostatní druhy emocí. Bude také pravděpodobně sdílen všemi savci a zároveň, vzhledem k předpokládanému původu modulu strachu, by se měl příslušný neurální okruh nacházet v evolučně starších částech savčího mozku, jako je např. limbický systém, spíše než v novějších strukturách neokortexu, který v době vzniku modulu ještě neexistoval. Ideálním kandidátem pro neurální lokalizaci modulu strachu se tak zdá být amygdala, párová struktura tvořená skupinou několika jader nacházející se mediálně v přední části obou spánkových laloků před hipokampem (Koukolík, 2012, viz Obr. 7).

V současné době už existuje celá řada přesvědčivých důkazů z oblasti animální i lidské neurobiologie a neuropsychologie, že amygdala je skutečně v mozku primátů i dalších savců centrem aktivace a zpracování strachu, který vzniká v kontextu predace i sociální dominance (LeDoux, 2000, pro přehled viz Öhman, 2005). První studie zaměřené na funkci amygdaly u primátů potvrdily, že oboustrané léze (vlivem nemoci, úrazu, či záměrným experimentálním poškozením) vedou k celé řadě behaviorálních změn označovaných jako Klüver-Bucyho syndrom, kam patří především zvýšená nebojácnost, neobyčejná krotkost, emoční otupělost, ale i změna v potravních preferencích včetně koprofágie (Ward, 2015). Lidé s poškozenou amygdalou nejenom že mají omezenou schopnost prožívat strach, ale také nedokáží rozpoznat strach ve tváři či hlasu ostatních, ani v muzice (pro přehled viz Janak & Tye, 2015). Naopak elektrická stimulace amygdaly pomocí elektrod vyvolá u zvířat i člověka intenzivní prožívání strachu (LeDoux, 1996).

Obrázek 7. Umístění amygdaly v lidském mozku (počítačová simulace, převzato z https://library.neura.edu.au/).



Amygdala však není pouze strukturou aktivující se při prožívání strachu, ale významnou roli hraje i při jeho učení. Laboratorní myši s poškozenou amygdalou (konkrétně basolaterální nucleus), nebyly schopné klasického podmiňování strachové reakce, tedy vytváření a zapamatování si asociací mezi podmíněným a averzivním podnětem. Pokud byla léze provedena až po úspěšném učení, tak brzy došlo ke ztrátě takové asociace (Phillips & LeDoux, 1992). Podobný vztah mezi správnou funkcí amygdaly a podmíněným učením strachu se prokázal i u lidí. U pacientů, kterým byla v rámci léčby epileptických záchvatů jednostranně odstraněna amygdala, nebylo možné pomocí klasického podmiňování vyvolat automomní reakci strachu (změnu kožní vodivosti), ačkoliv fyziologicky reagovali na samotný averzivní podnět (elektrickou ránu) a uvědomovali si vztah mezi podmíněným a nepodmíněným podnětem (LaBar, Gatenby, Gore, LeDoux, & Phelps, 1995).

Významný posun pak přinesl rozvoj neurozobrazovacích metod, pomocí nichž bylo možné přímo pozorovat aktivaci amygdaly při prožívání strachu. Pozitronová emisní tomografie (PET) monitorující pomocí kontrastní látky průtok krve mozkem potvrdila aktivaci pravé amygdaly u lidí sledujících averzivně napodmiňované obrázky agresivních tváří (Morris, Öhman, & Dolan, 1998). Schopnost hadů a pavouků vyvolat reakci na neurální úrovni v oblasti amygdaly potvrdila jiná PET studie, která rekrutovala lidi se zvýšeným strachem z hadů nebo pavouků (ne však z obou současně). Během rychlé prezentace maskovaných obrázků těchto zvířat byla aktivní levá amygdala (ve srovnání s kontrolními obrázky hub), a to stejně u obou skupin experimentálních osob. Při delší nemaskované prezentaci umožňující vědomé zpracování už byla silná bilaterální aktivace amygdaly pouze v případě obrázků specifického fobického zvířete (tedy např. pavouk již nevyvolal signifikatní aktivaci u lidí bojících se hadů; Carlsson et al., 2004). Jiná PET studie provedená na ženách s fobií z hadů nebo pavouků zase popsala zvýšenou aktivaci v pravé amygdale, mozečku a levé zrakové kůře. Aktivace v amygdale navíc pozitivně korelovala se subjektivním pocitem rozrušení (Åhs et al., 2009).

Relativně nedávný výzkum využívající funkční magnetickou rezonanci (fMRI) prokázal zvýšenou oboustranou aktivaci amygdaly při sledování videí hadů (ve srovnání se záběry ryb), a to u lidí s normálním i zvýšeným strachem z hadů. Zatímco u jedinců s normativním strachem tuto intenzivní neurální odpověď vyvolají pouze záběry útočících hadů, fobičtí jedinci reagují výrazně zvýšenou aktivací amygdaly i v případě plazících se hadů. Navíc míra aktivace amygdaly je u fobiků mnohem vyšší než u lidí s normálním strachem (Schaefer, Larson, Davidson, & Coan, 2014)[45]. Jiná fMRI studie zase potvrdila, že amygdala u nefobických subjektů reaguje zvýšenou aktivací na evoluční hrozby (hady a pavouky), nikoliv však na moderní zdroje nebezpečí (zbraně), přestože jsou obě kategorie podnětů hodnoceny negativně (Yang, Bellgowan, & Martin, 2012).

Pravděpodobně nejzajímavějším přínosem výše zmíněných PET studií je přesvědčivý důkaz, že amygdala může být aktivována i maskovanými (podprahovými) podněty, které jsou vnímány na nevědomé úrovni, bez zapojení oblastí mozkové kůry (viz kapitola 6). Neurální mechanismus mimovědomé aktivace strachu navrhl jako první LeDoux (1996, 2000), který na základě výzkumu neurobiologie strachu u krys popsal dvě dráhy zpracování vizuálních signálů. První je kortikální vědomá dráha, která je u savců evolučně modernější a zároveň primární cestou zpracování informací ze zrakového orgánu. Signál z neuronů sítnice vede nejprve do hrbolu mezimozkového (thalamus, konkrétně laterální genikulátní jádro) a odtud pokračuje do primární zrakové kůry, kde dochází k jeho vědomému zpracování. V případě, že je podnět vyhodnocen jako ohrožující pro organismus, primární vizuální kortex odešle signál do amygdaly, která spustí reakci strachu.

Vedle toho je v mozku ještě evolučně starší subkortikální dráha (existuje již od obojživelníků), kterou informace ze sítnice putuje přes strop středního mozku (tectum - lamina quadrigemina, konkrétně horní párové hrbolky colliculi superiores), a pulvinární jádro thalamu (součást zadních thalamických jader) přímo do amygdaly, čímž obchází vizuální kůru (Pessoa & Adolphs, 2010; Tamietto & de Gelder, 2010; viz Obr. 8). Právě horní pár hrbolků je jednou ze struktur zodpovědných za přepojování zrakové informace a řízení pohybů spojených s prostorem (např. odklonění ruky ve snaze vyhnout se objektu). Funkcí pulvinárních jáder je zase nasměrování pozornosti na potenciální zdroje ohrožení. Sekundární dráha pro zrakové signály tedy umožní rychlou aktivaci reakce na nebezpečné podněty ještě před tím, než dojde ke zpracování ve vizuálním kortexu (LeDoux, 1994; Hannula, Simons, & Cohen, 2005).

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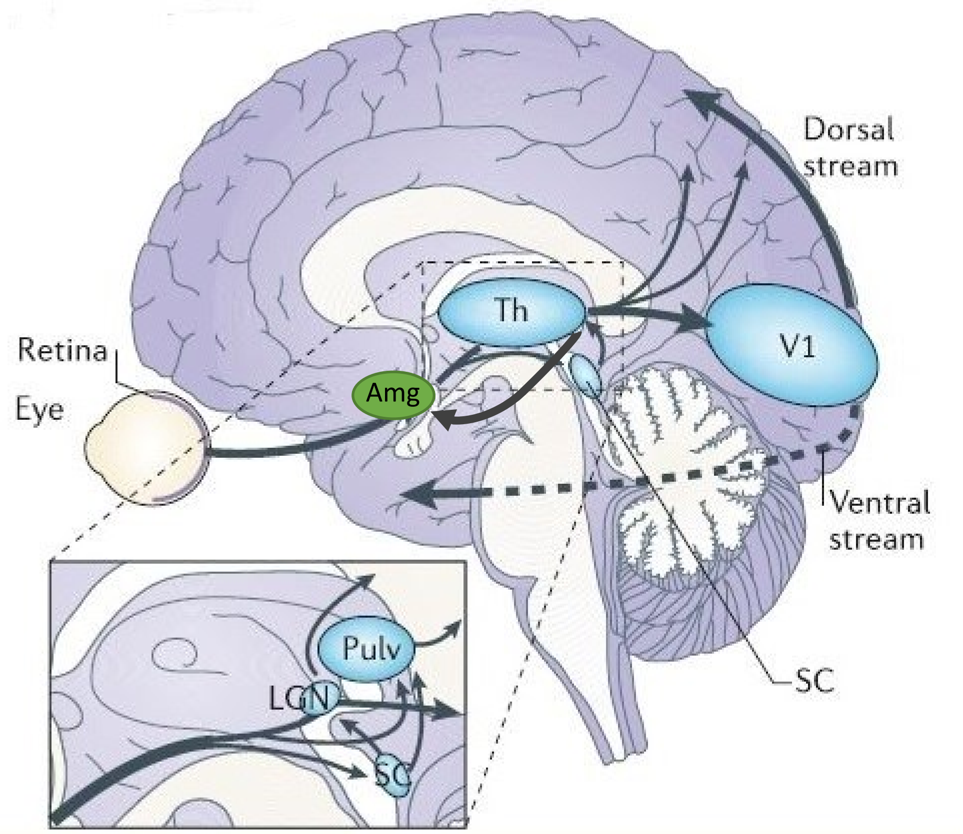
[45] Metanalýza 13 fMRI a PET studií specifických fobií, v naprosté většině z pavouků, uvádí vyšší aktivaci konkrétně v levé amygdale, pulvinárním jádru thalamu a levé insule u diagnostikovaných pacientů oproti zdravé populaci (Ipser, Singh, & Stein, 2013).

Obrázek 8. Kortikální a subkortikální zraková dráha v mozku. Hlavní cesta zpracování zrakových signálů vede z neuronů sítnice přes laterální genikulátní jádro (LGN) v thalamu (Th) do primární zrakové kůry (V1) o odtud ventrálním (okcipitotemporálním) a dorsálním (okcipitoparietálním) proudem do sekundární zrakové kůry (extrastriátní area). Současně slabší nervová vlákna vedou signál přes horní párový hrbolek (SC) a pulvinar (Pulv), které mají přímé spojení do amygdaly (Amg) (převzato z Diederich, Stebbins, Schiltz, & Goetz, 2014).



Existenci subkortikortikální zrakové dráhy potvrdila experimentální PET studie, ve které byly zdravým dobrovolníkům prezentovány maskované i nemaskované obrázky obličejů vyjadřujících hněv. Pomocí analýzy neuronální konektivity mezi amygdalou a dalšími oblastmi mozku (tedy korelací v současné aktivaci různých neurálních struktur) bylo potvrzeno, že zvýšená aktivace zejména pravé amygdaly úzce souvisela se zapojením horního párového hrbolku i pulvinaru, zatímco spojení amygdaly s korovými oblastmi bylo potlačeno (Morris, Öhman, & Dolan, 1999). Tyto výsledky později podpořil i výzkum Liddella a kol. (2005), ve kterém maskované obrázky vystrašených obličejů vyvolaly současně zvýšenou aktivaci ve třech zmíněných oblastech, tedy v horním párovém hrbolku, pulvinaru a amygdale (oboustraně). Výzkum provedený na jednom pacientovi s korovou slepotou zase prokázal, že i u lidí s lézí v oblasti primární zrakové kůry dochází k aktivaci amygdaly zprostředkované horním párovým hrbolkem a pulvinarem. Amygdalu je tedy možné aktivovat i bez přítomnosti funkčních procesů vizuálního kortexu (Morris, DeGelder, Weiskrantz, & Dolan, 2001).

Z dříve popsaných výzkumů prioritizace pozornosti pro evolučně relevantní podněty hrozby vyplývá, že hadi a pavouci mohou být zprácovány ještě v předpozornostním stádiu a rychle tak k sobě připoutat vědomou zrakovou pozornost (kapitola 5)[46]. Je tedy možné předpokládat, že kromě vědomých procesů je amygdala nezávislá i na pozornosti, a může být tedy automaticky aktivována i emočními podněty, které jsou sice prezentovány vědomě (nejsou podprahové), ale zrovna není jim věnována pozornost. Öhman, Carlsson, Lundqvist a Ingvar (2007) se dokonce domnívají, že z funkčního hlediska je právě registrace strach vzbuzujících podnětů mimo ohnisko zorného pole a následné zaostření aktivní pozornosti na ně ústřední rolí neurálního okruhu strachu. Vuilleumier, Armony, Diver, & Dolan (2001) vystavili své subjekty během skenování ve fMRI dvojici obrázků tváří a budov prezentovaných současně a jejich úkolem bylo pokaždé určit, zda dvojice v jedné z kategorií (tváře nebo domy) je shodná, čímž manipulovali pozorností participantů. Zatímco aktivace fusiformního gyru (laterální okcipitotemporální gyrus spánkového a týlního laloku), struktury zodpovědné za rozpoznávání tváří, byla zvýšená jen v případě, kdy byla pozornost přímo zaměřena na tváře, amygdala výrazně reagovala na obrázky vyděšených obličejů bez ohledu na to, zda jim byla právě věnována pozornost či nikoliv. Jiná fMRI studie pak zase prokázala, že tři hlavní struktury subkortikální zrakové dráhy, tedy amygdala, horní pár hrbolků colliculi superiores a pulvinární jádra thalamu jsou zvýšeně aktivní nejenom při prezentaci hadů uprostřed zorného pole, ale i na jeho periferii, a hrají tak specifickou roli při zpracování podnětů hrozby, kterým není věnována aktivní pozornost (Almeida, Soares, & Castelo-Branco, 2015).

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[46] Gomes, Silva, Silva, & Soares (2017) provnávali schopnost hadů a pavouků jako prototypických strach vzbuzujících podnětů automaticky proniknout do vědomé pozornosti. Prokázalo se, že zatímco při prezentaci do dominantního oka jedince dokáží oba podněty zaujmout vědomou pozornost, v náročnějších podmínkách prezentace do nedominantního oka pouze hadi získávají přednostní přístup do vědomé pozornosti. Tyto závěry potvrzuje i dalšé studie autorů, která se zaměřila na analýzu elektrofyziologické aktivity mozku pomocí EEG záznamu, kdy hadi ve srovnání s pavouky a ptáky vyvolali nejvyšší amplitudu evokovaného potenciálu asociovaného s exogenní (automatickou) předvědomou pozorností (Soares et al., 2017). Zároveň Deweese et al. (2014) demonstrovali, že hadi působí jako velmi silné distraktory v situaci, kdy má člověk věnovat aktivní vizuální pozornost jinému podnětu, a to především u lidí se zvýšeným strachem z hadů. Strach z fobického podnětu tedy namísto záměrného vyhýbání se vyvolává zvýšenou ostražitost (hypervigilanci).

Amygdala je sice hlavním, rozhodně ne však jediným centrem v mozku aktivujícím se při prožívání strachu, má totiž celou řadu nervových spojení s dalšími oblastmi účastnícími se emočního zpracování. Její střední část je vzájemně propojena např. s nucleus accumbens (párové jádro, které je součástí bazálních ganglií a tvoří ho shluk neuronů v rámci striata hluboko uvnitř hemisfér koncového mozku), které hraje důležitou roli při kognitivním zpracování strachu, ale i vzniku averze, závislosti, apod. Z amygdaly vedou i sestupné dráhy do hypothalamu, středního mozku a mozkového kmene (periakvaduktální šedá hmota a locus coeruleus), což jsou struktury řídící psychofyziologické změny organismu (např. změnu srdečního tepu) a také behaviorální reakce, které jsou často spojeny se strachem a úzkostí (boj nebo útěk), připravují člověka na nebezpečnou situaci a umožňují mu okamžitě reagovat (Öhman et al., 2007; Pessoa & Adolphs, 2010; Ward, 2015). Analýza funkční konektivity[47] měřené pomocí PET u žen trpících fobií z hadů nebo pavouků při prezentaci fobického podnětu zase odhalila zvýšené propojení mezi pravou amygdalou, fusiformním gyrem a motorickou kůrou (Åhs et al., 2009). Fusiformní gyrus se podílí na správném rozpoznání objektu, zapojení motorické kůry pak při ohrožení umožňuje rychlou behaviorální reakci typu „útěk nebo boj".
Amygdala má dále propojení s prefrontální, cingulární a primární zrakovou kůrou a dovoluje tak vědomou kontrolu emočně zabarvených stimulů (Vuilleumier, 2005; Obr. 9). Aktivace či naopak utlumení těchto korových oblastí tak nejspíš hraje významnou roli při fobické reakci na hady. Pacienti s diagnostikovanou fobií se totiž od zdravých kontrol liší nejenom zvýšenou aktivací v amygdale, ale zároveň i abnormální aktivitou ve zrakové, orbitofrontální (OFC) a prefrontální kůře (PFC, především její dorsální a laterální část), což se projeví zhoršenou emoční regulací po vystavení fobickému podnětu (Schiller & Delgado, 2010; Del Casale et al., 2012). Straube, Mentzel a Miltner (2007) zase u arachnofobiků objevili vyšší aktivaci v anteriorní cingulární kůře limbického systému (ACC), tento rozdíl se navíc ještě zvětšil, pokud pacienti očekávali fobické, spíše než neutrální stimuly. Tyto nálezy potvrdila i další fMRI studie s arachnofobiky, u kterých fotografie pavouka vyvolala ve srovnání se zdravými kontrolami nejenom signifikatně zvýšenou aktivaci v amygdale, pulvinárním jádru thalamu a levé insule, ale i bilaterálně v oblasti ACC a suplementární motorické kůry (Goossens, Schruers, Peeters, Griez, & Sunaert, 2007a).

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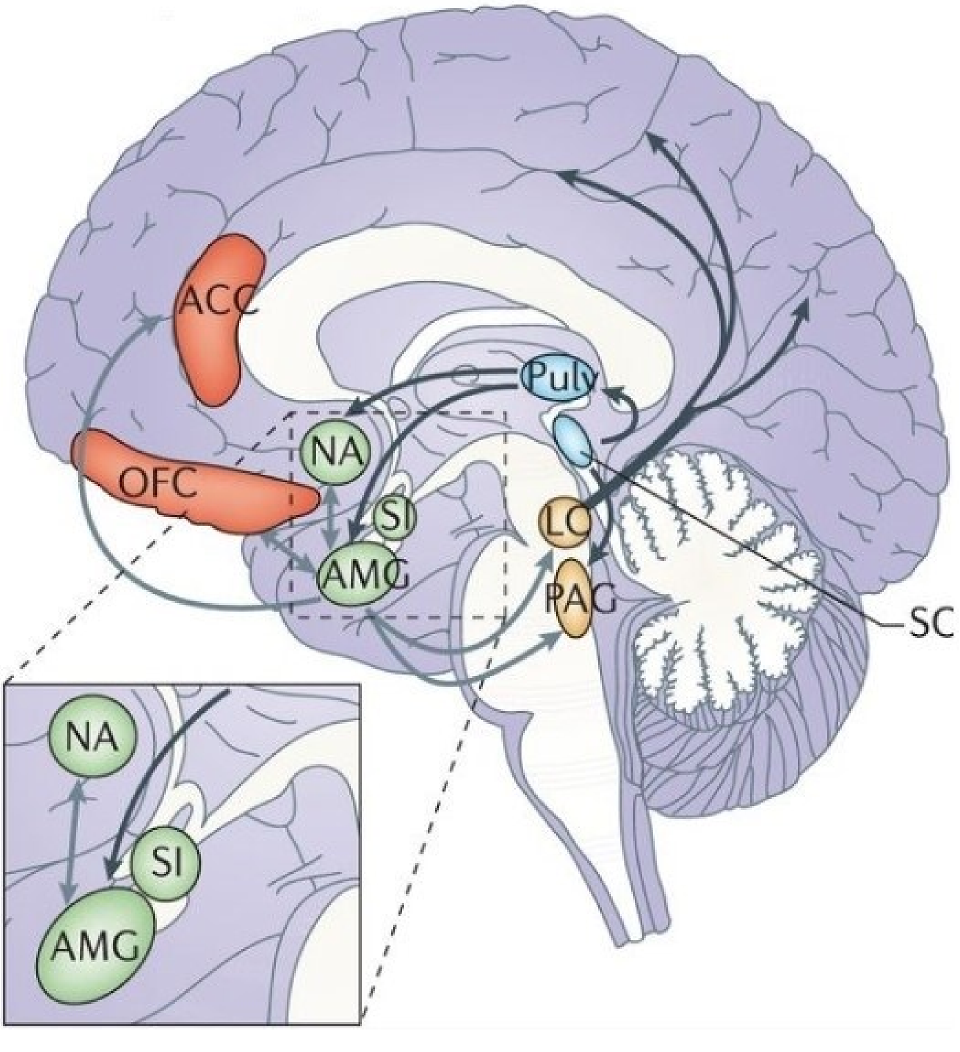
[47] Korelace mezi vzdálenými neurofyziologickými událostmi.

Obrázek 9. Emoční okruh zahrnuje v mozku několik korových i podkorových struktur. Mezi ty podkorové patří především amygdala (AMG) uložená hluboko ve spánkových lalocích, substantia innominata (SI) na bázi předního mozku, nucleus accumbens (NA) jako součást bazálních ganglií a některá jádra mozkového kmene, jako periakvaduktální šedá hmota (PAG) a locus coeruleus (LC). Ke korovým strukturám patří především orbitofrontální (OFC) a přední cingulární kůra (ACC). Vizuální a emoční systém mají v mozku řadu vzájemných nervových spojení, především na subkortikální úrovni mezi horními párovými hrbolky (colliculi superiores, SC), pulvinarem (Pulv) a amygdalou. Existuje také přímé spojení mezi kortikálními a subkortikálními oblastmi pro zpracování emocí (např. mezi amygdalou a OFC a ACC), stejně tak jako mezi subkortikálními emočními oblastmi a kortikálními vizuálními oblastmi (např. mezi amygdalou a spánkovým lalokem a mezi jádry mozkového kmene a kůrou (převzato z Diederich, Stebbins, Schiltz, & Goetz, 2014).



Zvýšená aktivace v OFC, amygdale, insule, ACC a bazálních gangliích u fobických pacientů poklesne, prodělají-li kognitivně-behaviorální terapii (KBT; Paquette et al., 2003; Goossens, Suanert, Peeters, Griez, & Schruers, 2007b), při které se využívá metody hierarchické/graduální expozice fobickému podnětu. Naopak některé regulační mechanismy jsou po ukončení terapie aktivnější, jako například pravý dorso-laterální PFC (self-regulace emocí) a kaudální část posteriorní cingulární kůry (Hauner, Mineka, Voss, & Paller, 2012)[48]. Dosavadní neuropsychologický výzkum tak ukazuje, že PFC je pravděpodobně součástí složitého zpětnovazebného systému prožívání a zvládání strachu vyvolaného nebezpečnými zvířecími stimuly, jehož rovnovážná funkce je u fobických pacientů narušena (viz také Johanson, Risberg, Tucker, & Gustafson, 2006). Psychoterapie však dokáže změnit aktivitu PFC a navrátit abnormální funkci regulačních oblastí zpět do rovnováhy, čímž ve výsledku pomůže pacientům uvědomit si a následně ovládnout své myšlenky, na jedné straně potlačit negativní představy a očekávání spojená s fobickým objektem, na druhé pak posílit kontrolu nad intenzivní fobickou reakcí. Tento pozitivní terapeutický efekt byl navíc pozorovatelný i 6 měsíců po ukončení KBT (Hauner et al., 2012).

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[48] Tyto výsledné efekty však mohou být velmi variabilní v závislosti na metodě prezentace stimulů (podprahové vs. prahové podněty). Např. Lipka, Hoffmann, Miltner a Straube (2014) prokázali, že po ukončení KBT vedla vědomá prezentace obrázků pavouků k signifikantnímu poklesu aktivace v pravé amygdale a dorsální ACC, a mírnému poklesu v levé amygdale, fusiformním gyru, insule a dorsomediální PFC. Avšak žádné výrazné změny nebyly zaznamenány, pokud byly stimuly prezentovány podprahově. Z toho vyplývají jistá omezení KBT, která úspěšně vede k lepší regulaci neurálních struktur okruhu zpracování strachu (tj. pravá amygdala a ACC), ale jen při možnosti vědomého zpracování podnětu v korových centrech.

8. Teorie detekce hada

Modulární teorii a evoluční podstatu strachu z hadů dále rozpracovala americká primatoložka Lynne Isbell do konceptu, který se v literatuře často označuje jako teorie detekce hada (the snake detection theory; Isbell 2006, 2009). Hadi sdílejí s primáty milióny let komplexního koevolučního vývoje a po celou jeho dobu pro ně představovali jeden z prvních a zároveň nejvýznamnějších zdrojů predační hrozby. To vše hrálo podstatnou roli při rozvoji mozku raných primátů i pozdějších lidoopů včetně člověka, především při zdokonalování jejich vizuálního systému. Isbell (2006) argumentuje skutečností, že v době vzniku primátů před zhruba 85 miliony let nežil na Zemi ještě po dlouho dobu jiný typ predátora, kromě velkých škrtičů (jejich primitivní zástupci se objevili už před zhruba 100 miliony let), který by je byl schopný lovit. Selekční tlak ze strany hadů se pak ještě více zintenzivnil se vznikem jedovatých hadů v období paleocénu (před 60 miliony let).

Protože hlavní loveckou strategií jedovatých hadů bylo číhání v úkrytu a překvapení kořisti náhlým útokem, u řady druhů se vyvinulo dokonalé kryptické zbarvení, pomocí kterého had opticky splynul s prostředím. Smrtelné nebezpečí, které navíc bylo velmi obtížně rozpoznatelné, tak vytvořilo silný selekční tlak na rychlý vývoj zrakového systému primátů a jeho integraci s neurálním okruhem strachu. Pro přežití primátů a následně i předků člověka totiž bylo nezbytné, aby v nepřehledném terénu objevili ukrytého jedovatého hada co nejdříve. Hadi, na rozdíl od jiných významných predátorů lovících primáty, jakými jsou šelmy a dravci, nejsou schopni rychlého pohybu na větší vzdálenost a největší nebezpečí tak představují jen tehdy, pokud zůstanou nezpozorováni. Naopak včasná detekce i z poměrně krátké vzdálenosti pár metrů většinou zcela eliminuje nebezpečí, které hadi představují pro svou kořist (Etting, Isbell, & Grote, Factors increasing snake detection and perceived threat in captive rhesus macaques (Macaca mulatta), 2014).

Tento evoluční závod ve zbrojení mezi predátorem a kořistí u primátů postupně vedl k větší orbitální konvergenci[49], která umožnila lepší prostové vidění na kratší vzdálenost, zejména ve spodní části zrakového pole. Isbell (2006) dále hypotetizuje, že došlo i k současnému rozvoji

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[49] Orbitální konvergence označuje přesměrování vizuálních os obou očnic z postranní (laterální) do přední (anteriorní) orientace vzhledem k zornému poli, k čemuž došlo v průběhu evoluce primátů pootočením oka více směrem ke středu hlavy

dvou vizuálních drah, koniocelulární[50] a parvocelulární[51]. První z nich propojuje sítnici s laterálním genikulátním jádrem, horním párovým hrbolkem a pulvinarem, což napomohlo především efektivnější předpozornostní detekci hadů a dalších strach vzbuzujících podnětů. Parvocelulární dráha vedoucí ze sítnice do laterálního genikulátního jádra zase umožnila trichromatismus a dokonálné centrální (foveální) vidění (rozpoznávání barev a objektů), které pravděpodobně usnadnilo odhalení hadů na zemi nebo ukrytých v listí[52]. Podobně vedl selekční tlak ze strany hadů i ke zvětšení zrakových center v mozkové kůře, konkrétně v oblasti temenního (parietálního) laloku, horního spánkového závitu (sulcus temporalis superior) a dorso-laterální PFC (Öhman et al., 2007). Výsledkem byla schopnost rychlé detekce obtížně viditelných jedovatých hadů v nepřehledném terénů umožňující okamžitou reakci (více o sensitivitě subkortikální zrakové dráhy na hady a její úlohu při přednostním vizuálním zpracování a rychlé reakci viz přehledová studie od Soares, Maior, Isbell, Tomaz, & Nishijo, 2017).

Isbell (2006, 2009) tak v podstatě navrhuje alternativní hypotézu vývoje pokročilého trichromatického vidění u primátů oproti jiným savcům[53] a hlavní podíl na tom přikládá právě hadům, což se snaží podpořit řadou nepřímých důkazů. Uvádí například, že některé oblasti mozku zapojené do ostražitosti, strachu, učení a paměti související s ohrožením (predací) jsou u primátů zvětšené a silněji propojeny s vizuálním systémem. Navíc se mezi sebou jednotlivé taxony primátů liší v expanzi těchto mozkových oblastí v závislosti na délce koevoluce s recentními druhy jedovatých hadů. Proto skupiny primátů, které se vyvíjely delší dobu v přítomnosti jedovatých hadů na africkém kontinentě, projevují větší strach a zároveň mají dokonalejší zrakový systém, než skupiny, než skupiny, které predačnímu tlaku ze strany hadů

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[50] Zraková dráha ze sítnice tvořená gangliovými koniocelulárními (K-) buňkami, které jsou v sítnici nejmenší a zároveň nejpomaleji vedou vzruch. Axony K-buněk přenáší informaci do dalších subkortikálních struktur mozku, především do colliculi superiores. K-buňky se výrazně podílejí při okulomotorických mechanismech a orientaci v prostoru.

[51] Zraková dráha tvořená malými gangliovými parvocelulárními (P-) buňkami. Tento typ tvoří v sítnici zhruba 80% všech buněk. P-buňky vedou odděleně barevné informace ze tří typů čípků lokalizovaných ve fovea centralis a slouží k paralelnímu vedení informací pro barvy, formy a detaily obrazu (jeho ostrost).

[52] Další úlohou parvocelulární dráhy měla být i ochrana mozku před zvyšujícími se energetickými nároky souvisejícími s neurální kapacitou rychlé detekce zdrojů ohrožení.

[53] Nejrozšířenější hypotéza barevného vidění primátů zase tvrdí, že příčinou byl přechod na rostlinnou potravu, především zařazení ovoce do jídelníčku. Schopnost rozeznat jednotlivé zralé plody na pozadí listů vyžadovala zdokonalené rozpoznávání barev a lepší prostorovou orientaci (Osorio & Vorobyev, 1996). Isbell (2006) však namítá, že vývoj vizuálního systému byl reakcí na výskyt jedovatých hadů a zvýšené energetické nároky takového mozku mohly být uspokojeny právě díky konzumaci ovoce bohatého na cukry.

unikly[54]. Stejně tak i rozdíly mezi různými taxony primátů ohledně délky evoluční expozice jedovatým hadům odpovídají taxonomickým rozdílům v rychlosti evoluce genů pro cytochromoxidázu a její metabolické aktivitě alespoň v určitých vizuálních oblastech mozku[55]. Zatímco tedy jiní savci v odpovědi na výskyt jedovatých hadů vyvinuli fyziologickou rezistenci na jed (ježci, promyky, surikaty,…), primáti zvolili strategii zdokonalení schopností vizuálního systému pro lepší detekci hadů ještě před útokem.

Nejdůležitější předpoklad hypotézy o silném predačním tlaku ze strany nebezpečných hadů během evoluce primátů a člověka nelze prokázat, vzhledem k vysoce účinnému hadímu metabolismu, který kořist polknutou v celku zcela stráví (včetně kostí, zubů i nehtů) a nezanechá tedy žádný fosilní záznam. Existuje však několik nepřímých důkazů. McGrew (2015) analyzoval data o sledování tlupy divokých šimpanzů v Senegalu. Během čtyř let terénnních pozorování této skupiny zaznamenali primatologové celkem 142 setkání s hady 14 různých druhů, přičemž ve dvou třetinách případů se jednalo o jedovaté hady. Podle autora tato data potvrzují, že primáti jsou i v dnešní době často vystavěni smrtelnému nebezpečí ze strany jedovatých hadů, a jsou tedy v souladu s původní hypotézou. Headland a Greene (2011) zase uveřejnili longitudinální etnografickou studii provedenou na lidech z etnika Agta Negritos, což je původní kmen z Filipín žijící ještě tradičním způsobem lovců-sběrač. Mezi lety 1934 a 1974 přežilo 26% všech mužů napadení krajtou mřížkovanou (*Python reticulatus*), nejdelším žijícím škrtičem dorustájícím v dospělosti až 10m (viz Obr. 10), šest útoků bylo fatálních. Přestože Agta Negritos jsou stále společností na předindustriálním stupni vývoje, mají nože i podomácku vyráběné střelné zbraně. Lze tedy předpokládat, že ještě v nedávné minulosti musel být podíl úspěšných útoků hada na naše předky mnohem vyšší.

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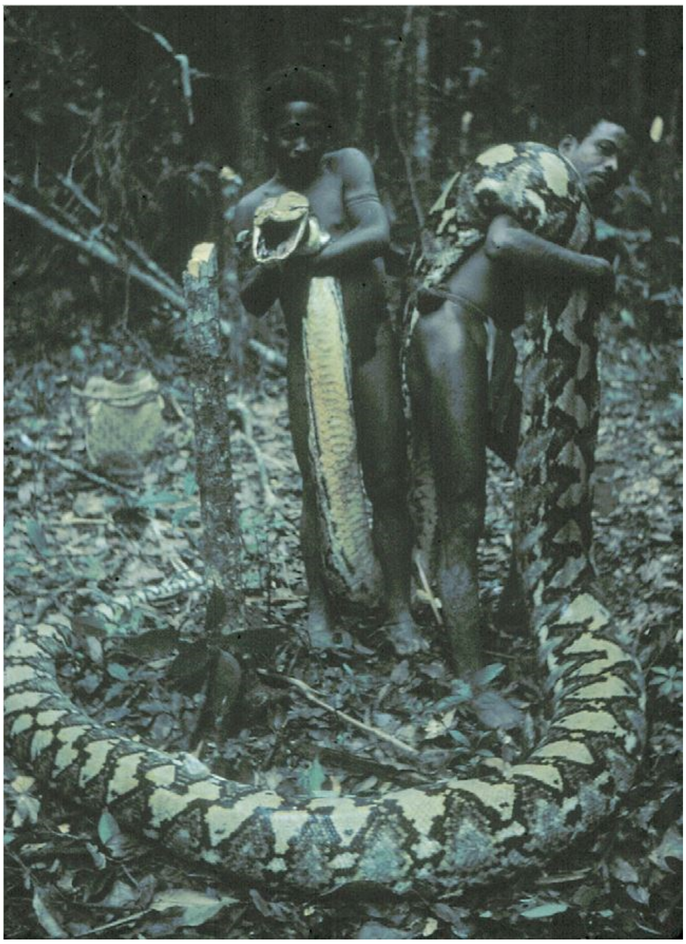
[54] Poloopice žijící na Madagaskaru, které se z Afriky dostaly ještě před vznikem jedovatých hadů, a tedy s nimi nemají žádnou evoluční zkušenost, se hadů příliš nebojí a zároveň mají špatný zrak (často se jedná zvířata s noční aktivitou). Naproti tomu starosvětské opice a lidoopi, kteří s jedovatými hady koexistovali několik desítek miliónů let po celou dobu svého evolučního vývoje, většinou projevují velký strach z hadů a zároveň jejich zrakový systém patří k těm nejpokročilejším. Přechodový článek pak tvoří novosvětské opice, které po určité době vývoje v Africe nakonec unikly tlaku jedovatých hadů na americký kontinent. Tomu odpovídá i úroveň strachu z hadů a zrakové schopnosti, jež jsou mezistupněm mezi poloopicemi a starosvětskými opicemi.

[55] Cytochromoxidáza je komplex cytochromů v dýchacím řetězci, který je schopný přenést elektrony na kyslík a tím v reakci s vodíky vytvořit vodu.

Obrázek 10. Krajta mřížkovaná (délka 6,9m) zastřelená v roce 1970 mužem z kmene Agta (na snímku vpravo, převzato z Headland & Greene, 2011).



Hadi jsou však významným zdrojem mortality i v současné době. Přes veškerou dostupnou lékařskou péči, celosvětové ubývající množství hadů a většinu lidské populace žijící ve městech mimo jejich dosah, mají stále podle nejnovějších odhadů Světové zdravotnické organizace je každoročně 4,5 - 5,4 miliónů lidí po celém světě kousnuto hadem a pro až 138 000 z nich je to smrtelné[56]. Dalších zhruba 400 000 obětí skončí s trvalými následky jako je amputace končetiny (WHO, 2019a). Hadí uštknutí bylo nedávno prohlášeno za celosvětově nejzávažnější a zároveň nejvíce opomíjenou skrytou zdravotní hrozbu, zejména v rozvojových zemích

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[56] Had tak stojí v čele žebříčku nejnebezpečnějších zvířat pro člověka sestaveného na základě celkového počtu smrtelných případů za rok. Více obětí už mají na svědomí jen komáři přenášející malárii, která podle odhadů Světové zdravotnické organizace zabila v roce 2019 409 000 lidí (WHO, 2020).

tropického a subtropického pásma (Fry, 2018), např. jen v Indii ročně hadi zabijí téměř 50 000 lidí (WHO, 2019a)[57].

Především v posledních pěti letech se však objevilo i několik přímých experimentálních důkazů z neurobiologických a neurofyziologických studií podporujících hypotézu detekce hada. Van Le a kol. (2013) měřili pomocí elektrod zavedených do mozku dvou makaků červenolících aktivitu neuronů v pulvinaru během prezentace různých podnětů. Dokázali, že v mediálním a dorsolaterálním pulvinaru, což je struktura typická pouze pro primáty a nevyskytuje se u jiných savců, existují neurony, které specificky reagují na obrázky hadů[58]. Ve srovnání s obrázky opičích obličejů a rukou nebo jednoduchých geometrických obrazců byla odpověď těchto neuronů na hady nejenom signifikantně intenzivnější, ale i rychlejší. Zároveň tato přednostní elektrofyziologická odpověď zůstala zachována i v případě, kdy byly obrázky hadů rozostřeny, aby zobrazovaly pouze siluetu bez detailů. Autoři studie tak nejenom potvrdili význam pulvinárního jádra při rychlé detekci hadů, zároveň ale také ukázali, že pulvinaru stačí hrubý signál bez přesných kontur a konkrétních detailů, aby podnět vyhodnotil jako hrozbu a přepojil informaci do amygdaly[59].

V navazující studii pak stejný tým autorů prokázal, že u opic je možné zaregistrovat i rozdílnou neurofyziologickou odpověď na obrázky hadů v klidné a výhružné pozici. Několik desítek ze sledovaných neuronů v pulvinaru makaků totiž mělo signifikantně vyšší elektrofyziologickou aktivitu při prezentaci hada připraveného k útoku oproti situaci, kdy ležel v klidu stočený. Přitom obě kategorie podnětů byly dobře diskriminovány již během 50ms po zobrazení, což svědčí o velmi rychlém zpracování (Van Le et al., 2014). Schopnost efektivně diskriminovat mezi různým stupněm ohrožení ze strany hadů v klidné a útočící pozici byla navíc prokázána i na základě etologických dat u makaka rhesus, kdy gumové modely hadů zobrazující hrozbu

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[57] Podle vědců existuje protijed jen pro 60% všech jedovatých druhů hadů, a proto byla v tomto roce schválena masivní investice biomedicinské grantové agentury Wellcome Trust v hodnotě 80 miliónů liber na klinický výzkum léčby uštknutí a vývoj nových protijedů (Schiermeier, 2019).

[58] Z celkem 95 sledovaných neuronů jich nejlépe reagovalo na obrázek hada téměř polovina (n=37, tedy 40,6%). Neuronů nejlépe reagujících na opičí obličej bylo 26 (28,6%), na opičí ruku 17 (18,7%) a nejméně neuronů reagovalo přednostně na jednoduché geometrické tvary (n=11, 12,1%).

[59] Úlohu pulvinaru primátů při přednostním vizuálním zpracování hadů potvrdila i další podobná studie, tentokrát zaměřená na gamma oscilace neuronální aktivity v pásmu 30-80Hz (Van Le et al., 2016).

(zvednutá hlava s pootevřenými čelistmi a esovitě prohnutý krk) vyvolaly intenzivnější behaviorální odpověď (postoj na zadních nohou, držení se oplocení) (Etting & Isbell, 2014)[60]. Detekční teorie se současně testovala i na lidských subjektech za použití měření elektrofyziologické aktivity mozku pomocí EEG, které poskytuje ve srovnání s dalšími neurozobrazovacími metodami (PET, fMRI) mnohem lepší časové rozlišení v řádu milisekund, které je v takových výzkumech zcela klíčové. Van Strien, Eijlers, Franken a Huijding (2014) předpokládali, že pokud se skutečně zrakový systém u primátů a člověka zdokonalil především jako evoluční odpověď na výskyt nebezpečných hadů, potom by mělo být možné měřit rozdíly v evokovaných potenciálů ve zrakové kůře (okcipitální lalok) vyvolaných obrázky hadů, pavouků a malých ptáků. Vzorku 24 nefobických žen se během měření EEG na obrazovce v náhodném pořadí za sebou pouštěly stimuly z těchto tří kategorií zvířat, a to buď v rychlé (tři obrázky za sekundu), či pomalé prezentaci (jeden obrázek za sekundu). Skutečně se potvrdilo, že časná posteriorní negativita (early posterior negativity, EPN), což je komponenta elektrického signálu objevující se 225 až 300 ms po prezentaci podnětu a jež odráží prvotní selektivní vizuální zpracování emočně nabitých stimulů (zejména tech evolučně relevantích), dosahuje největší amplitudy v případě hadů, následovaných pavouky a nakonec ptáky (viz Obr. 11)[61].

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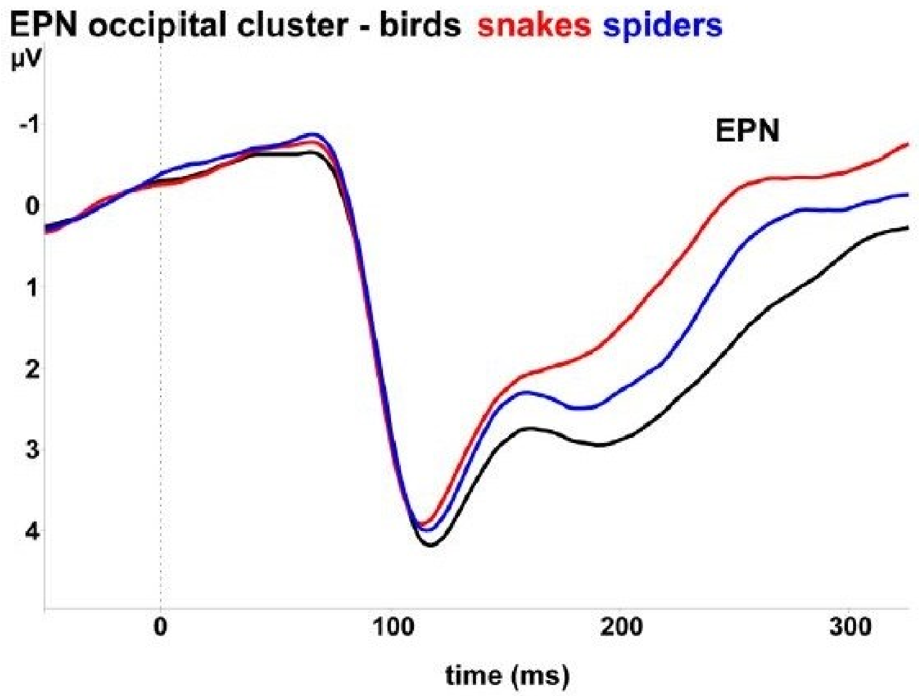
[60] Zatímco had v klidné pozici volně ležící na zemi většinou nepředstavuje významné riziko, pokud není přímo ohrožen, had ve výhružném postavení signalizující připravenost k rychlému útoku může být velmi nebezpečný, především na kratší vzdálenost.

[61] Amplituda EPN je zcela nezávislá na tom, jak moc se daný jedinec bojí hadů (nijak nekoreluje se skórem v psychologickém dotazníku měřícím individuální míru strachu z hadů). Naopak v případě pavouků takový vztah existuje a čím větší z nich má člověk strach, tím více u něj pavouci zvyšují EPN aktivitu. Opět se tedy zdá, že rychlá a intenzivní neurální odpověď vyvolaná hadem je u lidí univerzální (vrozená) a oproti pavoukovi neovlivněná individuální hladinou prožívaného strachu.

Obrázek 11. EPN evokované potenciály vyvolané obrázky hadů (červená), pavouků (modrá) a ptáků (černá) v okcipitální oblasti u nefobických žen (převzato z Van Strien et al., 2014).



Negativní EPN potenciál jdoucí přes okcipitální oblast mozku je následován zvýšeným pozdním pozitivním potenciálem (late positive potential, LPP) v temenní (parietální) oblasti mozkové kůry, který začíná zhruba 300 ms po prezentaci podnětu (měření probíhá v čase 500-900 ms) a je ukazatelem udržování trvalé pozornosti vedoucí nakonec k vědomému rozpoznání podnětu. I v tomto případě byl naměřen nejvyšší nárůst LPP pro hady, před pavouky a nejmenší pro ptáky, mezi hady a pavouky už však nebyl statisticky významý rozdíl. Autoři studie to interpretují tak, že zatímco v rané fázi zpracování signálu (EPN) přitahují hadi nejvíce předpozornostní, automatické pozornosti, v dalším stádiu je už nepřetržitá pozornost věnována v podobné míře hadům i pavoukům, což svědčí o tom, že mozek se připravuje na obranou reakci[62].

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[62] Nejnovější studie potvrzuje původní předpoklad, že zatímco LPP aktivitu (aktivně udržovaná motivovaná pozornost) v odpovědi na hady a pavouky je možné modulovat emoční regulací (pomocí kognitivního přehodnocení), EPN aktivita (raná selektivní pozornost) zůstává intaktní (Langeslag & Van Strien, Cogntive reappraisal of snake and spider pictures: An event-related potentials study, 2018). Naproti tomu maskovaná prezentace podnětů zcela vyruší rozdíl v elektrofyziologické EPN odpovědi na hady a další zvířecí podněty (pavouci, ptáci, motýli), ačkoliv při nemaskované stimulaci je EPN amplituda pro hady největší (Grassini, Holm, Railo, & Koivisto, 2016). To však není příliš překvapivé zjištění, když uvážíme, že principem podprahové stimulace je zamezení proniknutí signálu do primární zrakové kůry, jeho zpracování tak probíhá na nevědomé úrovni v podkorových oblastech.

V navazující studii pak stejný tým autorů (Van Strien, Franken, & Huijding, 2014) rozšířil původní výsledky a ukázal, že EPN amplituda je v okcipitální oblasti významně vyšší při zobrazení hadů ve srovnání s obrázky krokodýlů anebo želv, ačkoliv respondenti hodnotí hady i krokodýly velmi podobně, co se týče valence (pozitivní vs. negativní) a vybuzení[63]. Zároveň se jim podařilo prokázat, že prioritizace hadů jako evolučně relevantních stimulů je na úrovni elektrofyziologické odpovědi mozku podobná u mužů i žen, u žen je pouze výraznější. U obou pohlaví současně lze naměřit největší amplitudu EPN pro hady, následované pavouky, nejmenší je pak při sledování slimáků[64]. Navíc rozdíl mezi amplitudou EPN pro hady a slimáky u žen signifikatně větší než u mužů, což pravděpodobně odráží rozdílnou evoluční zkušenost s hady (Rakison, 2009). To vše má tedy být experimentálním důkazem detekční teorie Isbell (2006, 2009), podle které byl vizuální systém v mozku primátů přednostně vyladěn na hady[65]. Je přitom zajímavé, že k vyvolání intenzivní neurální odpovědi (EPN amplituda) v primární zrakové kůře stačí neúplný obrázek hadího těla bez hlavy, ale dokonce i detailní záběr na hadí šupiny (ve srovnání se šupinami ještěrky či peří ptáků), které jsou v rámci živočišné zvíře velmi specifické (Van Strien & Isbell, 2017). Etologické experimenty s primáty navíc prokázaly, že např. kočkodanům zeleným stačí k detekci hada jen nepatrná část hadí kůže odhalující šupiny, kterou rozpoznávají jako zdroj nebezpečí a dané místo si dobře pamatují (Isbell & Etting, 2017). Hadí šupiny jsou tedy pro primáty i člověka nejspíš klíčovým rozpoznávacím znakem.

Existují však i důkazy, které detekční teorii nepodporují. Např. tým antropologů (Wheeler, Bradley, & Kamilar, 2011) zkoumal morfologii zrakového aparátu recentních primátů a předpokladál přitom, že pokud má teorie platit, měla by být orbitální konvergence větší u druhů, které 1) se delší dobu vyvíjely v blízkosti jedovatých hadů (Afrika, Asie), 2) žijí v oblastech s vyšší početností hadů (nízká nadmořská výška, teplejší klima), 3) mají větší

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[63] Dokonce byla naměřena vyšší aktivita EPN v reakci na hady než na rozzlobené lidské obličeje (Langeslag & Van Strien, 2018), jedovatá zvířata, či trypofobické podněty (Van Strien & Van der Peijl, 2018).

[64] Ani v této studii nebyla měřená aktivita EPN ve zrakové kůře nijak ovlivněna subjektivně vnímaným strachem či odporem z testovaných zvířat, valencí či vybuzením. Přestože hadi vyvolávají v respondentech průměrně menší strach než pavouci a menší odpor než slimáci, mají stále největší EPN amplitudu, a tedy i nejvíce automatické pozornosti.

[65] Specifický zatočený tvar hadího těla může pravděpodobně do určité míry, ne však zcela, vysvětlit přednostní elektrofyziologickou odpověď EPN v okcipitální parieto-okcipitální oblasti na hady. V jiném experimentu porovnávaly reakci na hady, červy, pavouky a brouky. Zatímco největší amplituda EPN byla opět naměřena u hadů, červi s podobným tvarem těla byly až na předposledním místě za pavouky, před posledními brouky (Van Strien, Christiaans, Franken, & Huijding, 2016).

pravděpodobnost setkání s jedovatými hady (denně cestují na delší vzdálenosti), 4) mají menší šanci si všimnout hadů anebo je v případě ohrožení zahnat (žijí v menších skupinách či solitérně) a 5) mají větší šanci stát se kořistí hadů (mají menší tělesnou velikost). V této studii se však nepodařilo najít jakýkoliv vztah mezi zmíněnými proměnnými a orbitální konvergencí. Naopak, oproti očekávání byla nalezena vyšší orbitální konvergence u těch druhů primátů, na které je ze strany hadů vyvíjen nižší predační tlak.

II. Výzkumná část

1. Úvod

Hadi patří mezi zvířata vyvolávající silný strach ve značné části obecné populaci. Stejně tak jsou i jedním z nejčastějších fobických objektů způsobujícím iracionální, neovladatelný, ochromující strach. Ofidiofobií, tedy chorobným strachem z hadů, trpí 2-3% populace, což je mnohem vyšší prevalence než jaká platí u řady jiných, i když méně závažných, duševních onemocnění. Spolu s arachnofobií se tak jedná o jednu z nejrozšířenějších specifických fobií (Fredrikson et al., 1996). I přesto však stále přesně neznáme neuropsychologické vysvětlení vzniku fobického strachu z hadů. Kvůli technickým omezením nebylo po dlouhou dobu funkční zobrazení neurálních procesů strachu vyvolaného spatřením hada vůbec možné. Teprve pokrok, který na poli neurozobrazovacích metod nastal především v posledních dvou desetiletích, nám nyní konečně umožňuje propojit neurobiologické poznatky s teoretickými psychologickými koncepty a zkoumat tak pravou podstatu mechanismů zapojených do vzniku a následné regulace strachu, který zajistil přežití našich předků.

Přestože se v posledních letech několik málo výzkumů snažilo o zobrazení neurální odpovědi při vizuální prezentaci hada (e.g., Carlsson et al., 2004; Goossens et al., 2007a,b; Åhs et al., 2009), ve všech případech ho výzkumníci automaticky považovali za jednoznačný, uniformní podnět vzbuzující strach, čímž zcela ignorovali jeho potenciální mnohotvárnost. V současnosti je známo celkem 3 709 druhů hadů, mezi kterými existuje relativně vysoká velikostní, tvarová i barevná variabilita. Je tedy otázkou, zda lidé vnímají všechny druhy hadů stejně, tedy pouze jako různé varianty jednoho stimulu univerzálně vyvolávajícího strach, anebo mezi nimi dokáží rozlišovat, vnímat percepční i emoční rozdíly a specificky reagovat jen na ty skutečně nebezpečné.

Celá situace je dále komplikovaná tím, že některá zvířata mohou současně vzbuzovat více emocí, jejichž zpracování probíhá na úrovni různých funkčních okruhů. Tak například mnoho prací využívajících fMRI ke studiu neurálních změn v mozku u respondentů s arachnofobií popisují během zobrazování fobických stimulů (pavouků) aktivaci jak amygdaly, tak insuly. Zatímco amygdala se aktivuje při prožívání strachu, insula (insulární kortex), je část mozkové kůry uložené hluboko v laterální rýze oddělující temporální lalok od parietálních a frontálních laloků, která je hlavním centrem zpracování pocitů fyzického hnusu, ale i morálního opovržení a aktivuje se i v případě vnímání tváří vyjadřujících odpor. Podobně i v další studii byla u arachnofobiků aktivována současně amygdala i insula během sledování fobických podnětů, ale pouze amygdala při sledování obecně strach vzbuzujících podnětů, v tomto případě obrázků hadů (Goossens et al., 2007a). Naproti tomu práce zabývající se výhradně strachem z hadů téměř nikdy aktivaci insuly nepotvrdily. Je však možné, že různé druhy hadů vzbuzují rozdílné emoce, a tak aktivují i odlišné mozkové oblasti. Zatímco dosud byl zkoumán pouze strach z hadů, je pravděpodobné, že u některých druhů hraje důležitou roli i odpor (znechucení), který je kvalitativně odlišnou emocí s rozdílným neuropsychologickým profilem. Takové zjištění by pak mohlo najít uplatnění i v klinické praxi při léčení specifické fobie z hadů. Pokud by se totiž ukázalo, že existují dva typy fobií, jedna založená na strachu a druhá na znechucení vyvoleného hady, mohlo by následně dojít i k lepšímu zacílení KBT.

2. Cíle a hlavní hypotézy

Vzhledem k tomu, že role amygdaly a insuly (včetně dalších přidružených oblastí) při prožívání strachu či odporu z hadů zatím nebyla vyjasněna, hlavním cílem mého dizertačního projektu je odhalení příslušných neurálních okruhů při sledování obrázků různých druhů hadů. Smyslem by především mělo být dokázat, že velmi záleží na konkrétních percepčních charakteristikách daného objektu, které ve výsledku mohou vést ke zcela odlišným emočním reakcím na straně subjektu, a to jak na psychologické (prožitkové a behaviorální), fyziologické a neurální úrovni. Vedle variability v rámci podnětu se však zaměřím i na interindividuální variabilitu testovaných osob, tedy do jaké míry se liší aktivita mozku v odpovědi na různé druhy hadů u lidí s různými osobnostními charakteristikami, kterými jsou v tomto případě intenzita subjektivně prožívaného strachu z hadů a tendence k pocitům odporu měřené pomocí dvou standardních škál, Snake Questionnaire (SNAQ: Klorman et al., 1974) a Disgust Scale-Revised (DS-R: Haidt, McCauley & Rozin, 1994, modified by Olatunji et al., 2007).

Celý projekt je pak rozdělen na čtyři hlavní části: 1) subjektivní hodnocení strachu a odporu z hadů na základě verbálních a 2) nonverbálních (vizuálních) stimulů, a 3) objektivní měření fyziologických a 4) neurálních korelátů strachu a odporu z hadů.

První (psychometrická) část projektu bude zaměřena na český překlad a standardizaci diagnostických nástrojů pro měření strachu z hadů (SNAQ) a sklonům k odporu (DS-R). Jejich pomocí pak budu vyhledávat osoby s rozdílnou mírou obou emocí do dalších fází projektu.

Ve druhé části se pak budu zabývat subjektivním hodnocením emocí vyvolaných celou řadou druhů všech žijících plazů, se zvláštním důrazem na podřád hadů. Výzkumné osoby budou pomocí řazení (relativní hodnocení) i skórovaní na Likertově stupnici (absolutní hodnocení) posuzovat vlastní strach a odpor (případně krásu) vyvolaný zvířaty na fotografiích uspořádaných v několika různých sadách. V tomto experimentu budu testovat hypotézu, že lidé i bez jakékoliv předchozí zkušenosti či znalosti hadů od sebe dokáží na první pohled spolehlivě odlišit hady vzbuzující strach a odpor, a to na základě jejich rozdílných morfologických znaků. Hlavním cílem této studie pak bude především vyhledat relevantní, dostatečně emočně salientní podněty (druhy hadů) specificky aktivující příslušné emoční okruhy, které budou následně použity v následujících dvou experimentech.

Třetí část se bude věnovat měření autonomní fyziologické odpovědi těla na dvě skupiny hadů, nebezpečné a strach vzbuzující zmije vs. neškodné a spíše odpudivé podzemní hady. Testovanou hypotézou bude předpoklad, že rozdíl v subjektivně popisované emoci vyvolané oběma skupinami hadů se projeví i rozdílnou fyziologickou odpovědí, přičemž budu předpokládat zvýšenou tělesnou reakci v podobě kožního vodivosti a srdečního tepu v případě jedovatých zmijí a naopak snížení obou fyziologických parametrů při prezentaci podzemních hadů budících odpor. Stejně tak očekávám intenzivnější tělesnou reakci u lidí se zvýšeným strachem z hadů či odporem.

V závěrečné čtvrté, přitom však nejdůležitější, části projektu provedu experiment ve fMRI, kdy budu výzkumné osoby stimulovat fotografiemi hadů vyvolávajících strach nebo odpor a sledovat aktivaci vybraných mozkových oblastí. Testované stimuly budou vybrány na základě výsledků v druhé části projektu. Očekávám přitom, že hadi působící strach budou aktivovat převážně amygdalu, zatímco druhy vyvolávající odpor budou spojeny s aktivací v oblasti insuly. Podobně jako v předchozím fyziologickém experimentu, i v tomto případě očekávám vyšší neurální aktivaci u lidí se zvýšeným strachem z hadů či sklonem k prožívání odporu.

Následující čtyři tematické okruhy výzkumné části práce předkládají dosažené výsledky, a to buďto formou článků již publikovaných či odeslaných k recenznímu řízení v odborných zahraničních časopisech, fMRI experiment je pak popsán vcelku, vzhledem k tomu, že jeho sepsání do podoby publikace se teprve chystá.

3. Psychometrická studie strachu a odporu

První část dizertačního projektu se věnuje měření strachu a odporu pomocí standardizovaných psychodiagnostických nástrojů a tvoří ji tři publikované články. Dva z nich se detailně věnují psychometrickým vlastnostem českého překladu SNAQ (Polák, Sedláčková, Nácar, Landová, & Frynta, 2016; Příloha 1) a DS-R (Polák, Landová, & Frynta, 2019; Příloha 2). Třetí článek (Polák, Sedláčková, Landová, & Frynta, 2020) pak analyzuje zkrácené verze škály strachu z hadů (SNAQ) a její obdoby pro strach z pavouků (Spider Questionnaire, SPQ: Klorman et al., 1974; Příloha 3).

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Fear the serpent: A psychometric study of snake phobia

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ABSTRACT

Millions of people worldwide suffer from specific phobias. Almost any stimulus may trigger a phobic reaction, but snakes are among the most feared objects. Half of the population feel anxious about snakes and 2–3% meet the diagnostic criteria for snake phobia. Despite such a high ratio, only one instrument is commonly used, the Snake Questionnaire (SNAQ). The aim of this study was to develop a standardized Czech translation, describe its psychometric properties and analyze the distribution of snake fears. In a counter-balanced design 755 respondents were asked to complete the English and Czech SNAQ (first or last) with a 2–3 month delay; 300 of them completed both instruments. We found excellent test-retest reliability (0.94), although the total scores differed significantly when the English version was administered first. The mean score was 5.80 and Generalized Linear Models revealed significant effects of sex and field of study (women and people with no biology education scored higher than men and biologists). A cut-off point for snake phobia as derived from a previous study identified 2.6% of the subjects as phobic. Finally, the score distribution was similar to other countries supporting the view that fear of snakes is universal.

1. Introduction

Phobias, persistent and overwhelming irrational fears of people, objects, or situations, are widespread in the population and are the most common anxiety disorder. According to Doctor et al. (2008), an estimated 19.2 million adults over the age of 18 in the United States (9% of population) have experienced a specific phobia reaction at some point in their life. Andrews (2004) reviewed epidemiological studies of phobic disorders and concluded that the average prevalence rate of specific phobias is 8.8%. This is comparable to the prevalence of affective disorders and up to 20 times the prevalence of schizophrenia.

Although any object, no matter its actual fear relevancy, may trigger a phobic reaction, it seems that animals particularly stand out of the otherwise endless list of phobic stimuli as they can elicit strong fear (or disgust, which is a common component of animal phobias: Arrindell et al., 1999; Davey, 1994; Tucker and Bond, 1997) in a vast number of people (Fredrikson et al., 1996). Dysregulated, irrational fear of animals is one of the most common specific phobias in humans (Becker et al., 2007; Davey et al., 1998; Kirkpatrick, 1984) with a life-time prevalence 3.3–5.7% (LeBeau et al., 2010). However, the average rate of zoophobias can be even higher with considerable gender differences, as Fredrikson et al. (1996) reported on the Swedish population (12.1% of women and 3.3% of men). Furthermore, of all animals snakes are feared the most. Davey (1994) reported that snakes elicited anxiety in 53.3% of subjects and ophidiophobia, a clinically relevant fear of snakes, is held to affect 2–3% of population (Klieger, 1987; Klorman et al., 1974), thus representing a half of all animal phobias. Moreover, there is an evidence nowadays that fear of snakes may have an innate component and is shared with other non-human primates (Weiss et al., 2015). Therefore, it does not necessarily require a traumatic experience to be triggered, as opposed to other specific phobias (Doctor et al., 2008; Fredrikson et al., 1997; for a review on the etiology of specific phobias see Merckelbach et al., 1996).

Despite the relatively high prevalence of snake phobia in the general population, diagnostic tools are rather scarce (Rowa et al., 2008). Until recently, only a few psychometric instruments to quantify fear of snakes have been developed. The most commonly used is the Snake Questionnaire (SNAQ; Klorman et al., 1974). This is of surprise when compared to other specific phobias whose instruments tend to be overrepresented given their actual rate, e.g. there are six standardized measures of dental phobia (Antony, 2001).

The SNAQ has been so far subjected to a few validation studies (Fredrikson, 1983; Klieger, 1987, 1994; Klieger and Siejak, 1997; Klorman et al., 1974). Although it shows good internal consistency (0.78–0.90; Klorman et al., 1974), excellent test-retest reliability ($r = 0.84$: Fredrikson, 1983) and discriminates snake phobics from

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those fearing spiders and from nonphobics (Fredrikson, 1983), its psychometric qualities has been questioned by others. Especially Klieger (1987, 1994) argued against using the SNAQ as a good measure of snake phobia due to its low construct and criterion validity. He performed a behavioral test in which a significant number of people who reported high fear of snakes were actually able to approach a caged snake (Klieger, 1987). Therefore, after having reviewed studies using the SNAQ, Klieger and Gallagher (1993) concluded that it is sensitive for identifying fearful individuals, but strongly biased towards false positives. According to Klieger and Siejak (1997) the low specificity (i.e. sensitivity for discriminating individuals with no fear of snakes) can be attributed to ambiguous formulation of several items. In fact, they argued that the SNAQ, one of the most researched self-report psychometric instruments, is not only a measure of respondent's fear, but higher scores may also reflect disgust. For these reasons, Klieger (1994) proposed an extensive series of follow-up questions to remove the inherent ambiguities which significantly improved the disagreement between the SNAQ and behavioral measures.

Even though it remains disputable, whether the SNAQ can accurately estimate the number of snake phobics, it is still valuable as the only self-administered and formerly standardized tool assessing a verbal-cognitive component of the widespread fear of snakes. It provides a quick evaluation of the respondent's fear of snakes that may inform initial clinical judgement. Finally, it can also serve as a useful tool in epidemiological studies and when evaluating treatment outcomes. For these reasons, it is important to study if its formerly verified translation can be used in another cultural background to allow relevant comparisons with other research on snake phobia. The SNAQ has already been translated into other languages (e.g. Swedish: Fredrikson, 1983), but a Czech version is missing. Therefore, the aim of this study was to standardize the Czech translation of SNAQ and to obtain local norms on a nonclinical sample. Here we present data on its psychometric properties together with preliminary results on the distribution of snake phobia within the Czech population.

2. Materials and methods

2.1. Snake Questionnaire

The SNAQ is a 30-item self-report scale to assess the verbal-cognitive component of snake fear. Each item is a fearful or non-fearful statement related to snakes. Participants rate each item as true or false. The instrument is scored by assigning a “1” to each true response and “0” to each false response, 9 items are reversed-scored. A total score (ranging from 0 to 30) is calculated by summing all ‘true’ statements and it serves as a measure of the degree of phobic fear (Wikstrom et al., 2004; Wright et al., 2002). The SNAQ takes about 5–10 min to complete. The copyright author has provided his written consent for the SNAQ to be translated to Czech.

2.2. Participants

In total, 755 subjects (245 men and 510 women), aged 12–68 years with a range of demographic and socio-economic/educational backgrounds were recruited for the study. In order to obtain a heterogeneous sample, the authors contacted young children attending a local naturalists' center ($n=12$), high school students ($n=165$), university students of psychology ($n=34$) and veterinary sciences ($n=53$), pre- and postgraduate biologists ($n=139$), psychologists, psychiatrists, researches and administrative staff working at the National Institute of Mental Health ($n=36$), members of the university choir ($n=23$) and others ($n=20$). The rest of participants were recruited through the Internet ($n=273$), where data was collected using the Google Forms platform. Informed consent was obtained from all participants included.

2.3. Procedure

The standardization procedure followed recommendations of the American Psychological Association for developing translations (APA, 2014). First, the original English questionnaire was independently translated to Czech by two persons fluent in both languages. To identify and resolve potential discrepancies in the forward translations the two versions were then checked by a psychologist with a Master's degree experienced in test development. Subsequently, back-translation to English was developed by a third translator who had no previous knowledge of the questionnaire. Three native English speakers then compared the original and back-translated items to determine whether they were equivalent in content meaning. Any substantive differences for particular items were considered and revised by an expert panel consisting of researchers in psychology with the objective to obtain a translation most closely corresponding to the original instrument. Finally, both pen-and-paper and computer versions were created.

In order to standardize the Czech translation and evaluate its psychometric properties, a counter-balanced experimental design was adopted. After recruitment, a half of the subjects was administered the English SNAQ first, followed by the Czech translation 2–3 months later. The other half was asked to complete the questionnaires in the reverse order, i.e. first in Czech and then in English. Participants were randomly divided into these two groups. Each respondent had a brief explanation of the purpose of his/her participation and was instructed on how to complete the measure. The respondents were told that the questionnaire focused on human attitudes towards snakes and any mention of ‘fear’ was avoided. Before administering the SNAQ in English subjects were asked about their language proficiency and instructed not to complete the measure if they did not feel confident about the items meaning. However, as the majority of our respondents were high school or university students having been studying English for several years, it may be expected that they understood the full meaning of each item.

Prior completing the questionnaire, information on the individual's age, sex and education was collected. For statistical analyses the age was categorized into seven groups (less than 15; 15–20; 21–30; 31–40; 41–50; 51–60; and 60+). The education was divided into the following four categories: (1) high school students; (2) natural science education (biology, veterinary) (3) social science education (psychology, sociology, etc.); (4) other or unknown. Furthermore, categories 1, 3, and 4 were pooled together to create a non-biologists group and compared to the respondents with biology education as it was expected this could explain some response variability. We also recorded the method of administration, i.e. whether the subject completed the SNAQ using the pen-and paper or computer version.

The selected period length of 2–3 months between each administration is generally recommended when retesting personality questionnaires (McCrae et al., 2010). It is believed that after this time the subject can no longer remember his previous answers, thus the carry over effect is minimized (McConnell et al., 1998). For the second administration the participants filling out the pen-and-paper version were approached directly, others were asked by email to complete the questionnaire on a computer.

2.4. Statistical analysis

First, considering a non-normal distribution of the total raw

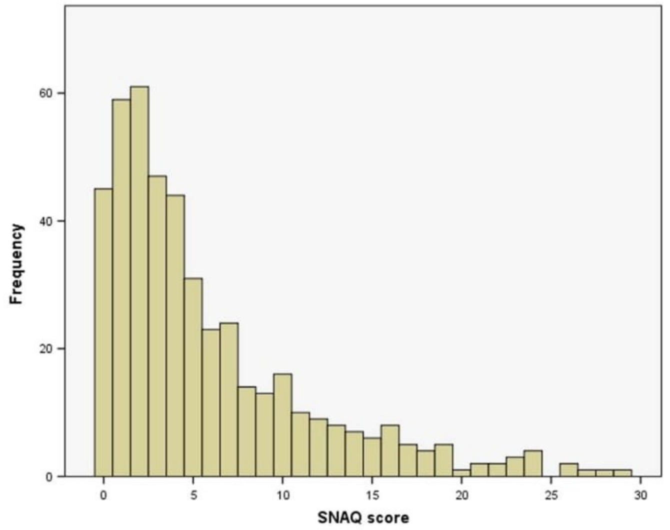

Fig. 1. Distribution of raw scores on the Czech translation of SNAQ from the first administration (N=456 respondents).

scores (skewness: 1.546, kurtosis: 2.168), we performed a Wilcoxon signed-rank test to analyze the effect of administration order (test vs. retest) and language (Czech vs. English) for those subjects who completed both questionnaires. Subsequently, a score difference between the test and retest was calculated and the Mann-Whitney *U* test for independent samples was employed to check whether this was affected by language of the questionnaire completed first. Individual item responses were then analyzed using a McNemar test for related samples. Score correlation between both language versions was calculated using a formula for test-retest reliability ($r = \mathrm{cov}_{1,2}/s_1 \times s_2$, $\mathrm{cov}_{1,2}$ – covariate of test-retest, $s_{1,2}$ – standard deviation for test and retest).

Second, to describe psychometric properties of the translated instrument, total scores from the Czech version were analyzed separately. Reliability was calculated using the split-half method and internal items consistency was expressed using the Cronbach's alpha. In order to normalize the non-normal (negative binomial) scores distribution (see Fig. 1), we applied the McCall's area transformation with a data continuity adjustment (McCall, 1922). Using the transformed Z-scores we calculated norms for our sample. Finally, we employed Generalized Linear Models (GzLM) for the negative binomial distribution with a log link function to analyze the effect of age, sex, education background, and type of administration (pen-and-paper vs. computer). All calculations were performed in the SPSS, version 22 (IBM Corp., 2013).

3. Results

Of the total of 755 respondents screened, 300 completed the SNAQ in both languages (148 were administered the original version first, while 152 first completed the Czech translation). The other 455 participants (151 completed the SNAQ in English and 304 in Czech) were either unavailable for the second administration or did not reply to an invitation for retest and therefore, were not included in the standardization part of our study. First, test-retest differences were analyzed. Based on the data distribution, it was arbitrarily decided to treat respondents with an absolute test-retest difference higher than six as outliers ($n=4$) and to exclude them from further analyses. The sex ratio of this sample was skewed in favor of women (185 vs 111), the most common age category was 15–20 years.

The Wilcoxon signed-rank test confirmed a statistically significant effect of both the administration order and language on the total score ($p < 0.001$). Having performed item analyses we found out that responses on the English and Czech version differed significantly ($p < 0.05$) on 13 items. Furthermore, the Mann-Whitney *U* test revealed that the test-retest score difference was affected by language of the first administration with a slight increase in scores when the English SNAQ was completed first (mean score difference for EN-CZ and CZ-EN administration order: 0.86 and −0.08, respectively, $z=3.69$, $p < 0.001$). Therefore, the studied sample was divided with respect to the language version that was given first and those two data subsets were analyzed separately. Interestingly, significant differences in scores on the two instruments were found only when the English SNAQ was administered first (mean score for the English and Czech SNAQ: 6.40 ± 0.48 and 5.53 ± 0.47, respectively, $z=4.49$, $p < 0.001$). However, this was not the case when the reversed order was applied (English: 5.02 ± 0.48, Czech: 4.94 ± 0.46, $z=0.35$, $p=0.723$). In spite of these effects, the test-retest reliability remained relatively high ($r=0.94$).

Further analyses were performed on the data obtained only by the Czech measure completed first ($n=456$). In this subsample there were 158 men and 298 women, the most common age category was 21–30 years. The mean score was 5.80 ± 0.27 ($SD=5.83$, see raw scores distribution in Fig. 1, standardized McCall transformed scores and respective norms can be found in Table 1).

Estimates of internal consistency were high as shown by split-half reliability and Cronbach's alpha analyses (both $r=0.91$). The GzLM revealed a significant effect of sex ($\chi^2=11.82$, $df=1$, $p=0.001$) and education ($\chi^2=15.38$, $df=4$, $p=0.004$) but not age ($\chi^2=7.36$, $df=6$, $p=0.289$) nor type of administration ($\chi^2=1.59$, $df=1$, $p=0.207$). The effect of respondent's education background was pronounced when the biologists vs. non-biologists

Table 1
Raw and transformed scores with norms. McCall's area transformation with correction for continuity (cumulative frequency) was applied. No respondent scored 25 or 30 points.

Raw score	Absolute frequency	Relative frequency	Cumulative frequency	Z score	T score	Percentile
0	45	0.0987	0.0493	−1.651	33.487	0.0
1	59	0.1294	0.1634	−0.981	40.193	9.8
2	61	0.1338	0.2950	−0.539	44.610	22.8
3	47	0.1031	0.4134	−0.219	47.811	36.2
4	44	0.0965	0.5132	0.033	50.330	46.5
5	31	0.0680	0.5954	0.241	52.414	56.2
6	23	0.0504	0.6546	0.398	53.978	63.0
7	24	0.0526	0.7061	0.542	55.421	68.1
8	14	0.0307	0.7478	0.668	56.676	73.4
9	13	0.0285	0.7774	0.763	57.635	76.4
10	16	0.0351	0.8092	0.875	58.750	79.3
11	10	0.0219	0.8377	0.985	59.851	82.8
12	9	0.0197	0.8586	1.074	60.738	85.0
13	8	0.0175	0.8772	1.161	61.611	87.0
14	7	0.0154	0.8936	1.246	62.461	88.7
15	6	0.0132	0.9079	1.328	63.279	90.3
16	8	0.0175	0.9232	1.427	64.272	91.6
17	5	0.0110	0.9375	1.534	65.341	93.4
18	4	0.0088	0.9474	1.620	66.199	94.5
19	5	0.0110	0.9572	1.719	67.195	95.3
20	1	0.0022	0.9638	1.797	67.968	96.4
21	2	0.0044	0.9671	1.840	68.399	96.7
22	2	0.0044	0.9715	1.903	69.032	97.1
23	3	0.0066	0.9770	1.995	69.949	97.5
24	4	0.0088	0.9846	2.161	71.609	98.2
26	2	0.0044	0.9912	2.375	73.751	99.1
27	1	0.0022	0.9945	2.544	75.438	99.5
28	1	0.0022	0.9967	2.717	77.174	99.7
29	1	0.0022	0.9989	3.063	80.628	100.0

Table 2
Descriptive statistics of raw scores obtained from the Czech translation of the Snake Questionnaire categorized according to sex, age, whether the respondent has biology education, and type of administration. Mean scores with respective 95% confidence intervals (CI) as predicted by the reduced generalized linear model were included for those variables with a significant effect.

		N	Percent (%)	Mean	95% CI	Predicted mean	Predicted 95% CI
Overall		456	100	5.80	5.26–6.34	4.76	4.20–5.39
Sex	Men	158	34.6	4.51	3.74–5.28	4.04	3.37–4.84
	Women	298	65.4	6.49	5.78–7.19	5.61	4.86–6.48
Age	Up to 15	7	1.5	2.00	0.07–3.93	–	–
	15–20	112	24.6	4.70	3.68–5.71	–	–
	21–30	185	40.6	5.99	5.14–6.85	–	–
	31–40	87	19.1	6.77	5.43–8.11	–	–
	41–50	27	5.9	6.56	4.73–8.39	–	–
	51–60	20	4.4	6.25	2.66–9.84	–	–
	Over 60	18	3.9	5.83	3.67–8.00	–	–
Biology education	No	350	76.8	6.36	5.73–6.98	5.92	5.25–6.68
	Yes	106	23.2	3.96	2.98–4.94	3.83	3.09–4.74
Administration	Pen-and-pencil	217	47.6	4.75	4.06–5.43	–	–
	Computer	239	52.4	6.76	5.96–7.56	–	–

comparison was done ($\chi^2=12.48$, $df=1$, $p<0.001$). Parameter estimates of the reduced model including only the significant effects were as follows: intercept - $B=1.64\pm0.16$, $p<0.001$; men - $B=-0.30\pm0.11$, $p=0.007$; non-biologists - $B=-0.153\pm0.12$, $p=0.016$. On average, women scored higher than men (6.49 ± 0.36 and 4.51 ± 0.39, respectively). Finally, people with no biology education received a higher score as compared to pre- and post-graduate biologists (6.36 ± 0.32 and 3.96 ± 0.49, respectively; for more details see Table 2).

With respect to the SNAQ's sensitivity to identify fearful individuals and its ability to discriminate between people with a normal level of fear and phobic individuals, Fredrikson (1983) found in a group of 18 snake phobics recruited through local newspapers that their average SNAQ score was 24.44 (CI 23.08–25.80). If we adopt this criterion and take score 23 (i.e. the lower limit of CI in phobics) as a cut-off point for snake phobia, then 12 respondents from our sample (representing 2.6%) could be pre-classified as phobics.

4. Discussion

In this study, we describe psychometric qualities of a Czech translation of the SNAQ, the most commonly used diagnostic instrument for measuring fear of snakes. Data from respondents who completed both the original English and Czech questionnaire show that there is a high correlation between the total scores ($r=0.94$). This is despite a relatively long delay between each administration giving the participants enough time to forget their answers. Surprisingly, even though two different languages were used, this correlation is significantly better ($p=0.027$) than in Lang et al.'s control subjects ($r=0.78$ over periods of approximately one month, as cited in Klorman et al., 1974). Similar conclusion, although at the limit of statistical significance ($p=0.054$), can be drawn from a comparison to test-retest reliability $r=0.84$ found by Fredrikson (1983) in the Swedish population (for the SNAQ administered 1 year apart).

Despite the high correlation, significant differences in total scores attributed to the language and administration order were found. Further analyses revealed that an interaction between these variables might explain the different outcomes. Scores obtained by the original SNAQ but not the translation depended on whether it was completed first or last. It may be hypothesized that some items were not fully understood when the English instrument was tested first, hence causing divergent responses on the following Czech version. On the other hand, this was not an issue when the original instrument was completed last as understanding might have been facilitated by having previously seen the items in Czech. In any case, a Spearman correlation coefficient between test and retest calculated only for those respondents having English as the first administration is still high ($r=0.82$).

It is also noteworthy that the selected design may have caused the high attrition of participants between the first and second administration as only 300 out of 755 respondents completed both versions of the SNAQ. It is of no surprise that the highest dropout was among the subjects recruited through the Internet who did not answer to our invitation for retest. Nevertheless, there were also a number of respondents who declined to take part in the second round if they were to receive the original instrument saying their English competency was insufficient.

Our results are comparable to those reported in the original validation study published by Klorman et al. (1974). They administered the SNAQ to 456 males and 851 females in the USA and reported mean scores of 4.92 and 7.79, respectively. Slightly higher mean scores were reported from a Swedish translation administered to 300 students at the University of Uppsala (5.80 for males and 9.06 for females; Fredrikson, 1983). Thus, it seems plausible that fear of snakes is a universal phenomenon with a similar distribution across the general population irrespective of the culture or local environment. The North America is inhabited by 127 snake species, four of which are deadly venomous (the copperhead, coral snake, cottonmouth, and rattlesnake; Wallach et al., 2014). In comparison, only three snake species live in Sweden and five in the Czech Republic, a single one being venomous but not presenting a risk to healthy adults (the common European adder). It has been estimated that 7000–8000 people per year receive venomous bites in the United States, and about 5 of those people die (NIOSH, 2015). In contrast, only 17 people per year are bitten by the common adder in the Czech Republic (Valenta, 2008).

If fear of snakes was learnt through lifetime experiences, higher scores in the American population should be expected as Americans would be at higher risk to encounter a dangerous snake. On the other hand, the similarities across countries are supportive of the evolutionary hypothesis that the tendency to fear snakes is innate both in humans and other primates (Cook and Mineka, 1989; LoBue and DeLoache, 2008) and may have served to help our common ancestors to survive in the wild (Isbell, 2006; Öhman and Mineka, 2001). It should be noted, however, that the American study was performed on a group of college students from urban areas with no information about their experience with snakes. Alternative explanation for the similarity in fear level among the Americans on one side and the Swedes and Czechs on the other, may therefore be that despite higher abundance of snakes in the US, the selected sample had limited chances to encounter a live snake in the wild.

In accordance with other studies of snake phobia (Fredrikson, 1983; Fredrikson et al., 1996; Klieger, 1987; Klorman et al., 1974; see also Klieger and Gallagher, 1993), women tended to report significantly higher fear of snakes compared to men. In fact, higher prevalence among females are found for all specific phobias (Andrews, 2004; Fredrikson et al., 1996; see McLean and Anderson, 2009 for a comprehensive review of the gender differences in fear) and animal phobias in particular affect considerably more women than men (according to a DSM-IV review up to 91% of animal phobics are females; LeBeau et al., 2010). We also demonstrated that people with biology education scored significantly lower as compared to those without one or even as compared to the average (see Table 2 for CIs of mean). Two hypotheses might explain such an outcome. Enrolling for a biology degree can either serve as a preselection factor, as people with higher fear of snakes may not choose this field in order to avoid their feared object. It may also be that biology courses provide knowledge with therapeutic effects (Makashvili et al., 2014) or represent some form of exposure therapy that subsequently decreases the fear level in initially fearful individuals. The Czech curriculum of biology majors includes numerous compulsory courses on reptile morphology, ecology, and behavior. Therefore, it may be argued that bachelor students are presented with information about snakes throughout their study. However, our research design does not allow us resolve this issue.

We could not confirm that fear of snakes would be related to age. This is contrary to Doctor et al. (2008) who argued that snake fear increases in prevalence up to age 20 and then gradually declines. This was corroborated by Fredrikson et al. (1996) who found more intense animal fears in younger than older individuals. Contrary to that, the SNAQ scores in our sample tended to be positively correlated with age (although not significantly), which is similar to results reported by Germano and Blaha (2001). On the other hand, a limited inclusion of subjects below 15 years of age in our study might have caused the absence of a clear relation between the two variables as fear of snakes seems to peak around 8–9 years (Kendler et al., 2008). In conclusion, age associated changes of snake fear remain unclear.

Our data show that fear of snakes is not normally distributed in the population as some other psychological dimensions (e.g. personality traits, cognitive skills, etc.). Instead it follows a negative binomial distribution when a majority of people that are non-phobic have low SNAQ score (median is 4). As the frequency of scores over the median drops rapidly, only those that score close to the maximum can be considered as phobics (Fig. 1). A total of 22 respondents exceeded the 95th percentile which is generally considered as a clinically significant limit (see Table 1); this corresponds to score 19. Furthermore, 2.6% of respondents scored positive on at least 23 items (see above) which is in accordance with the usually accepted 2–3% prevalence rate of snake phobia (Klieger, 1987; Klorman et al., 1974).

There is a consistent evidence that specific phobias constitute a major public health problem with considerable social and economic burden (Greenberg et al., 1999; Gustavsson et al., 2011). The individuals' lives are often dominated by intense fear and they go to great lengths to avoid the feared object. All snake phobics recruited by Fredrikson (1983) considered their phobia to be a serious handicap. This can make life extremely difficult for both the phobic patients and their families and considerably lower their overall psychological well-being (LeBeau et al., 2010). Unless treated, it is a chronic mental disorder; the average person with phobia can expect to be troubled for 7 in 12 months, year after year. The disability attributed to the panic and phobic disorders are two-thirds that due to the affective disorders and, more surprisingly, the total disability attributed to schizophrenia is only a quarter of that due to panic and phobia (Andrews, 2004).

Despite availability of effective and evidence based therapeutic interventions, a high proportion of affected individuals do not seek treatment and carry on living with this mental disorder for years. Moreover, it is suggested that early prevention of phobic disorders may considerably lower the chance of further psychopathological development in individuals at risk (Andrews, 2004). Therefore, it is of high public interest to possess an easy to administer, quick and reliable measure for one of the most widespread specific phobias to enable identification and treatment of at risk individuals.

In conclusion, the Czech SNAQ is a reliable tool for measuring snake fears. It has satisfactory psychometric properties and outcomes are generally in agreement with those of the English original and other language versions (e.g. Swedish). The fear distribution across countries suggests that fear of snakes is a universal component of the human mind shared by different cultures with various lifetime experiences.

Conflict of interest

None of the authors have competing interests.

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Undisguised disgust: a psychometric evaluation of a disgust propensity measure

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Abstract

Disgust, considered as one of the basic emotions universally shared across various cultures, has only recently attracted increased research interest. Originally developed as a key component of the behavioural immune system serving to protect the body from infectious pathogens, disgust has taken on other roles such as guiding our moral judgements, political preferences, or even choices of sexual partners. Despite these adaptive roles, disgust may, on the other hand, be responsible for negative social (xenophobia, homophobia) or clinical phenomena (common anxiety disorders such as specific phobias of obsessive-compulsive disorder), thus, a reliable measure of individual tendencies to experience disgust is indispensable. The aim of this study was to develop and analyse a Czech version of the Disgust Scale – Revised, one of the most widely used assessment of disgust propensity. Using a back-translation procedure and a counterbalanced test-retest experimental design, we demonstrated that scores on the Czech measure correlated with those on the English original (test-retest reliability $r = 0.82$) and both measures were found equivalent ($p = 0.019$). We also adopted a general linear model to show that the level of disgust is affected by sex, age, and education/occupancy, as women and people with no biology education score significantly higher than men and biologists, respectively. Finally, our data provide support to a bifactor model composed of general disgust taping into all items in addition to three distinct disgust domains.

Keywords Behavioral immune system · Contamination · Disgust scale · DS-R · Test translation

Introduction

Within the growing body of research on human emotions, disgust has only recently attracted substantial interest of various disciplines (Rozin et al. 2016). Nowadays, it is considered as one of the basic emotions with a cross-culturally recognizable facial expression (Ekman 1992), distinct physiological response (Stark et al. 2005) and specific neuroanatomical correlates (reviewed in Schienle 2009). Originally, it serves as the "behavioural immune system" protecting the body from dangerous pathogens (Curtis et al. 2011). However, through a process of preadaptation disgust has been useful in serving new functions, such as guiding moral judgments (Schnall et al. 2008) or facilitating the in-group cohesion through xenophobia (Faulkner et al. 2004). Disgust is also of interest to clinical researchers due to its role in aetiology of various mental disorders ranging from animal phobias (Davey and Marzillier 2009), contamination-based obsessive-compulsive disorder (OCD), eating disorders, and sexual dysfunctions (Olatunji et al. 2010).

Despite the need of a reliable valid measurement of disgust (Olatunji and Sawchuk 2005), it has become a challenging task given the vast diversity of disgust elicitors that extends beyond contaminated food (Rozin et al. 2016). Waste products, body envelope violations (i.e. surgery, puncture wounds, deformity, and other situations in which the normal exterior envelope of the body is breached or altered, Haidt et al. 1994), deviant sexual practices, or even violations of adopted moral codes (Chapman et al. 2009; Tybur et al. 2013) are new sources of disgust that require an inclusive and reliable form of measurement. Haidt et al. (1994) put forth an influential theoretical model categorizing disgust into two principal subtypes: core disgust (food, animals, and body products) and

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animal reminder disgust (death, sex, body envelope violations). To measure disgust propensity (individual tendency to experience disgust) the authors presented a self-report instrument, the Disgust Scale (DS), which has become the method of choice with more than a hundred published articles (Olatunji and Sawchuk 2005). Recently, Olatunji et al. (2007) suggested to revise the measure by dropping seven items and regroup the rest into three factors called core, animal reminder, and contamination-based disgust.

Although the Disgust Scale – Revised (DS-R) appears to have some utility across cultures (Olatunji et al. 2009), a specific cultural background can modulate what objects or situations are considered being disgust elicitors (Rozin and Fallon 1987; Tybur et al. 2009). It is thus valuable to possess a local instrument for measuring disgust propensity that allows cross-national comparisons. So far, several language versions of the DS-R have been developed (e.g., Dutch, Korean, or Hebrew), but a Czech translation has yet to come.

Therefore, the aim of this study was to (1) create a standardized Czech translation of the DS-R, (2) analyse its psychometric qualities including reliability and validity (using an alternative measure of disgust propensity, the Three-Domain Disgust Scale, TDDS; Tybur et al. 2009), (3) verify its three-factor structure, and (4) test the effect of selected demographic variables (sex, age, education) on disgust scores. As people from different disciplines are exposed to varying levels of disgust elicitors, which require a different ability to manage these experiences, we expect people with biology education to demonstrate lower disgust propensity than those educated in social sciences (psychology, sociology, law, etc.).

Methods

Subjects

In total, 1069 healthy subjects of both sexes (272 men and 797 women) aged 16–89 years were recruited for the study. Most of them were high school ($N = 81$) or college students ($N = 751$). In order to test for the effect of study field, students of natural (biology) and social sciences (psychology, sociology, politics, etc.) took part. The additional participants were recruited from staff members of a biology faculty and psychiatric research centre, or through the Internet. The study has been approved by the respective institutional ethics committee. All the subjects gave their written informed consent prior to testing.

Psychometrics

The DS-R is a self-report personality scale to assess individual differences in propensity to disgust developed by Haidt et al. (1994) and modified by Olatunji et al. (2007). There are 25 disgust elicitor items loading on one of the three factors (core disgust, animal reminder disgust, contamination-based disgust) and two catch questions (item 12 and 16) to identify those respondents that are not paying attention to the task or do not take it seriously. Each item is rated by the participant on a 5-point Likert scale from 0 ("Strongly disagree/Not disgusting at all") to 4 ("Strongly agree/Extremely disgusting"). The total score (ranging from 0 to 100) is calculated by summing scores on all the 25 disgust elicitor items but three (item 1, 6, 10) that are reverse-scored. Similarly, subscale scores may be calculated. All the participants that do not give valid answers on the catch questions should be dropped. The DS-R demonstrates acceptable Cronbach's alpha estimates for the overall internal consistency (0.84) and the three subscales (core disgust: 0.74; animal reminder disgust: 0.78; contamination-based disgust: 0.61; Olatunji et al. 2007, which was replicated by van Overveld et al. 2011).

The TDDS is a 21-item self-report measure of disgust propensity in three domains: pathogen, sexual, and moral disgust. The items are scored on a 7-point Likert-type scale. The three subscales have demonstrated very good internal consistency (Cronbach's alpha: 0.84, 0.87, and 0.84, for pathogen, sexual, and moral disgust, respectively) and validity (Olatunji et al. 2012; Tybur et al. 2009, 2011). Prior to the study it has been translated into Czech by two independent bilingual translators.

Procedures

The standardization procedure followed the guidelines for translating and adapting tests set by the International Test Commission (ITC 2017; see also Hambleton et al. 2005). First, having the permission of the copyright holder, the original DS-R was translated from English to Czech independently by two bilingual professionals. These two versions were then checked by a psychologist experienced in test development to identify and resolve potential item discrepancies in the translations. Subsequently, a back-translation to English was performed by another translator unfamiliar with the questionnaire. Three native English speakers then compared the original and back-translated items to determine whether they were equivalent in meaning. Any substantive differences in particular items were considered and appropriately revised by a team of psychologists with the objective to obtain a translation best corresponding the original instrument.

Next, a counterbalanced experimental design was adopted to standardize the Czech translation of the DS-R and evaluate its psychometric properties. Thus, a half of the subjects were administered the original English version first, followed by the Czech one approximately two months later. The other half was asked to complete the questionnaires in the reverse order, i.e., first in Czech and then in English. The way the participants were divided into these two groups was completely random. The selected period of two months between each administration is generally recommended when retesting personality questionnaires (McCrae et al. 2011). It is believed that after this time the subjects can no longer remember their previous answers that could influence the current score, thus the carry over effect is eliminated (McConnell et al. 1998). In addition, to check for convergent validity, a subsample of 288 respondents also completed the Czech version of the TDDS a few months later.

Prior to testing, we asked the subjects about their English proficiency and instructed them not to complete the instrument if they did not feel confident. However, as mentioned above, the majority of our sample were high school or university students who have learned English for several years. Moreover, as a part of the curriculum at Charles University, students are required to pass an English exam equivalent to "A Cambridge English: First" qualification (FCE). Therefore, a good level of English skills among our participants was expectable. Information on the individual's age, sex, and occupancy/education was collected as well. For statistical analyses, the age was categorized into seven groups (less than 15; 15–20; 21–30; 31–40; 41–50; 51–60; and more than 60 years). The occupancy/education was categorized either as 1) biological (university students of biology, lecturers of the Faculty of Science, and doctors) and 2) other than biological (high school students, university students of psychology, sociology, economics, politics, and law, IT technicians, psychologists, etc.).

Statistical Analyses

First, the scores distribution from both language versions was checked for normality using a Shapiro-Wilk test. Based on the outcome, we employed either a paired samples t-test or Wilcoxon signed-ranked test to analyse the effect of administration order (test vs. retest) and language (Czech vs. English). Responses on individual items were compared using a Wilcoxon matched-pair signed-rank test for related samples. Subsequently, a score difference between the test and retest was calculated and a t-test for independent samples was employed to check, whether this was affected by the language of the questionnaire used first. Score correlation between both language versions was calculated as well using a formula for test-retest reliability.

We also employed methods of statistical equivalence testing, specifically a two one-sided t-test (TOST; Schuirmann 1987), to analyse the measurement invariance. An acceptance criterion θ was calculated using the following formula: $\theta = \delta + s' \left[t_{(1-\alpha, 2n-2)} + t_{(1-\beta/2, 2n-2)} \right] \sqrt{\frac{2}{n}}$ (δ: the absolute value of true difference between the groups' mean values, arbitrarily set to 0; s': the upper 95% confidence interval (CI) of standard deviation s; t-test critical values for $\alpha = \beta = 0.05$). Subsequently, a 90% CI of difference in mean total scores from both measures was compared to $[-\theta; \theta]$ interval.

Secondly, to verify psychometric properties of the translated instrument, total scores from the Czech DS-R were analysed separately. The items factor structure was examined using a factor analysis with the maximum likelihood extraction method and Direct Oblimin rotation that allows for correlation which is expectable in psychological phenomena (Costello and Osborne 2005). As the data were on a 5-point Likert scale, they were treated as ordinal. The appropriate number of factors to retain was determined using a parallel analysis (Horn 1965) which has been demonstrated as one of the most accurate methods for such purpose (Zwick and Velicer 1986). Here we followed a procedure developed by O'Connor (2000) using his updated syntax (O'Connor n.d.). We ran 5000 random permutations of a raw data set with 891 cases and 25 variables (i.e. the disgust elicitor items; item 1, 6, and 10 were first rescored) to which the real data eigenvalues were compared. Furthermore, in order to verify the factor structure of the Czech DS-R, Tucker's congruence coefficients of factor similarity with the original scale were calculated and the same analysis was repeated after a Procrustes rotation had been applied to our matrix of factor loadings. We have also computed a Mantel test to compare the items correlation matrix calculated from our data with that originally published by Olatunji et al. (2007).

The model fit was then checked by conducting a confirmatory factor analysis (CFA) comparing several alternative factor solutions based on the literature (including a parsimonious one-factor model and a bifactor model allowing to test for a general latent "g" disgust factor in addition to distinct components of disgust; see Olatunji et al. 2014). Competing nested models were compared using a chi-square difference test (χ^2_{diff}).

Reliability was calculated using the split-half method and items internal consistency was expressed as the Cronbach's alpha. We also used the Pearson correlation coefficient between the three subscale scores of the DS-R and TDDS to demonstrate convergent validity. Finally, a General Linear Model (GLM) was used to analyse the effect of age, sex, and education background. Most of the calculations were performed in the SPSS Statistics, version 22 (IBM Corp. 2013). The CFA was conducted in the SPSS Amos, version 24 (Arbuckle 2016). Finally, the Mantel test and Tucker's congruence coefficients were calculated in the XLSTAT add-on statistical package for Excel, version 2017.4 (Addinsoft 2017).

Results

Translation Evaluation

In total, 351 participants completed the DS-R in both languages, the rest of subjects did not take part in retest (62 completed the DS-R in English, 656 in Czech). The fit of total scores on both versions to a normal distribution was acceptable at $\alpha = 0.01$ (English: $p = 0.014$, skewness 0.15, kurtosis −0.58; Czech: $p = 0.032$, skewness 0.18, kurtosis −0.53). We found a statistically significant difference in total scores on the English ($M = 44.38 \pm 0.77$, $SD = 14.46$) and Czech DS-R ($M = 42.38 \pm 0.72$, $SD = 13.51$); $t(350) = 4.44$, $p < 0.001$; see Table 1). Item analyses with a Bonferroni correction revealed that responses on both versions differed significantly at the selected level ($p < 0.002$) on 7 items (1, 2, 6, 10, 18, 24, and 27).

We also found a slight though nonsignificant decrease in total scores from the first ($M = 43.73 \pm 0.75$, $SD = 14.01$) to the second administration ($M = 43.03$, $SD = 14.03$); $t(350) = 1.52$, $p = 0.128$. The test-retest score difference was significantly higher when the English DS-R was administered first ($M = 3.15 \pm 0.76$, $SD = 9.25$) compared to the reversed order ($M = -1.13 \pm 0.54$, $SD = 7.63$); $t(349) = 4.75$, $p < 0.001$. Based on these results, the studied sample was divided respective to the version tested first and each data subset was analysed separately.

When the original instrument was tested first, it yielded a significantly higher total score ($M = 47.94 \pm 1.25$, $SD = 15.24$) compared to retest using the Czech translation ($M = 44.79 \pm 1.22$, $SD = 14.88$); $t(149) = 4.18$, $p < 0.001$. Interestingly, the opposite pattern, although less pronounced, was found when the Czech DS-R was tested prior to the original ($M = 40.59 \pm 0.85$, $SD = 12.11$ vs $M = 41.79 \pm 0.94$, $SD = 13.25$); $t(200) = -2.10$, $p = 0.037$ (see Fig. 1). Despite these effects, test-retest reliability remained relatively high for the total score ($r = 0.82$, $p < 0.01$; see Table 1 for more results). Additionally, two alternative methods of the TOST confirmed that the two instruments were equivalent in measuring disgust propensity. The 90% CI of difference in mean total scores ($M = 1.99 \pm 1.74$) was completely contained within the interval of acceptance criterion (−4.20; 4.20). This was supported by the right and left one-sided t-test on the lower and upper bound; $t(700) = -2.09$, $p = 0.019$ and $t(700) = 5.87$, $p < 0.001$, respectively.

The following analyses were performed on the data from the Czech DS-R only ($N = 1006$). There was no significant difference in total scores between those who completed the translated instrument first ($N = 857$, $M = 43.27 \pm 0.49$, $SD = 14.34$) or second ($N = 149$, $M = 44.71 \pm 1.22$, $SD = 14.90$); $t(1004) = -1.13$, $p = 0.260$), leading to all data being pooled together. Considerably lower scores were found in subjects who provided invalid responses on the catch items 12 and 16 ($N = 115$, $M = 39.88 \pm 1.38$, $SD = 14.80$ vs. $N = 891$, $M = 43.95 \pm 0.48$, $SD = 14.31$); $t(1004) = 2.85$, $p = 0.004$, thus, they were excluded from further analyses.

Factor Analysis

The Kaiser-Meyer-Olkin measure of sampling adequacy (0.88) and Bartlett's test of sphericity ($\chi^2 = 4258.70$, $df = 300$, $p < 0.001$) confirmed that the item structure of the data set warranted a factor analysis. Although six factors had eigenvalues greater than one, the parallel analysis revealed that only the first four eigenvalues extracted from the real data exceeded both the mean and the 95th percentile of those based on the simulations of raw data sets (5.50, 1.76, 1.36, and 1.24). However, a close visual inspection of the scree plot showed that the fourth eigenvalue was not significantly different from the 95th percentile of the corresponding random data eigenvalue (1.24 vs. 1.23) and just represented a correlated residual of the items (Panter et al. 1997). Thus, the

Table 1 Comparison of results from the English and Czech version of the Disgust Scale – Revised (DS-R)

	Lang.	Mean	SD	SE	r	t	df	p
Total score	EN	44.38	14.46	0.77	0.82	4.44	350	< 0.001
	CZ	42.38	13.51	0.72				
Core	EN	23.56	7.30	0.39	0.80	4.49	350	< 0.001
	CZ	22.45	7.14	0.38				
Animal reminder	EN	14.02	6.12	0.33	0.76	0.22	350	0.826
	CZ	13.97	6.39	0.34				
Contamination	EN	6.79	3.96	0.21	0.71	5.52	350	< 0.001
	CZ	5.97	3.21	0.17				

Only those respondents who completed both instruments were included in the analysis ($N = 351$)

Lang. language version of the DS-R, *EN* English, *CZ* Czech, *SD* standard deviation, *SE* standard error of mean, *r* correlation coefficient between total/subscale scores from both language versions, *t* t-test value comparing total/subscale scores from both language versions, *df* degrees of freedom

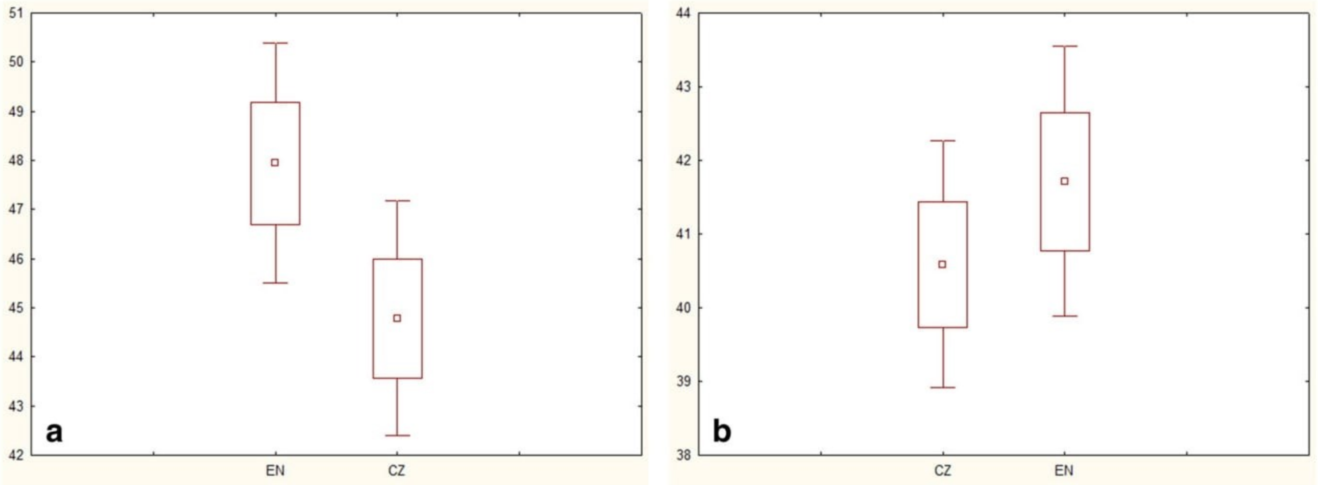

Fig. 1 Comparison of the total scores from the English and Czech DS-R. a The English original administered before the Czech translation; **b** The Czech translation administered before the English original. Inner square = mean; box = mean ± SE; whiskers = mean ± 1.96*SE

parallel analysis revealed that only three factors should be extracted, two of which were clear, while the third one was weaker, though still salient.

This three-factor solution explained 25.96% of the total variance. The first factor accounted for 19.04% of the total variance and consisted of nine items, all of them tapping into animal reminder with only one item from the core disgust subscale, though its factor loading was very low (0.202). The second factor, which accounted for 4.45% of the total variance, included nine items scoring on the core and one on the contamination-based disgust subscale. The last factor accounting for 2.47% of the total variance then contained six items, four belonging to the contamination-based and two to the core disgust subscale (see Table 2 for factor loadings).

Despite a relatively weak structure of the third factor, Tucker's coefficients of congruence with the original factor matrix were satisfactory for all three factors ($r = 0.90$, 0.86, and -0.81) and these slightly improved after the Procrustes rotation ($r = 0.91$, 0.86, and 0.82). This was corroborated by the Mantel test that revealed a significant correlation between the items correlation matrices ($r = 0.73$; $p < 0.001$).

Although there was a reasonable fit of the three-factor model (χ^2 (272) = 889.40, $p < 0.001$) as revealed by the CFA using various indices, including the Root Mean Square Error of Approximation (RMSEA = 0.05), Comparative Fit Index (CFI = 0.846), and the Tucker-Lewis Index (TLI = 0.830), the best fit among all the models was associated with the bifactor model of general disgust and three distinct disgust domains (χ^2 (250) = 739.04, $p < 0.001$; RMSEA = 0.047; CFI = 0.878; TLI = 0.854). Thus, adding a "g" disgust factor with loadings from all the items significantly improved the model (χ^2_{diff} (22) = 150.35, $p < 0.001$). Conversely, neither

Table 2 Factor loadings of the disgust elicitor items from the Czech DS-R. Extraction method: maximum likelihood, rotation method: Oblimin with Kaiser normalization ($N = 892$)

Item	Subscale	Factor		
		1	2	3
7	Animal reminder	**0.813**	−0.116	−0.034
2	Animal reminder	**0.628**	−0.015	−0.018
21	Animal reminder	**0.563**	0.231	0.169
19	Animal reminder	**0.477**	0.117	−0.130
24	Animal reminder	**0.453**	0.133	−0.239
14	Animal reminder	**0.420**	0.020	−0.222
10[a]	Animal reminder	**0.373**	0.137	0.054
5	Animal reminder	**0.347**	0.000	−0.254
11	Core	**0.202**	0.116	−0.173
25	Core	−0.159	**0.535**	−0.118
15	Core	0.183	**0.482**	0.118
17	Core	−0.062	**0.443**	−0.205
27	Core	0.082	**0.431**	−0.112
3	Core	0.102	**0.408**	0.076
20	Core	−0.013	**0.389**	−0.075
8	Core	0.149	**0.367**	0.128
22	Core	−0.040	**0.338**	−0.284
23	Contamination	0.034	**0.264**	−0.209
6[a]	Core	0.081	**0.254**	−0.019
13	Core	0.115	−0.005	**−0.458**
4	Contamination	0.011	−0.018	**−0.449**
9	Contamination	−0.026	0.062	**−0.398**
1[a]	Core	0.155	0.011	**−0.355**
18	Contamination	−0.003	0.147	**−0.340**
26	Contamination	0.093	0.185	**−0.247**

[a] Items have been re-scored prior to the analysis (see the Methods). The highest factor loading for each item is presented in boldface

Table 4 Spearman correlation coefficients between the total and subscale scores on the Czech version of the DS-R (reflecting the item structure as shown in Table 2) and TDDS ($N = 288$)

Disgust domain	1	2	3	4	5	6	7	8
1. DS-R total score	–	0.850**	0.823**	0.693**	0.345**	0.526**	0.293**	0.020
2. Factor I		–	0.516**	0.411**	0.239**	0.381**	0.209**	0.006
3. Factor II			–	0.453**	0.311**	0.547**	0.259**	−0.030
4. Factor III				–	0.345**	0.364**	0.305**	0.102
5. TDDS total score					–	0.490**	0.733**	0.732**
6. Pathogen						–	0.307**	−0.009
7. Sexual							–	0.276**
8. Moral								–

** Correlation is significant at $p < 0.001$ (two-tailed)

the unidimensional model with 25 indicator variables, nor a two-factor model showed a good fit to the data (see Table 3 for more results from the CFA).

Psychometric Properties of Czech DS-R

The total scores were normally distributed (skewness 0.15; kurtosis −0.42); see a table in Online Resource 1 for norms. The disgust elicitor items showed a moderate reliability through examining the split-half Spearman-Brown coefficient ($r = 0.70$) or the Cronbach's alpha coefficient of internal consistency ($\alpha = 0.75$). The DS-R total scores significantly correlated with those obtained on the TDDS ($r = 0.35$, $p < 0.001$); see Table 3 for more results.

The GLM model revealed a significant effect of sex ($F(1{,}773) = 68.74$, $p < 0.001$), age ($F(6{,}668) = 8.55$, $p < 0.001$), and occupancy/education ($F(1{,}773) = 45.53$, $p < 0.001$) on the DS-R total score. Conversely, neither the sex*age nor sex*occupancy/education interaction effect proved significant ($F(5{,}666) = 1.02$, $p = 0.402$ and $F(1{,}771) = 3.33$, $p = 0.068$, respectively); for parameter estimates see a table in Online Resource 2. On average, women scored significantly higher than men ($M = 46.06 \pm 0.54$ vs. 36.93 ± 0.89) and people with other than biology education scored significantly higher than biology students and postgraduates ($M = 46.34 \pm 0.67$ vs. 39.42 ± 0.72; see Table 4 and 5 for more details).

Discussion

Our data, gathered on respondents who completed both the English and translated instrument, show a high correlation of the total scores ($r = 0.82$). This result is within the range of 0.7–0.9 which is recommended for test-retest reliability of psychological assessment (Groth-Marnat 2009) and corresponds well to test-retest reliability as assessed with a Spearman correlation coefficient 0.85 reported by Kang et al. (2012) who adapted the DS-R into Korean. Slightly lower though still satisfactory correlations were found in our study for the scores on three subscales, i.e. core, animal reminder, and contamination-based disgust ($r = 0.79$, 0.76, and 0.71, respectively). These values clearly demonstrate that despite a relatively long delay between both administrations, which exceeds the usually advised period of one month, responses on the DS-R are relatively consistent and the adapted Czech measure provides reliable data that correlate significantly with the original DS-R. Moreover, we have demonstrated that the two instruments may be considered equivalent ($p = 0.019$) in measuring disgust propensity.

Further statistical analyses revealed elevated total scores on the English DS-R compared to its translation irrespective of the administration order. That is if the Czech respondents tend to self-report higher disgust propensity when answering in English than in their native language. This difference in scores remains even if they complete the original measure after having

Table 3 Comparison of different models of the Czech DS-R using a confirmatory factor analysis showing selected indices of model fit ($N = 892$). The models are in the order of increasing fit

Model tested	χ^2	df	χ^2/ df	AIC	AGFI	CFI	TLI	RMSEA
1-factor model	1260.60**	275	4.58	1360.60	0.859	0.754	0.732	0.063
2-factor model	984.77**	274	3.59	1086.77	0.900	0.823	0.806	0.054
3-factor model	889.40**	272	3.27	995.40	0.906	0.846	0.830	0.050
Bifactor model	739.04**	250	2.96	889.04	0.917	0.878	0.854	0.047

df degrees of freedom, χ^2/df a ratio of chi-square divided by the degrees of freedom, *AIC* Akaike information criterion, *AGFI* adjusted goodness-of-fit test, *CFI* comparative fit index, *TLI* Tucker-Lewis index, *RMSEA* root mean square error of approximation

** χ^2 test is significant at $p < 0.001$

Table 5 Descriptive statistics of the total scores obtained by the Czech DS-R categorized according to sex, age, and type of education/occupancy

Parameter	N	Mean	SE	95% CI
Overall	891	43.95	0.48	43.01; 44.89
Men	208	36.93	0.89	35.19; 38.68
Women	679	46.06	0.54	45.00; 47.12
< 15 yrs	5	63.60	6.27	46.18; 81.02
15–19 yrs	168	49.53	1.10	47.35; 51.71
20–29 yrs	528	43.74	0.60	42.56; 44.91
30–39 yrs	110	41.05	1.33	38.42; 43.67
40–49 yrs	41	36.71	2.21	32.25; 41.16
50–59 yrs	20	38.95	3.30	32.04; 45.86
60+ yrs	18	32.06	2.26	27.28; 36.83
Biologists	336	39.42	0.72	38.00; 40.84
Non-biologists	444	46.34	0.67	45.03; 47.66

N: Out of 1006 respondents who completed the Czech DS-R (i.e. those 351 with both languages +655 others who completed only the Czech scale but not the English original), 115 questionnaires were invalidated by responses on two catch questions 12 and 16, leaving 891 subjects for psychometric analysis of the Czech DS-R including its factor structure. Furthermore, 4 participants did not provide their gender and 111 did not state their field of study, thus not allowing us to assign them either to a "biologist" or "non-biologist" group. Therefore, the GLM model analysing the effect of sex, age, and education/occupation was based on 780 subjects. *SE* standard error of mean, *CI* confidence interval

read the Czech translation, so the effect of impaired comprehension is ruled out (see Fig. 1). It may be suggested, that it is not the order of presentation (that was nonsignificant), but rather the language it is written in that may affect the DS-R scores.

Interestingly, a very similar trend has been recently found in a study on psychometrics of the Snake Questionnaire (SNAQ), a self-report measure of snake fear (Polák et al. 2016). As the data from both questionnaires follow a different distribution, i.e. normally distributed scores of disgust, but a negative binomial function in the case of snake fear, it seems that either over-scoring in English or rather under-scoring in Czech might be a general psychometric phenomenon. Perhaps, English is seen by Czech students as a more formal, academic language used in scientific discourse, which might subsequently unconsciously lower the tendency for self-styled responses. It is also possible that the translation process has slightly shifted the items meaning despite a thorough back-translation procedure used in translation development, so disgust reported on the Czech DS-R tends to be a bit lower. Overall, the possible effect of a foreign language on self-disclosure tendencies is an interesting issue that would warrant further research.

Although the DS has been considerably improved by Olatunji et al. (2007) in terms of subscales' internal consistency and its factor structure, there is still an ongoing discussion about the number of factors of the DS-R. The original eight factors were reduced to three different but interrelated disgust factors, i.e. core, animal reminder, and contamination-based disgust. In an extensive cross-cultural study performed by Olatunji et al. (2009), the three-factor solution best accounted for data from seven countries including Australia, Brazil, Germany, Italy, Japan, Sweden, and the USA. Only the Netherlands showed a poor fit to the model, but this was later challenged by van Overveld et al. (2011) who again confirmed three factors. These were also found in an adolescent sample of US high school students (here the factors were called contagion, mortality, and contact disgust: Kim et al. 2013) or in Israeli Jewish citizens (Berger and Anaki 2014). Moreover, the concept of three different kinds of disgust was demonstrated to have a convincing convergent and divergent validity in a study by Olatunji et al. (2008) who showed that each disgust type is distinctively associated with personality, behavioural, physiological, and clinical correlates. Conversely, data from the Korean version of the DS-R best fitted to a five-factor model (Kang et al. 2012).

Based on our data and in accordance with Olatunji et al. (2014), the best fitting is a bifactor model of disgust composed of four latent variables of which one is a general disgust factor being loaded on by all the 25 DS-R items and simultaneously there are three distinct domains of disgust that were revealed in the parallel analysis as well. These three separate disgust domains then describe in more details the variance in disgust propensity towards various categories of stimuli among subjects. It should be noted however that despite having the best fit to the data, some indices are still slightly below the recommended threshold (e.g., CFI and TLI should be >0.9) and lower than those reported by Olatunji et al. (2014) for the bifactor model. It is difficult to get a good fit with a large sample size. Perhaps the measure might also need some revision, especially items 6, 11, 23, and 27 seem causing problems to the model fit due to their low standardized regression weights. Nevertheless, an independent sample would be required to re-analyze the factor structure of such revised scale.

The first and most robust factor almost exclusively consists of items from the animal reminder subscale (see Table 2) and there is a very strong correlation between the first factor scores and the animal reminder subscale scores ($r = 0.97$, $p < 0.01$). On the other hand, the remaining two factors were considerably weaker, accounting together for only around 7% of total variance, and were mutually correlated ($r = -0.44$). This was also supported by Tucker's congruence coefficients showing a fair similarity for the first two factors, though a bit lower for the third one. Note however, that the third factor referred to as contamination-based disgust was the most problematic one already in the original psychometric evaluation (Olatunji et al. 2007). In our study, no clear distinction between the original core and contamination-based disgust subscale could be inferred since items pertaining to these dimensions were mixed in the two factors.

This may reflect the conceptual ambiguity in the original model of disgust put forth by Rozin et al. (2000) and further developed by Olatunji et al. (2007). Core disgust is, according to the authors, based on a sense of offensiveness at the prospect of oral incorporation of disgusting stimuli (e.g., tainted food, body waste products, etc.). Contamination-based disgust is, on the other hand, defined as disgust reactions based on the perceived threat of transmission of contagion (e.g., interpersonal disgust associated with hygiene). In our view and in accordance with recent evolutionary models (Curtis 2011; Davey 2011), the main function of disgust is to act as the behavioural immune system which helps protect the body from the risk of disease. Stimuli triggering core (e.g., rotting foods, waste products, and small animals) or contamination touch-based disgust (e.g., a public toilet, a sick cook in a restaurant, or a new condom) may be seen together as sources of harmful pathogens and tap into a single construct of disease avoidance (Tybur et al. 2009). As Olatunji et al. (2014) demonstrated, core and contamination disgust are more strongly associated, whereas animal-reminder disgust may be more distinct. Thus, the motive to separate the core and contamination-based disgust items into two distinctive domains remains questionable (cf. van Overveld et al. 2011).

Some support for those conclusions can be found in our analysis of convergent validity. Correlation coefficients between scores on the DS-R and TDDS are significant and correspond to previous reports (Olatunji et al. 2012; Tybur et al. 2009). The strongest correlation was found between similar constructs, i.e. pathogen disgust on one hand and the three subscales of the DS-R on the other. This corroborates the view of Tybur et al. (2009) that the three components of disgust as measured by the DS-R, despite forming separate factors, conceptually all pertain to fear of pathogens transmission. Conversely, the lowest and non-significant correlations were found between moral disgust (TDDS) and the DS-R subscales. This is in line with the previous evidence (Tybur et al. 2009) and can be considered as a sign of discriminant validity as moral disgust is not being covered at all by the DS-R.

Despite the relatively abundant literature reporting psychometric properties of the DS-R, only a few studies use the new scoring format suggested by van Overveld et al. (2011; i.e. a unified 5-point Likert scale on all items vs. a true/false response on 13 items and a 3-point Likert scale on 12 items used previously). The mean total score we found on the Czech DS-R ($M = 43.95$) is considerably lower compared to the Dutch ($M = 50.45$; van Overveld et al. 2011) or Korean sample ($M = 54.92$; Kang et al. 2012). It is hard to speculate what might account for this difference. Even if we accept that diverse cultural background would be an intuitive explanation for the comparison of disgust propensity in the Czech Republic and South Korea, this is not the case of the Netherlands that is culturally very similar to Czechia.

Nevertheless, the Dutch sample was very uniform as it consisted exclusively of university students of psychology. On the other hand, we recruited people with a varied educational background (social vs. natural sciences), which was found to have a significant effect on disgust propensity. To our knowledge, this is the first time it has been tested and it provides support for construct validity of the translated questionnaire. As we show here, biologists demonstrate significantly lower disgust propensity compared to psychologists, sociologists, economists, and others. This is no surprise considering that disgust elicitors (faeces, bodily fluids, dead bodies and their parts, small animals, etc.) are at the very essence of biological science. However, similarly to what was already discussed for lower fear of snakes in biology students (Polák et al. 2016; but see Landová et al. 2018), it remains unclear whether higher disgust propensity precludes people from studying biology or rather pursuing a biology degree may lower the initial disgust propensity level through a process based on desensitization. In any case, even though the considerable number of biologists among our participants lowered the mean score, it cannot explain the difference in comparison to the Dutch study as the DS-R score in the non-biologists group was still approximately 5 points lower.

Lastly, we verified the effect of sex on disgust scores. It is generally agreed that disgust sensitivity and propensity is gender-dependent. On average, women score significantly higher than men, thus, tend to react with disgust more frequently and value this experience more negatively (Berger and Anaki 2014; Haidt et al. 1994; Rozin et al. 2016; Tybur et al. 2011). Based on our data, the DS-R score of women is more than 25% higher than that of men. Surprisingly, as has been shown in an fMRI study, higher experienced disgust in women is not reflected by increased brain activity in neuroanatomical structures processing repulsive stimuli (e.g. amygdala, insula, fusiform gyrus, or orbitofrontal cortex; Schienle et al. 2005). The effect of sex on self-reported disgust also fits into the well-known fact that women show generally higher tendency to experience negative emotions such as fear (see a review by McLean and Anderson 2009) which may develop more into some anxiety disorders. For example, up to 91% of animal phobics are women (LeBeau et al. 2010; for the link between disgust and animal phobias see a review by Davey and Marzillier 2009). From the evolutionary perspective, these results are not surprising given the higher reproductive value of women than men because of their ability to give birth to progeny. This is seen especially in pregnant women (note that in human ancestors, pregnancy used to be much more frequent than today) who should pay extra attention to sources of pathogens in the environment to protect not only themselves but also their unborn babies (Tybur et al. 2011, 2013).

These findings have an interesting implication. There is an extensive line of evidence that pathogen disgust from potentially infectious stimuli has been transformed to the domain of morality (Chapman et al. 2009; Pizarro et al. 2011). It is well supported in criminology statistics, that most of the crimes are committed by men (Rowe et al. 1995). It is possible, that higher propensity to feel disgusted is, on one hand, predisposing the person to suffer from some serious anxiety disorders, such as specific phobias (Page and Tan 2009; Thorpe and Salkovskis 1998; van Overveld et al. 2006) or OCD (McKay and Moretz 2009). On the other hand, it may serve as a protective factor helping individuals to obey social rules and avoid getting into trouble with the law. It could be suggested that people with biology education and a lower tendency to feel disgusted, such as men compared to women, are also more inclined to transgress moral codes of the society. This topic would require additional research.

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Compliance with Ethical Standards

Conflict of Interest The authors declare no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the appropriate institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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Research article

Faster detection of snake and spider phobia: revisited

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ABSTRACT

Snake and spider phobia are one of the most prevalent anxiety disorders, yet quick and reliable measures are rather scarce. Recently, attempts have been made to shorten two widespread measures of snake and spider fear, the Snake Questionnaire (SNAQ) and Spider Questionnaire (SPQ). The new 12-item scales demonstrate very good psychometric qualities in terms of internal consistency and discriminatory power. Using the same approach on a bigger sample from another cultural background, we aimed to verify psychometric properties of the short scales. In total, 2 644 Czechs completed the SNAQ, 1 816 of which also completed the SPQ. The item response theory revealed that nine and seven items on the shorter SNAQ and SPQ, respectively, were identical with the Hungarian study. The 12-item scales show excellent reliability ($\alpha = 0.84$ and 0.91) and highly correlate with scores on the full versions ($r = 0.81$ and 0.89) as well as with fear and disgust ratings of snake and spider images. Thus, despite slight discrepancies in the selected items, we confirm that the shorter SNAQ and SPQ keep considerable diagnostic strengths and can be used in the clinical practice as reliable, easy-to- administer, and fast screening tools for snake and spider phobia.

1. Introduction

There is a consensus throughout the literature that even though there are many triggers of human fears, animals in particular stand out of the list of phobic stimuli (Arrindell et al., 1991). Dysregulated, irrational fear of animals is considered as one of the most common phobias in human subjects with a life-time prevalence 3.3–5.7% (LeBeau et al., 2010). Similarly to other anxiety disorders, the prevalence of zoophobias is significantly gender-dependent affecting up to 4 times more women than men (12.1% vs. 3.3%; Fredrikson et al., 1996). However, the potential of various animal species to become a phobic stimulus is not evenly distributed as just of them, snakes and spiders, cause most of animal phobias. Davey (1994a) reported that snakes elicited anxiety in 53.3% and ophidiophobia, a clinically relevant fear of snakes, is believed to affect 2–3% of population (Klieger, 1987; Klorman et al., 1974; Polák et al., 2016), thus representing as much as a half of all animal phobias (Eaton et al., 2018; but see Wardenaar et al., 2017 who reported average prevalence of any animal phobia across the world to be estimated to 3.8%). Even higher prevalence of snake phobia, despite low local abundance of snakes, was found in the Swedish (5.5%, Fredrikson et al., 1996) or Hungarian population (4.2%, Zsido, 2017 and 3.3%, Zsido et al., 2018), while a Dutch study reported a little lower value of 1.2% (Oosterink et al., 2009).

Besides snakes, spiders trigger a strong fear in many people too, especially in the Western society (Davey et al., 1998), although disgust might also play an important role in spider phobia (Davey, 1994b). The average prevalence of spider phobia varies across different countries, ranging from 2.7% in the Netherlands (Oosterink et al., 2009), through 3.5% in Sweden (Fredrikson et al., 1996) to even 8.1% (Zsido et al., 2018) and 9.5% in Hungary (Zsido, 2017).

Despite the high prevalence of snake and spider phobia, the number of reliable assessment measures is surprisingly limited (Antony, 2001). So far, only one standardized psychometrics has been used to quantify fear of snakes, the Snake Questionnaire (SNAQ; Klorman et al., 1974). There is a bit bigger choice of scales for measuring fear of spiders, e. g. the Fear of Spiders Questionnaires (FSQ; Szymanski and O'Donohue, 1995), Watts and Sharock Spider Phobia Questionnaire (WS-SPQ; Watts and Sharrock, 1984); Spider Phobia Beliefs Questionnaire (Arntz et al., 1993), but it is especially the Spider Questionnaire (SPQ; Klorman et al., 1974) that is widespread in animal phobia research.

Psychometric properties of both the SNAQ and SPQ have been already verified in a few studies showing good results in terms of internal consistency (SNAQ: 0.78–0.89; SPQ: 0.81–0.89), excellent test-retest

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reliability (SNAQ: $r = 0.78–0.84$; SPQ: 0.87–0.94) and potential to discriminate between normative and clinical fear (Fredrikson, 1983; Klieger, 1987; Klorman et al., 1974; Muris and Merckelbach, 1996; Polák et al., 2016; Zsido, 2017). It should be noted, however, that others have questioned those results and especially the SNAQ has been criticized for not being a good measure of ophidiophobia. Klieger (1987) argued against using it due to its low construct and criterion validity as a significant number of people scoring high on the SNAQ were actually able to approach a snake in a cage. Therefore, Klieger and Gallagher (1993) conclude that the SNAQ can identify fearful individuals, but is strongly biased by false positives, because some of the items tap into disgust rather than fear. Despite the criticism, it is still valuable as the only self-administered and formerly standardized tool assessing a verbal-cognitive component of the widespread fear of snakes.

It can be agreed that clinical practice would greatly benefit from having an easy-to-administer and fast tool to screen for highly prevalent specific animal phobias and shortening already well-established psychometric tools has now become a common trend in assessment (see for example Rammstedt and John, 2007). In a recent paper, Zsido et al. (2018) have taken this approach and demonstrated, that the SNAQ and SPQ can be shortened to just 12 out of the original 30 or 31 items, respectively, without much detriment to their psychometric qualities. This, according to the authors, would save considerable time in the assessment of specific phobias. Using an extensive sample of 1354 Hungarian respondents, their study shows that the shorter scales are still highly reliable (Cronbach's $\alpha = 0.88$ and 0.90 for the SNAQ and SPQ, respectively) and their scores significantly correlated (after a correction for redundancy) with the original measures' scores ($r = 0.89$ and 0.91 for the SNAQ and SPQ, respectively).

Currently, there has been a growing demand by psychiatrists and psychologists for developing fast and reliable diagnostic tools that could be easily administered in their everyday practice. Shorter instruments would also prove beneficial in research by providing rapid screening for specific individuals without a risk of overloading them, which is often the case in studies using human subjects. Therefore, being inspired by the contribution of Zsido et al, (2018) we have decided to repeat the analyses and verify their outcomes on a substantially bigger sample of subjects from the Czech Republic. Doing so, we would demonstrate that their findings might be generalised to a population speaking a different language and living in a slightly different cultural environment, which would greatly increase their validity. It would provide a strong evidence that scales used for assessment of the most common specific phobias might be considerably shortened without compromising their psychometric quality. Thus, our main goal was to develop a Czech 12-item version of the SNAQ and SPQ and test whether it can satisfactorily substitute the original scales.

2. Materials and methods

2.1. Subjects

The data for the following analyses were taken from two separate projects. A majority of subjects completed an assessment battery in Czech (including the SNAQ and SPQ) in an online study of animal fears. In total, 2 291 subjects were recruited from a Facebook community of more than 16 thousand followers. Out of these, 1 816 subjects completed both the SNAQ and SPQ while another 85 participants returned only the former scale. There were considerably more women than men (N = 1278 vs 519, respectively, i.e. 70.4% women), the remaining subjects decided not to disclose their gender. The mean age in this sample was 33.2 ± 0.3 years. Most of the subjects have obtained a university degree (N = 889), 795 people have completed secondary education, and 108 participants have stopped after elementary school. In this study, the subjects were also asked about their field of study (specifically, whether it was biological or not), and the size of town where they had grown up for most of their childhood as both these variables might affect the level of animal fear (Polák et al., 2020).

Additionally, we had access to data from a sample of 745 subjects who completed a Czech translation of the SNAQ in a study testing its psychometric properties. There were almost twice as women as men (N = 488 vs. 257), the mean age was 27.8 ± 0.4 years. This variable sample consisted of high school and college students of natural and social sciences, psychologists, psychiatrists, researchers, university lecturers, etc. Overall, having combined these two data sets together, we acquired data from 2 646 subjects for the SNAQ and 1816 for the SPQ. All the participants provided their informed consent by pressing the corresponding button on the electronic form or signed a consent form and were debriefed after completing the measures. The study has been conducted in accordance with the ethical standards of the research ethics committee of the National Institute of Mental Health, Czechia and and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

2.2. Assessment

2.2.1. Snake Questionnaire

The SNAQ is a 30-item self-report scale (see Supplementary Material 1) to assess the verbal-cognitive component of snake fear. Each item is a fearful or non-fearful statement related to snakes. Participants rate each item as true or false. The instrument is scored by assigning a “1” to each true response and “0” to each false response, 7 items are reversed-scored. A total score (ranging from 0 to 30) is calculated by summing all 'true' statements and serves as a measure of snake fear. The Czech translation of SNAQ demonstrated excellent psychometric qualities in terms test-retest reliability ($r = 0.94$) and internal consistency (Cronbach's $\alpha = 0.91$; for more details see Polák et al., 2016).

2.2.2. Spider Questionnaire

The SPQ is very similar to the SNAQ, adapted to quantify fear of spiders (see Supplementary Material 2). It contains 31 items (fearful or non-fearful statement) rated as true or false. It is scored the same way as the SNAQ, 9 items are reverse-scored and scores can range from 0 to 31. Internal consistency is also high (Kuder-Richardson formula 20, KR-20 = 0.89; Klorman et al., 1974 and Cronbach's $\alpha = 0.94$; Zsido, 2017), as well as the test-retest reliability ($r = 0.95$; Zsido, 2017).

For validity reasons, scores on two other psychometrics have been used, the Fear Survey Schedule II (Geer, 1965) and Disgust Scale-Revised (Haidt et al., 1994; modified by Olatunji et al., 2007; Czech translation by Polák et al., 2019).

2.2.3. Fear Survey Schedule II

The FSS-II is a self-report instrument to assess overall level of anxiety in a person's life, as well as particular areas of anxiety (such as social situations, injury, death, animals, etc.). It contains 51 items that are nouns relating to animals, social situations, injury and death, objects, noises, and other situations that are rated by the respondent on a 7-point Likert scale according to elicited fear from 1 (“no fear”) through 4 (“some fear”) until 7 (“terror”). A total score is calculated as a sum of item scores and can range from 51 to 357. Its internal consistency is exceptionally high (KR-20 = 0.94).

2.2.4. Disgust Scale-Revised

The DS-R is a self-report personality scale to assess individual differences in propensity to disgust. There are 25 disgust elicitor items loading on one of the three factors (core disgust, animal reminder disgust, contamination-based disgust) and two catch questions (item 12 and 16) allowing to identify those respondents that do not pay attention to the task or do not take it seriously. Each of the 27 items is rated by the participant on a 5-point Likert scale from 0 (“strongly disagree/not disgusting at all”) to 4 (“strongly agree/extremely disgusting”), three items (1, 6, 10) are reverse-scored. A total score ranging from 0 to 100 is calculated by summing scores on all the 25 disgust elicitor items but three (item 1, 6, 10) that are reverse-scored. Similarly, subscale scores may be calculated. According to the recent paper, the Czech DS-R demonstrates very good psychometric properties (Cronbach's α = 0.75, test-retest reliability r = 0.82; Polák et al., 2019).

Finally, the participants scored three standardized photographs of a viper, grass snake, and spider on a 7-point Likert scale according to fear and disgust. The colour images representing typical individuals were taken from the Internet, digitally cropped, placed on a white background, and resized to a comparable size (regardless of their real size) using GIMP 2.8.16 (Kimball and Mattis, 2016).

2.3. Procedure

In this study, we used standardized Czech translations of the SNAQ and SPQ. These were developed in another project following the guidelines for translating and adapting tests set by the International Test Commission (ITC, 2017). This involved a translation to Czech by two fluent speakers of both languages and then a back-translation to English by an independent person. Three native English speakers then compared the original and back-translated items to determine whether they were equivalent in meaning. Any substantive differences in particular items were considered and appropriately revised by an expert panel consisted of researchers in psychology with the objective to obtain a translation corresponding the most the original instrument. Finally, both pen-and-paper and computer versions were created.

Subsequently, a counter-balanced experimental design was adopted to verify psychometric qualities of the translated scales. Thus, a half of the subjects was administered the English SNAQ or SPQ first, followed by the Czech translation 2–3 months later to eliminate the carry-over effect. The other half was asked to complete the questionnaires in the reverse order. Participants were assigned to one of these groups randomly.

2.4. Statistical analysis

Similarly to Zsido et al. (2018), we first dropped all the reverse-scored items from the SNAQ and SPQ (6, 12, 14, 16, 17, 20, 25, 27, and 28). Then we used a confirmatory factor analysis (CFA) on the remaining items to check for unidimensionality of the data to be able to then apply the item response theory (IRT) approach, specifically a two parameter logistic item response model (2PL). We used the same threshold of a = 1.7 for the discrimination parameter (i.e. items with a <1.7 were excluded from the analysis) and subsequently, from those surpassing the threshold we selected 12 items on each questionnaire based on their difficulty parameter b (four items with the lowest and highest b and four items with b closest to the median).

These new 12-item scales were then analysed for reliability using the Cronbach's α and Spearman-Brown coefficient of split-half reliability. Next, scores on the short questionnaires were calculated and correlated with the total scores on the original versions after correcting for redundancy as the items are shared (Levy, 1967). We also performed several validity analyses, including the Spearman's correlation between the short scales and other standardized assessment of fear and disgust or rating of snake and spider images according to fear and disgust. As the SNAQ and SPQ scores are not normally distributed in the general population (Fredrikson, 1983; Polák et al., 2016), a Generalized Liner Model (GLzM) for negative binomial distribution was used to analyse the effect of gender, age category, education level, field of study, and size of town on scores on the new shortened scales. Finally, we conducted a receiver operating characteristic (ROC) curve analysis and calculated the Youden index (*J* = maximum {sensitivity + specificity - 1}; Schisterman et al., 2005) to identify an ideal cut-off point on both shortened questionnaires for potential snake/spider phobia. First, the presumable snake or spider phobics in the data set were identified using their SNAQ or SPQ scores. Based on Fredrikson (1983) and Muris and Merckelbach (1996) we categorised all subjects scoring 23 points or higher on the SNAQ as snake phobics (N = 60, i.e. 2.27%; see also Polák et al., 2016 for more details) and those with at least 22 points on the SPQ as spider phobics (N = 177, i.e. 9.75%).

The IRT analysis was performed in the STATA, version 14 (StataCorp LP, 2015), for the CFA we used the SPSS Amos, version 24 (Arbuckle, 2016), all the remaining calculations were then conducted in the SPSS, version 22 (IBM Corp., 2013) and STATISTICA 13 (TIBCO Software Inc., 2017).

3. Results and discussion

3.1. CFA and 2PL model

The CFA revealed that a single latent variable (snake/spider fear) had the best fit to the data (SNAQ: GFI = 0.867, CFI = 0.841, TLI = 0.823, RMSEA = 0.075; SPQ: GFI: 0.872, CFI = 0.898, TLI = 0.887, RMSEA = 0.073). Based on the 2PL model (see also Figure 1 for a comparison of test information functions), 9 out of 12 items selected for the shorter version of the SNAQ (item 2, 3, 4, 8, 11, 19, 21, 22, and 29) were identical to those identified by Zsido et al. (2018). Instead of item 7, 13, and 30 reported in the original study on the 12-item scale (SNAQ-12), our 2PL analysis chose rather item 1, 9, and 26. The first two refer to avoiding outside activities (camping and swimming) when presence of snakes is expected, while the third one pertains to fear of snakes spreading onto similar animals (worms, other reptiles). On the other hand, items selected in the Hungarian study but not in ours refer to feeling terror or disgust when touching or just seeing a snake (item 7 and 13, respectively) or avoiding crossing an open field with a thought of snakes (item 30). Regarding the SPQ, the similarity with Zsido et al. (2018) seemed slightly lower, as 7 out of 12 items were the same (item 1, 3, 7, 9, 10, 29, and 30). While the authors included item 4, 5, 13, 21, and 26 into their short version (SPQ-12), our data showed there should rather be item 2, 8, 11, 15, and 22 instead (see Table 1 for detailed results from the 2PL analysis and the selected items). All these items found in our study but not in the Hungarian sample pertain to self-reported experience of anxiety triggered by any representation of spiders.

In order to distinguish between the 12-item scales as constructed by Zsido et al. (2018) from those re-analysed in our study, we will further refer to the short instruments based on the Czech sample as SNAQ-12 CZ and SPQ-12 CZ.

3.2. Reliability and validity

Both the SNAQ-12 CZ and SPQ-12 CZ showed excellent internal consistency (Cronbach's α = 0.84 and 0.91, respectively), which corresponds to the values reported by Zsido et al. (2018; α = 0.88 and 0.90 for SNAQ-12 and SPQ-12, respectively) and is only slightly below the internal consistency of the full versions (α = 0.91 and 0.95 for SNAQ and SPQ, respectively). Furthermore, the SNAQ-12 CZ and SPQ-12 CZ also demonstrated very good split-half reliability (Spearman-Brown r = 0.87 and 0.92, respectively). Reliability did not change significantly when calculated for items from the Hungarian version of SNAQ-12 and SPQ-12 on our data sample (α = 0.86 and 0.90; r = 0.86 and 0.91, respectively). It is noteworthy that we have also run the same analyses with all the original items (i.e. including the reversed scored ones), but it did not change the results substantially. We have also calculated the item-total score correlations confirming satisfactory values for the selected items (see Table 2).

For both questionnaires, scores on the shorter version highly correlated with the original scale after correcting for redundancy (r = 0.81 and 0.89 for the SNAQ and SPQ, respectively). Again, this is only slightly lower than the correlations reported by Zsido et al. (2018; r = 0.89 and 0.91 for the SNAQ and SPQ, respectively) and remained unchanged when calculated for items from the original SNAQ-12 and SPQ-12 on our data sample (r = 0.80 and 0.89, respectively). Furthermore, the discriminant construct validity expressed as a Spearman's correlation coefficient between the test scores on both scales of snake and spider fear has improved (i.e. lowered) by shortening the scales (r = 0.34 vs 0.26 for the long and short versions, respectively). Apart from that, scores on the SNAQ-12 CZ

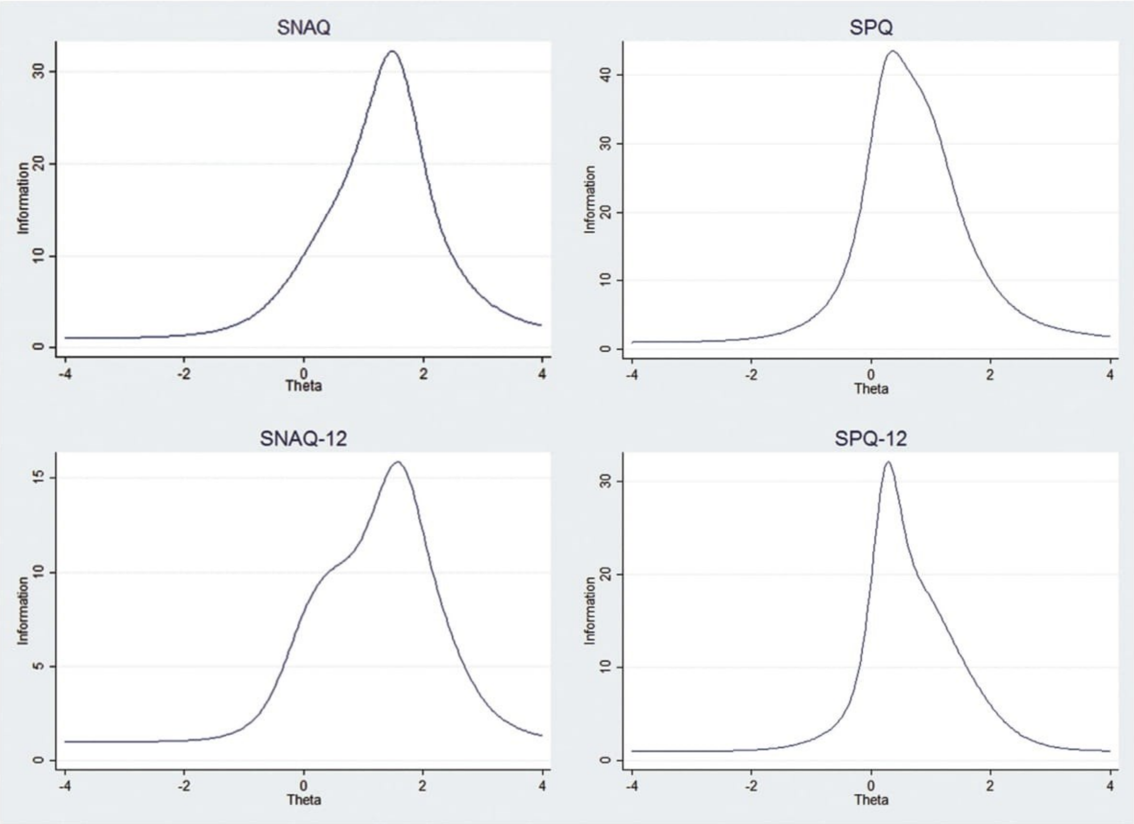

Fig. 1. Test information functions for the original Czech scales (SNAQ, SPQ) and their shorter 12-item versions (SNAQ-12, SPQ-12) as revealed by the IRT 2PL model.

and SPQ-12 CZ were positively correlated with a combined score from animal items of the Fear Survey Schedule II ($r = 0.56$ and 0.54, respectively, both $p < 0.05$) and a total score on the Disgust Scale - Revised ($r = 0.40$ and 0.38, respectively, both $p < 0.05$).

Finally, it was revealed that the SNAQ-12 CZ score was positively correlated with fear and disgust rating of an image of the viper (fear: $r = 0.61$, disgust: $r = 0.70$, both $p < 0.05$) and grass snake (fear: $r = 0.67$, disgust $= 0.73$, both $p < 0.05$). Similarly, there was a statistically significant high positive correlation between the SPQ-12 CZ score and fear and disgust rating of a spider image (fear: $r = 0.76$, disgust $= 0.80$, both $p < 0.05$). Overall, these values clearly demonstrate that shortening the original scales to just 12 items neither affected reliability nor did it compromise validity.

3.3. Descriptive statistics and effect of age and gender

The score distribution on both the SNAQ-12 CZ and SPQ-12 CZ is non-normal as evidenced by the Shapiro –Wilk test ($W = 0.81$, $p < 0.0001$, skewness $= 1.35$, kurtosis 1.30 and $W = 0.85$, $p < 0.0001$, skewness $= 0.84$, kurtosis $= -0.55$, respectively). The mean score on the SNAQ-12 CZ ($M = 2.19 \pm 0.05$, $SD = 2.60$; 95% CI = 2.09–2.29) and SPQ-12 CZ ($M = 3.36 \pm 0.08$, $SD = 3.56$; 95% CI = 3.20–3.53) were slightly lower than those reported by Zsido et al. (2018; $M = 3.21$ and 3.95 for the SNAQ-12 and SPQ-12, respectively). This might be due to the three, respectively five, different items. However, even when we recalculated the mean score using items from the Hungarian SNAQ-12 and SPQ-12 on our data set, these were again slightly lower than in the original study ($M = 2.12$ and 3.11, for the SNAQ-12 and SPQ-12, respectively). This could be explained by the fact that the total scores on the full scales were also lower compared to the study by Zsido et al. (2018; SNAQ: $M = 5.73$ vs 9.40, SPQ: $M = 8.63$ vs 11.16). Moreover, our sample included a higher proportion of biology students who generally score lower on these scales (see below and Polák et al., 2016).

As revealed by the GLzM model, the SNAQ-12 CZ score was significantly affected by gender ($W = 44.86$, $\eta^2 = 0.02$, $p < 0.0001$), age category ($W = 13.60$, $\eta^2 = 0.01$, $p = 0.018$), and biological study ($W = 42.56$, $\eta^2 = 0.02$, $p < 0.0001$), but no education level ($W = 2.40$, $p =$

Table 1. Discrimination (a) and difficulty coefficients (b) for the Snake (SNAQ) and Spider Questionnaire (SPQ). The items selected for the reduced scales are in bold.

SNAQ	a	b	SPQ	a	b
1	1.91	2.55	**1**	2.53	1.49
2	1.76	1.72	**2**	2.09	0.75
3	4.39	1.63	**3**	2.70	0.71
4	3.36	1.42	4	2.71	0.56
5	1.95	1.02	5	3.35	0.46
7	3.39	1.17	**7**	4.07	0.29
8	2.97	0.01	**8**	5.57	0.34
9	2.16	0.79	**9**	3.84	1.07
10	0.26	2.74	**10**	2.31	-0.37
11	3.23	0.49	**11**	6.43	0.22
13	4.43	1.59	13	4.07	1.05
15	4.94	1.44	**15**	4.17	0.79
18	0.91	3.30	18	1.23	1.93
19	2.73	1.44	19	2.79	0.45
21	2.29	0.51	21	4.24	0.92
22	3.15	1.42	**22**	3.42	0.68
23	1.46	1.43	23	1.86	0.85
24	0.84	2.26	24	1.06	2.10
26	2.10	1.22	26	2.63	0.59
29	3.13	2.20	**29**	2.69	1.66
30	2.03	1.13	**30**	2.91	1.40
			31	1.35	0.86

Table 2. Spearman correlation coefficients between individual item responses and the total score on the Czech version of SNAQ-12 and SPQ-12.

SNAQ-12	r	SPQ-12	r
1	0.26	1	0.47
2	0.43	2	0.64
3	0.41	3	0.67
4	0.49	7	0.79
8	0.81	8	0.81
9	0.66	9	0.60
11	0.75	10	0.75
19	0.49	11	0.83
21	0.72	15	0.69
22	0.50	22	0.71
26	0.57	29	0.42
29	0.26	30	0.50

All correlations significant at the 0.01 level (2-tailed).

0.494), nor size of town (W = 5.66, p = 0.341). Similarly, there was a statistically significant effect of gender (W = 100.72, $\eta^2 = 0.06$, $p < 0.0001$), age (W = 37.73, $\eta^2 = 0.03$, $p < 0.0001$), and biological study (W = 10.43, $\eta^2 = 0.01$, p = 0.001), but no education level (W = 5.06, p = 0.167) nor size of town (W = 10.70, p = 0.058) on the SPQ-12 CZ scores. The identical finding has been previously reported for the full version of SNAQ (Polák et al., 2016). However, the effect of age seems intricate as it tends to be correlated positively with fear of snakes but negatively with fear of spiders. Although some authors note that fear of animals should decrease with age (Doctor et al., 2008; Fredrikson et al., 1996), others have found a reversed trend (Germano and Blaha, 2001; Polák et al., 2016), and therefore the relationship remains elusive. For the detailed results according to gender, age, and biological education, see Table 3.

3.4. ROC curve analysis

A cut-off point score of >7.5 was identified for the SNAQ-12 CZ with the absolute sensitivity of 1 and specificity of 0.964, $J = 0.964$. The area under curve (AUC) was 0.996. The same cut-off score of >7.5 was then found for the SPQ-12 CZ, with the sensitivity of 0.977 and specificity of 0.921, $J = 0.899$, AUC = 0.988. Therefore, subjects scoring 8 or higher on either of the questionnaires might potentially experience snake or spider phobia, which corresponds to 151 (5.7%) and 302 (16.6%) individuals in our sample. This, again, is very similar to the results of Zsido et al. (2018) who reported score ≥8 and 7 for the SNAQ-12 and SPQ-12, respectively. Nevertheless, with our data we reached higher AUC values demonstrating excellent discriminatory power of both scales. It should be noted though that especially for fear of spiders, the prevalence of subjects with potentially specific phobia as based on the selected cut-off point seems highly overestimated and should be verified by further assessment. This may originate in the known high sensitivity and low specificity of the original scale (Fredrikson, 1983; Klorman et al., 1974). According to a Swedish study, prevalence of spider phobia is estimated to be 3.5% (Fredrikson et al., 1996), which would correspond to score 10 on the short scale.

4. Conclusion

The aim of this study was to re-analyse data from two popular measures of snake and spider phobia, the SNAQ and SPQ, using the approach of Zsido et al. (2018) to develop shorter, yet still reliable scales. We believe that bringing more evidence for psychometric qualities of these reduced and thus much faster-to-administer measures, which were tested on a nearly twice as big sample from another cultural background using a different language, would strongly support general reliability and validity of the new scales. Here we found a remarkable similarity with the original study. In total, 9 and 7 out of 12 items on the SNAQ-12 CZ and SPQ-12 CZ, respectively, were identical with those selected by Zsido et al. (2018). Furthermore, other psychometric indices of the short instruments, such as the internal consistency, correlations with their longer original versions, or their discriminatory power as diagnostic tools for specific animal phobias were all corresponding to the results published by Zsido et al. (2018).

Regarding the few conflicting items, it might have been caused by a different sample structure. While the proportion of men was comparable in both studies (H: 24.5% vs CZ: 30.7%), the Hungarian study included a bit younger subjects (mean age 25.6 compared to 31.2). Moreover, the proportion of biologically educated subjects was lower in the Hungarian study (11.5% vs 21.7%). All these variables are known to affect snake and spider fear. Although both studies present a comparably strong psychometric evidence with respect to the specific population they have been developed for, we have reached slightly higher AUC values, which correspond to better discriminatory power when distinguishing snake or spider phobics from healthy controls.

We have also provided more evidence of concurrent validity showing the shortened scales positively correlate with other measures of fear and disgust of animals. Some discrepancies between the original and our study in the selected items might be attributed to different sample characteristics. A high proportion of our subjects were biology students which is also reflected in the lower mean total scores on the SNAQ and SPQ compared with the Hungarian sample.

Despite that, it can be concluded that the short versions of SNAQ and SPQ the scales as presented here are reliable tools with a great clinical potential to provide quick and sound assessment of snake and spider fear. Their use is especially recommended in both research and clinical practice when quick screening for the two most prevalent animal phobias in the general population is needed. As snake and spider phobias remain often undetected, although their impact on health and socioeconomic

Table 3. Mean scores and their 95% confidence intervals (CIs) on the Czech version of SNAQ-12 (N = 2 540) and SPQ-12 (N = 1 797) categorized by gender, age, and biology education.

		SNAQ-12				SPQ-12			
		N	Proportion	Mean	95% CI	N	Proportion	Mean	95% CI
Gender	Men	779	30.7%	1.67	1.49–1.85	519	28.9%	1.97	1.68–2.27
	Women	1761	69.3%	2.40	2.28–2.52	1278	71.1%	3.92	3.73–4.10
Age	<19	328	12.9%	1.79	1.51–2.07	121	6.7%	4.31	3.68–4.93
	20–29	1043	41.1%	2.30	2.14–2.46	703	39.1%	3.86	3.60–4.12
	30–39	620	24.4%	1.98	1.78–2.18	515	28.7%	3.11	2.81–3.41
	40–49	304	12.0%	2.22	1.93–2.51	262	14.6%	2.97	2.54–3.39
	50–59	158	6.2%	2.42	2.02–2.83	133	7.4%	2.23	1.63–2.82
	60+	87	3.4%	3.00	2.46–3.54	63	3.5%	1.90	1.04–2.77
Biology education	Yes	574	24.6%	1.63	1.42–1.84	403	25.4%	3.26	2.91–3.61
	No	1757	75.4%	2.35	2.23–2.47	1185	74.6%	3.42	3.22–3.62

status of the person affected can be considerable, rapid screening might help identify those people and provide efficient and accessible treatment.

Declarations

Author contribution statement

J. Polák: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

K. Sedláčková: Performed the experiments; Contributed reagents, materials, analysis tools or data.

E. Landová: Contributed reagents, materials, analysis tools or data.

D. Frynta: Conceived and designed the experiments; Analyzed and interpreted the data.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

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4. Hodnocení vizuálních stimulů vyvolávajících strach a odpor

Druhá část dizertačního projektu se zameřuje na subjektivní hodnocení vizuálních podnětů, konkrétně standardizovaných fotografií hadů a dalších zvířat způsobujících specifické fobie, a to podle strachu a znechucení (případně krásy), které lidech vyvolávají. Cílem je nejenom snaha popsat intenzitu dané emoce pro konkrétní stimulus, ale i následná kategorizace podnětů na základě emočního hodnocení a výběr vhodných (salientních a emočně specifických) testových stimulů do následujících experimentů.

Tuto kapitolu tvoří celkem pět publikovaných studií. První se zabývá analýzou strachu a odporu ze zvířat vyvolávajících nejčastější fobie (Polák et al., 2020). Druhý článek se věnuje hodnocení strachu, krásy a znechucení u všech žijících podčeledí plazů (Janovcová et al., 2019). Poslední tři studie se už konkrétně zaměřují na hady a detailně zkoumají strach a odpor vyvolaný vybranými zástupci celého podřádu hadů (Rádlová et al., 2019), rozdíly v emočních reakcích na hady u lidí s nízkým vs. vysokým strachem a odporem (Rádlová et al., 2020) a nakonec mezikulturní rozdíly ve vnímání strachu a krásy eurasijských hadů u Čechů a Azerbajdžánců (Landová et al., 2018).

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Scary and nasty beasts: Self-reported fear and disgust of common phobic animals

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Animal phobias are one of the most prevalent mental disorders. We analysed how fear and disgust, two emotions involved in their onset and maintenance, are elicited by common phobic animals. In an online survey, the subjects rated 25 animal images according to elicited fear and disgust. Additionally, they completed four psychometrics, the Fear Survey Schedule II (FSS), Disgust Scale – Revised (DS-R), Snake Questionnaire (SNAQ), and Spider Questionnaire (SPQ). Based on a redundancy analysis, fear and disgust image ratings could be described by two axes, one reflecting a general negative perception of animals associated with higher FSS and DS-R scores and the second one describing a specific aversion to snakes and spiders associated with higher SNAQ and SPQ scores. The animals can be separated into five distinct clusters: (1) non-slimy invertebrates; (2) snakes; (3) mice, rats, and bats; (4) human endo- and exoparasites (intestinal helminths and louse); and (5) farm/pet animals. However, only snakes, spiders, and parasites evoke intense fear and disgust in the non-clinical population. In conclusion, rating animal images according to fear and disgust can be an alternative and reliable method to standard scales. Moreover, tendencies to overgeneralize irrational fears onto other harmless species from the same category can be used for quick animal phobia detection.

Since the famous case of 'Little Albert' (Watson & Rayner, 1920), human fears and anxieties have fascinated our mind. Fright is appealing to the entertainment industry as the trend in horror movies production and generated profits is constantly increasing (Phillips, 2005). For example, 8,055 horror titles were released in 2017 with grosses worth billions of dollars (IMDb, 2018). Accordingly, fear has attracted much of scientific research with more than 37,000 papers published only in the last 5 years (WoS, 2018). Besides that, clinical fears have considerable public health and economic impact (Olesen et al., 2012).

There is general consensus that animals are one of the most common triggers of human fears (Agras, Sylvester, & Oliveau, 1969; Arrindell, 2000). Throughout the evolutionary history, many animal species have been an important source of imminent

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threat to our survival either as predators (Barrett, 2005) or parasites (Hoberg, 2006). Thus, humans and non-human primates have been shaped by the natural selection to 'beware the beast' (Öhman, 2007) and new abilities to quickly identify a hidden threat have evolved, including an improved visual system (Isbell, 2006) and category-specific attention enabling rapid detection of animals over other objects in the environment (New, Cosmides, & Tooby, 2007), especially snakes (Öhman, Flykt, & Esteves, 2001), spiders (Blanchette, 2006), or big cats (Yorzinski, Penkunas, Platt, & Coss, 2014). Öhman and Mineka (2001) hypothesized that these instinctive reactions have been embedded in specific neural structures and circuits of the mammalian brain, the so-called fear module.

Although these selection pressures have substantially weakened as humans have become an efficient super-predator dominating the ecosystem and inflicting fear in others (Clinchy *et al.*, 2016), the pattern of our reactions in the presence of threatening animals has remained unchanged (Mineka & Öhman, 2002). In general, two basic emotions with the associated physiological and behavioural correlates may be triggered by species considered as dangerous, fear and disgust (Ekman, 1999; Gerdes, Uhl, & Alpers, 2009). Functionally, both emotions serve to protect the biological integrity of an organism (Nesse, 1990), but are principally different as to the characteristics of impending danger (Keltner & Gross, 1999). While fear is an adaptive response in situations of imminent threat that could lead to injury or even death (Davis, 1997; LeDoux, 2012), disgust is a part of the behavioural immune system that protects the individual against disease or contamination (Curtis, De Barra, & Aunger, 2011).

Therefore, dangerous animals trigger either of the emotion (or both at the same time) depending on the kind of threat they pose. While larger predatory species capable of harming or killing humans (crocodiles, bears, lions, tigers, snakes, etc.) evoke fear, disgust is usually triggered by smaller (and often parasitic) animals associated with dirt, decay, or disease (rats, cockroaches, ticks, worms, etc.; Davey *et al.*, 1998; Merckelbach, van den Hout, & van der Molen, 1987; Ware, Jain, Burgess, & Davey, 1994). Although once developed as adaptive responses in threatening situations, fear and disgust of animals may have significant clinical implications when they get out of control. Specific animal phobias are globally the most frequent mental illness (Steel *et al.*, 2014) with a lifetime prevalence 3.3–5.7% (Eaton, Bienvenu, & Miloyan, 2018) and considerable psychological, social, and economic burdens (Greenberg *et al.*, 1999).

The distribution of animal fears is, however, non-random, and some species tend to be feared and avoided by humans much more often than others (Agras *et al.*, 1969; Davey *et al.*, 1998; McNally & Steketee, 1985), especially snakes and spiders often elicit strong negative emotions in people (Bennett-Levy & Marteau, 1984; Davey, 1992, 1994a; Merckelbach *et al.*, 1987; Ware *et al.*, 1994). Given the fact that only a few animals cause the majority of animal phobias, Seligman (1971) proposed an influential theoretical model of biological preparedness arguing that phobic reactions reflect our evolutionary past and are associated with stimuli posing a real threat to survival of human pre-technological ancestors, hence snakes and spiders being among the most feared animals today (see also Bracha, 2006).

Although there has been some supportive evidence (see McNally, 1987 for a review), the preparedness theory cannot satisfactorily explain why so many people suffer from irrational fears of small animals presenting a low risk, such as mice, insect, snails, or worms. Similarly, the potential threat posed by venomous spiders to our ancestors has been repeatedly questioned and has no empirical support (Davey, 1994b; Gerdes *et al.*, 2009). Therefore, Matchett and Davey (1991) proposed an alternative disease-avoidance model, suggesting that animal phobias are not mediated by fear of being attacked, but have primarily evolved as a mechanism protecting us from the transmission of infectious pathogens. It is thus disgust, rather than fear, that is the primordial negative emotion involved in aversion to animals, particularly the smaller ones (Arrindell, Mulkens, Kok, & Vollenbroek, 1999; Davey, 1992, 1994a, 1994b; de Jong & Merckelbach, 1998; Sawchuk, Lohr, Tolin, Lee, & Kleinknecht, 2000; Ware *et al.*, 1994).

According to Rozin and Fallon (1987), nearly all disgust elicitors are animals, their parts or products, or objects that have been in contact with those. So far, there has been an extensive line of evidence demonstrating the strong association between high disgust sensitivity and fears and phobias of certain animals. For example, Matchett and Davey (1991) or Davey (1994a) found a significant correlation between disgust/contamination sensitivity scores and self-reported fear of animals that are unlikely to attack and harm humans, but still evoke high fear (e.g., rat, spider, cockroach) or revulsion (e.g., maggot, snail, slug; see also Arrindell *et al.*, 1999). On the contrary, disgust sensitivity was not associated with fear of predatory animals (e.g., tiger, lion, shark; Matchett & Davey, 1991; Tucker & Bond, 1997). Especially the relationship between disgust sensitivity and spider phobia has been repeatedly demonstrated (de Jong & Merckelbach, 1998; de Jong & Muris, 2002; Sawchuk *et al.*, 2000; for a review, see Davey & Marzillier, 2009). Moreover, Webb and Davey (1992) showed that disgust is not merely an emotion accompanying experienced fear of animals, but a causal link exists between experimentally manipulated disgust sensitivity and reported fear of certain animals. In the similar vein, treatment for spider phobia attenuates the spider's disgust-evoking status in both adults (de Jong, Vorage, & van den Hout, 2000) and adolescents (de Jong, Andrea, & Muris, 1997). At last, recent evidence suggests that even typically highly fearful animals such as snakes also pose a significant disgust potential (Rádlová *et al.*, 2019).

To our knowledge, no study has ever aimed to categorize animals according to both fear and disgust. Nevertheless, as shown above, the latter too may play a significant role in the human perception of certain animals and subsequently lead to development of severe and prevalent phobias when dysregulated. Therefore, one of the main purposes of our study was to investigate the intensity of animal fears and revulsions as well as potential association between these two negative emotions people experience when confronted with species that are actually responsible for the most frequent animal phobias (see Materials and methods for selection criteria). This way we could elucidate whether certain animals have the potential to trigger phobic disorder in humans either through dysregulated fear or disgust by studying responses of the non-clinical population.

In fact, the elusive role of fear and disgust in animal phobias could mean that qualitatively distinctive types of anxieties caused by different animal species exist (Merckelbach *et al.*, 1996). So far, only a limited number of studies have tried to group common animals into separate coherent clusters using a factor analysis. According to Ware *et al.* (1994), 34 animals rated according to fear could be categorized into two distinct dimensions referred to as predatory animals (e.g., tiger, alligator, lion, bear, shark, or wolf) and fear-relevant animals (e.g., bat, eagle, lizard, rat, slug, leech, mouse, spider, or cockroach). While the former group includes dangerous animals capable of causing serious injuries to humans if confronted in the wild, the latter one is formed by animals that are highly feared by people without posing real threat. Interestingly, the snake is the only animal that falls into both categories.

The two-factor solution for reported fears was also confirmed in a study using animals living in the United Kingdom (Davey, 1994a). These were referred to as either invertebrates (slug, snail, worm, maggot, etc.) or fear-relevant animals (mouse, rat, snake, bat, lizard, etc.). However, both clusters corresponded to the 'fear-relevant animals' identified by Ware *et al.* (1994), which only caused some confusion in the terminology. Arrindell (2000) repeated Davey's study with Dutch subjects and found a four-factor solution: (1) fear-relevant animals (mouse, rat, bat, etc.); (2) dry or non-slimy invertebrates (wasp, maggot, beetle, cockroach, spider, etc.); (3) slimy or wet looking animals (snail, worm, slug, eel, fish, etc.); and (4) farm animals (cow, goat, horse, goose, and chicken). A three-factor model for categorizing a list of 15 animals was found in a study by Tucker and Bond (1997), who called them (1) predatory (lion, tiger, bear, etc.); (2) fear-relevant (spider, snake, and eel); and (3) repulsive (slug, maggot, cockroach, rat, and leech).

Finally, in a cross-cultural study of animal fears, Davey *et al.* (1998) reported that a list of 51 animals could be separated into three coherent groups: (1) fear-irrelevant animals that are harmless with a low-fear status (chicken, duck, hamster, rabbit, etc.); (2) fear-relevant animals that can be characterized as fierce, dangerous, and predatory (lion, bear, shark, etc.); and (3) disgust-relevant animals that are typically small, harmless species evoking negative emotions through revulsion (cockroach, spider, worm, leech, mouse, rat, etc.). Furthermore, this three-factor solution was closely comparable across seven Western and Asian countries. Cross-cultural agreement in perception of animals seems to be a general pattern, not only for fear (Landová *et al.*, 2018), but positive emotions too (Frynta, Marešová, Reháková-Petrú, Šklíba, Šumbera, & Krása, 2011; Marešová, Krása, & Frynta, 2009).

Despite several attempts, categorization of animal fears remains inconclusive. The conducted studies used different animal sets and labels for the identified clusters. Especially, the use of the 'fear-relevant animals' term has not been consistent and referred to a variety of species ranging from fear-evoking, big predatory mammals to small, harmless invertebrates triggering disgust. The research has been further flawed by the way the tested species were selected and presented to subjects. The animal stimuli were either devised by undergraduate students (Davey, 1994a) or adopted from previous studies where the selection had been done arbitrarily by the authors (Matchett & Davey, 1991). They were presented to participants as a list of items to be rated on a Likert-type scale according to elicited fear. However, visual rather than verbal stimuli work better in evoking emotions as they leave less space for interpretation and thus have higher ecological validity. For example, it has been previously demonstrated that photographs may reliably substitute live snakes (Landová, Marešová, Šimková, Cikánová, & Frynta, 2012).

Thus, the second main goal of our study was to separate the phobic animals into coherent meaningful clusters based on their fear and disgust ratings. For these reasons, pictures of animals presumed to be a target of the most frequent phobias were selected. Such data concentrated only on clinically relevant species might shed more light on the characteristics of irrational animal fears and their aetiological mechanisms. We argue that by having included animals that may be highly fearful but in fact only very rarely trigger phobias in human subjects (predatory animals such as the lion, bear, shark, etc.), the previous factor analyses do not provide a clear picture of animal phobic categories. We also added four widely used standardized assessments, two measuring general fear and disgust propensity and two specific fear scales focused on snakes and spiders. This would allow us to evaluate different psychometric tools (picture vs. verbal) for fear and disgust of animals as well as to make comparisons with previous findings.

Additionally, our specific aims were to: (1) investigate whether fear and disgust are distinct, mutually exclusive dimensions or rather interlinked mental experiences that might be evoked in the same subject by the same species; (2) show the association between fear and disgust ratings of animal pictures and standardized questionnaires; (3)

compare a factor analysis of fear and disgust based on animal pictures to dimensions based on verbal items (Davey, 1994a; Davey *et al.*, 1998; Ware *et al.*, 1994); and (4) analyse the effect of individual characteristics or negative experiences with animals on self-reported fear and disgust.

Materials and methods

Subjects

In total, 2,291 subjects were recruited from a Facebook community of Czech and Slovakian volunteers willing to participate in various psychology research that has more than 16,000 followers. Several posts published on the Facebook wall were inviting for an online study focused on human perception of animal beauty. The data collection was conducted between March and December 2017. Out of those who joined the study, 1,798 subjects completed the whole survey providing comprehensive data. There were considerably more women (N = 1,278) than men (N = 519), one respondent did not indicate the gender. The mean age was 33.2 ± 0.3 years. Most of the subjects have obtained a university degree (N = 889), 795 people have completed secondary education, and 108 participants have stopped after elementary school.

Assessment battery

The online assessment battery consisted of images of phobic animals that the respondents rated according to fear and disgust, two psychometrics of the most common animal fears of snakes (Snake Questionnaire, SNAQ: Klorman, Weerts, Hastings, Melamed, & Lang, 1974; Czech translation: Polák, Sedláčková, Nácar, Landová, & Frynta, 2016) and spiders (Spider Questionnaire, SPQ: Klorman *et al.*, 1974), one assessment of general fear of various objects or situations (Fear Survey Schedule II, FSS: Geer, 1965), and a measure of disgust propensity (Disgust Scale – Revised, DS-R: Haidt, McCauley, & Rozin, 1994, modified by Olatunji *et al.*, 2007 and van Overveld *et al.*, 2011; Czech translation: Polák, Landová, & Frynta, 2018). The FSS and SPQ not available in Czech were first translated by two independent native bilingual speakers, and the items were checked through a back-translation procedure.

Images of phobic animals

Unlike previous research, where the choice of tested animal stimuli was sometimes arbitrary, our goal was to study human perception of animals objectively triggering the most common specific phobias. The aim was to cover the variety of animal species feared by humans, yet keeping the number of visual stimuli reasonable not to overload the respondents. However, as the exact data on prevalence of various animal phobias are rare and mostly concern only the one of snakes and spiders, we devised our list of species based on two approaches. First, we searched through several literature sources that mention which animals become the most frequent phobic targets (Becker *et al.*, 2007; Curtis, Magee, Eaton, Wittchen, & Kessler, 1998; Davey, 1994a; Davey *et al.*, 1998; Doctor, Khan, & Adamec, 2008; McNally & Steketee, 1985). Subsequently, to complete the list, we consulted an encyclopaedia of phobias (Doctor *et al.*, 2008). In order to objectivize each animal phobia frequency without having real prevalence data, we used the amount of information available in the encyclopaedia (quantified as the word count) as a proxy. We expected that the longer the description, the more knowledge clinicians have about, and the more frequent the animal phobia is in the general population.

This way, the following list of 23 animals (animal categories) has been devised (in the alphabetic order): ant, bat, bull, cat, cockroach, dog, fish, frog, horse, lizard, louse, maggot, moth, mouse, pigeon, rat, rooster, roundworm, snail, snake, spider, tapeworm, and wasp. Furthermore, a recent paper suggests that the snake is rather a heterogeneous category as different snake species strikingly vary in elicited fear or disgust (Landová *et al.*, 2018). Based on this finding, two kinds of snakes were used in our study, a venomous viper and a non-venomous grass snake. Finally, a picture of the red panda has been included as a control stimulus, hence 25 pictures in total (for specific animal species used in the set as typical representatives of the category, see Table S1). The image set consisted of colour photographs representing typical individuals of wild species (except for the domestic forms) taken from the Internet. All the source files had a licence to be freely used for scientific purposes. We digitally cropped the photographs, placed them on a white background, and resized them to a comparable size (regardless of their real size) using GIMP 2.8.16 (Kimball & Mattis, 2016).

Snake Questionnaire

The SNAQ is a 30-item self-report scale to assess the verbal–cognitive component of snake fear. Each item is a fearful or non-fearful statement related to snakes. Participants rate each item as true or false. The instrument is scored by assigning a '1' to each true response and '0' to each false response, seven items are reversed-scored. A total score (ranging from 0 to 30) is calculated by summing all 'true' statements, and it serves as a measure of the degree of phobic fear (Wikström, Lundh, Westerlund, & Högman, 2004).

Spider Questionnaire

The SPQ is a scale very similar to the SNAQ, adapted to quantify fear of spiders. It contains 31 items (fearful or non-fearful statement) rated as true or false. It is scored the same way as the SNAQ, nine items are reverse-scored. Scores can range from 0 to 31.

Fear Survey Schedule II

The FSS is a self-report instrument to assess overall level of anxiety in a person's life, as well as particular areas of anxiety (such as social situations, injury, death, animals). It contains 51 items that are nouns relating to animals, social situations, injury and death, objects, noises, and other situations that are rated by the respondent on a 7-point Likert scale according to elicited fear from 1 ('no fear') through 4 ('some fear') until 7 ('terror'). A total score is calculated as a sum of item scores and can range from 51 to 357.

Disgust Scale – Revised

The DS-R is a self-report personality scale to assess individual differences in propensity to disgust. There are 25 disgust elicitor items loading on one of the three factors (core disgust, animal reminder disgust, and contamination-based disgust) and two catch questions (item 12 and 16) allowing to identify those respondents who do not pay attention to the task or do not take it seriously. Each of the 27 items is rated by the participant on a 5-point Likert scale from 0 ('strongly disagree/not disgusting at all') to 4 ('strongly agree/extremely disgusting'). A total score (ranging from 0 to 100) is calculated by summing scores on all the 25 disgust elicitor items but three (items 1, 6, and 10) that are reverse-scored. Similarly, subscale scores may be calculated.

At the end, the subjects were asked a series of questions regarding their socio-demographic characteristics including the gender, age, and size of town when one grew up for the greatest part of childhood (further referred to as size of town). It has been previously shown that these variables have a significant effect on prevalence of animal phobias (Fredrikson, Annas, Fischer, & Wik, 1996) and other anxiety disorders (George, Hughes, & Blazer, 1986) and thus might affect fear and disgust of animals as well. Moreover, it is reasonable to presume that different early experiences (frequency of encounter) with animals in rural versus urban areas (hence the size of town during childhood) might shape our perception of them. Finally, one would expect that fear and disgust associated with animals might stem from negative painful experiences; therefore, we asked our subjects whether they have ever been scratched by a cat, bitten by a dog, or attacked by another animal. We asked specifically for injuries caused by cats and dogs not only because they are the most common pets that everybody has already come across, but also based on the evidence that cat and dog phobias usually have a precedent traumatic conditioning experience (Doogan & Thomas, 1992). All the participants provided their informed consent by pressing the corresponding button on the electronic form. The study has been approved by the respective institutional ethics committee.

Procedure

Prior to completing the survey, the respondents were briefly instructed on the general purpose of the study and the way their data would be handled. Upon clicking a button to commence, the individual parts of the assessment battery were presented in the following order: (1) rating the image set according to fear, (2) SNAQ, (3) FSS, (4) rating the image set according to disgust, (5) SPQ, (6) DS-R, and (7) socio-demographic characteristic questionnaire. There were several reasons for this specific task sequence. First, our primal interest lied more within the image ratings rather than the questionnaires, so we wanted to present the animal images before the corresponding scales to avoid a potential bias in the image evaluations. We focused on the emotion of fear, that is why we started with the fear evaluation followed by the fear-related questionnaires (i.e. SNAQ and FSS). Evaluation of the same image set, this time according to disgust, came after, followed by the disgust-related questionnaires (i.e. SPQ and DS-R; note that although the SPQ is presented as a measure of fear of spiders, it is generally accepted that spider phobia is associated more with disgust rather than fear, see above).

When rating the image set, all the 25 pictures were shown at once on the screen, one beneath the other. The image size was automatically set by the system to 655 × 436 px. There was a question above each image asking how fearful/disgusting the respondent finds the pictured animal and below was a 7-point Likert scale ranging from 'not at all' through 'moderately' until 'extremely'. The order of image presentation on the screen was completely random.

Statistical analyses

First, mean scores for fear and disgust evaluation of each tested animal were calculated. To identify a potential discrepancy in the evaluation of fear and disgust, we also calculated a mean difference between the two ratings for each tested stimulus and compared them by a paired samples *t*-test. A Pearson correlation coefficient was calculated between the mean fear and disgust ratings as well.

We have used several approaches to test for the association between individual scores on the four psychometrics and fear and disgust ratings of the tested animals. First, given the non-normal score distribution on some of the questionnaires, a Spearman correlation coefficient between the fear and disgust ratings and four questionnaire scores was calculated. The contribution of the respondent's gender, age, and scores on the four assessments to the animal fear and disgust ratings was examined in a redundancy analysis (RDA) as implemented in the R package vegan (Oksanen *et al.*, 2017; R Development Core Team, 2010). The RDA is a multivariate direct gradient method (Ter Braak & Šmilauer, 2018). It extracts and summarizes the variation in a set of response variables (subjective evaluation of the animal pictures according to fear and disgust) that can be explained by a set of explanatory variables (age, gender, disgust propensity, general fear, and specific fear of snakes and spiders as measured by the DS-R, FSS, SNAQ, and SPQ, respectively). This analysis permits to plot both the response and explanatory variables to a space defined by the extracted gradients and enables to detect redundancy (i.e., shared variability) between sets of response (subjective evaluation of pictures) and explanatory variables (scores on questionnaires). Statistical significance of the gradients was confirmed by permutation tests. Moreover, for the two most phobic animals, the snake and spider, a generalized linear model (GLzM) for the negative binomial distribution with a log link function has been used to evaluate the association between the fear/disgust rating and the score on a standardized measure of specific fear (i.e., the SNAQ and SPQ).

Next, we performed a parallel analysis on the original animal fear and disgust ratings to determine the appropriate number of factors to extract (Horn, 1965). It has been demonstrated that the parallel analysis is one of the most accurate methods for such purpose (Zwick & Velicer, 1986). Here, we followed a procedure developed by O'Connor (2000) using his updated syntax (). We ran 5,000 random permutations of a raw data set (which is a recommended procedure for scale data that might not necessarily follow a normal distribution) with 1,901 cases and 25 variables (fear/disgust scores for each tested animal) for fear and disgust separately to which the real data eigenvalues were then compared. Subsequently, a factor structure in the image ratings was examined using a factor analysis with the maximum likelihood extraction method and direct oblimin rotation. We also calculated subscale scores for fear and disgust evaluation by summing ratings of individual images within each of the identified factors. We then calculated a correlation coefficient between those subscale scores and the four questionnaire scores (based on the data distribution, a Pearson correlation is used for FSS and DS-R and a Spearman correlation for SNAQ and SPQ).

Finally, we performed general linear models (GLMs) to verify how mean fear and disgust rating calculated across all the tested animals for each participant and the subscale scores are affected by the size of town (categorized by population as follows: [1] up to 1,000, [2] between 1,000 and 5,000, [3] between 5,000 and 50,000, [4] between 50,000 and 100,000, [5] between 100,000 and 500,000, and [6] more than 500,000) and a negative experience with pet animals (being scratched by a cat or bitten by a dog, categorized as: [1] never, [2] only as a part of a game, [3] only as a warning, [4] yes, but only a little, [5] yes, I was bleeding, and [6] yes, I had to seek medical treatment), or attacked by another animal (categorized only as: [1] no, [2] yes). These calculations were performed in SPSS, version 22 (IBM Corp., 2013).

Results

Association between fear and disgust ratings and questionnaire scores

The mean scores of perceived fear and disgust of the tested stimuli are provided in Table 1; moreover, these were highly correlated ($r = .72$, $p < .0001$; Figure 1). Frequency of the highest score (7) given to each animal on both scales is shown in Figure 2.

Next, we employed the RDA to examine the contribution of respondent's scores on four questionnaires, gender, and age to the fear and disgust ratings of particular animals. The RDA model has generated six constrained axes, which explained 29.66% of the full variability. We then performed a permutation test (number of permutations = 10,000) to confirm the significance of each of the independent variables (constraints) in a sequential ('type I') test: FSS, $F(1,\ 1{,}774) = 359.36$, $p < .0001$; SNAQ, $F(1,\ 1{,}774) = 195.68$, $p < .0001$; SPQ, $F(1,\ 1{,}774) = 129.25$, $p < .0001$; DSR, $F(1,\ 1{,}774) = 39.46$, $p < .0001$; age, $F(1,\ 1{,}774) = 15.57$, $p < .0001$; and gender, $F(1,\ 1{,}774) = 8.72$, $p < .0001$. The visualization of the RDA results (see Figure 3) showed that negative evaluation of the animal stimuli is generally associated with high scores on both the FSS and DSR. This relationship dominated the first multivariate axis (RDA1). Although the SNAQ and SPQ

Table 1. Mean raw and standardized scores for fear and disgust evaluation of the tested animals with a difference in the mean fear and disgust score

Animal	Mean fear	Mean disgust	Difference in mean fear and disgust scores
Ant	2.12	2.26	−0.14**
Bat	2.11	2.01	0.10**
Bull	3.84	1.62	2.22**
Cat	1.24	1.17	0.07**
Cockroach	3.10	4.16	−1.06**
Dog	2.25	1.20	1.05**
Fish	1.15	1.38	−0.23**
Frog	1.84	2.48	−0.66**
Grass snake	3.32	2.47	0.85**
Horse	1.82	1.11	0.72**
Lizard	1.46	1.46	0.00**
Louse	3.58	4.83	−1.25**
Maggot	2.90	4.49	−1.59**
Mouse	1.62	1.78	−0.16**
Panda	1.57	1.17	0.40**
Pigeon	1.48	2.01	−0.53**
Rat	2.11	2.25	−0.14**
Rooster	1.78	1.34	0.44**
Roundworm	3.49	4.79	−1.30**
Snail	1.15	1.69	−0.54**
Spider	4.39	4.47	−0.08*
Tapeworm	3.60	4.83	−1.23**
Viper	4.34	2.83	1.51**
Wasp	3.42	2.84	0.58**

The difference in means is significant at $*p < .01$; $**p < .001$.

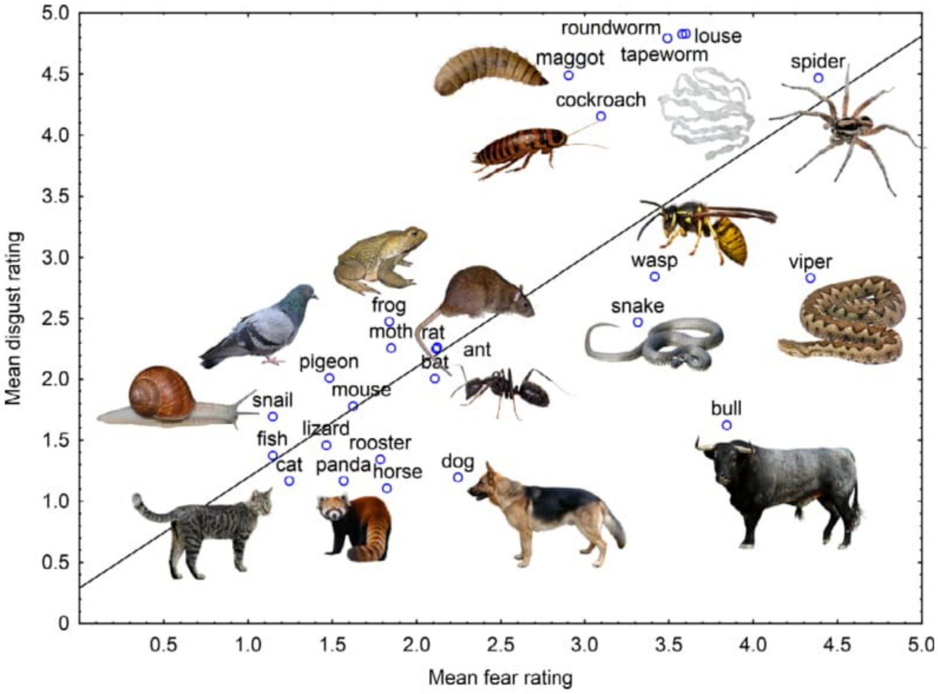

Figure 1. Correlation between the mean fear and disgust scores of the tested animals ($r = .72$).

contribute to RDA1 as well, their opposition defines RDA2 axis. As expected, the SNAQ and SPQ scores are closely associated with negative evaluation of their target stimuli (according to both fear and disgust), i.e. snakes and spiders, respectively.

In order to standardize the questionnaires' weight and to examine the effects of high scoring respondents, we rescaled the scores on the DSR, FSS, SNAQ, and SPQ based on quartiles and recoded them as either (1) low (below the lower quartile), (2) medium (interquartile values), or (3) high (above the upper quartile). These were further included into the RDA as explanatory variables instead of the original ones. In this case, we utilized the automatic model-building feature based on both the Akaike criterion (but with permutation tests) and permutation p-values. Both methods agreed on inclusion of the following variables into the reduced model (constrained axes explained 26.83% of the full variability), which were then confirmed as significant by the sequential 'type I' test (number of permutations = 10,000): SNAQ3, $F(1, 1{,}770) = 259.08, p < .0001$; FSS1, $F(1, 1{,}770) = 129.93$, $p < .0001$; SPQ3, $F(1, 1{,}770) = 99.81$, $p < .0001$; FSS3, $F(1, 1{,}770) = 45.71$, $p < .0001$; SPQ2, $F(1, 1{,}770) = 41.95$, $p < .0001$; DSR1, $F(1, 1{,}770) = 21.79$, $p < .0001$; age, $F(1, 1{,}770) = 15.94$, $p < .0001$; SNAQ1, $F(1, 1{,}770) = 14.88$, $p < .0001$; DSR3, $F(1, 1{,}770) = 13.09$, $p < .0001$; and gender, $F(1, 1{,}770) = 6.74$, $p < .0001$). For correlation coefficients between the individual fear/disgust animal ratings and questionnaire scores, see Table S2.

This was further supported by a GLzM model that revealed a significant effect of both the fear and disgust rating of the grass snake on the SNAQ score (fear: Wald $\chi^2_{6,1848} = 49.53$, $p < .001$; disgust: Wald$\chi^2_{6,1848} = 20.45$, $p = .002$) and the effect of disgust elicited by the viper (Wald$\chi^2_{6,1848} = 43.37$, $p < .001$) but not fear of it (Wald$\chi^2_{6,1848} = 3.93, p = .686$) on the SNAQ score. Similarly, there was a strong significant association between the fear and disgust rating of the spider and the SPQ score (fear: Wald $\chi^2_{6,1816} = 50.59, p < .001$; disgust: Wald $\chi^2_{6,1816} = 179.99, p < .001$).

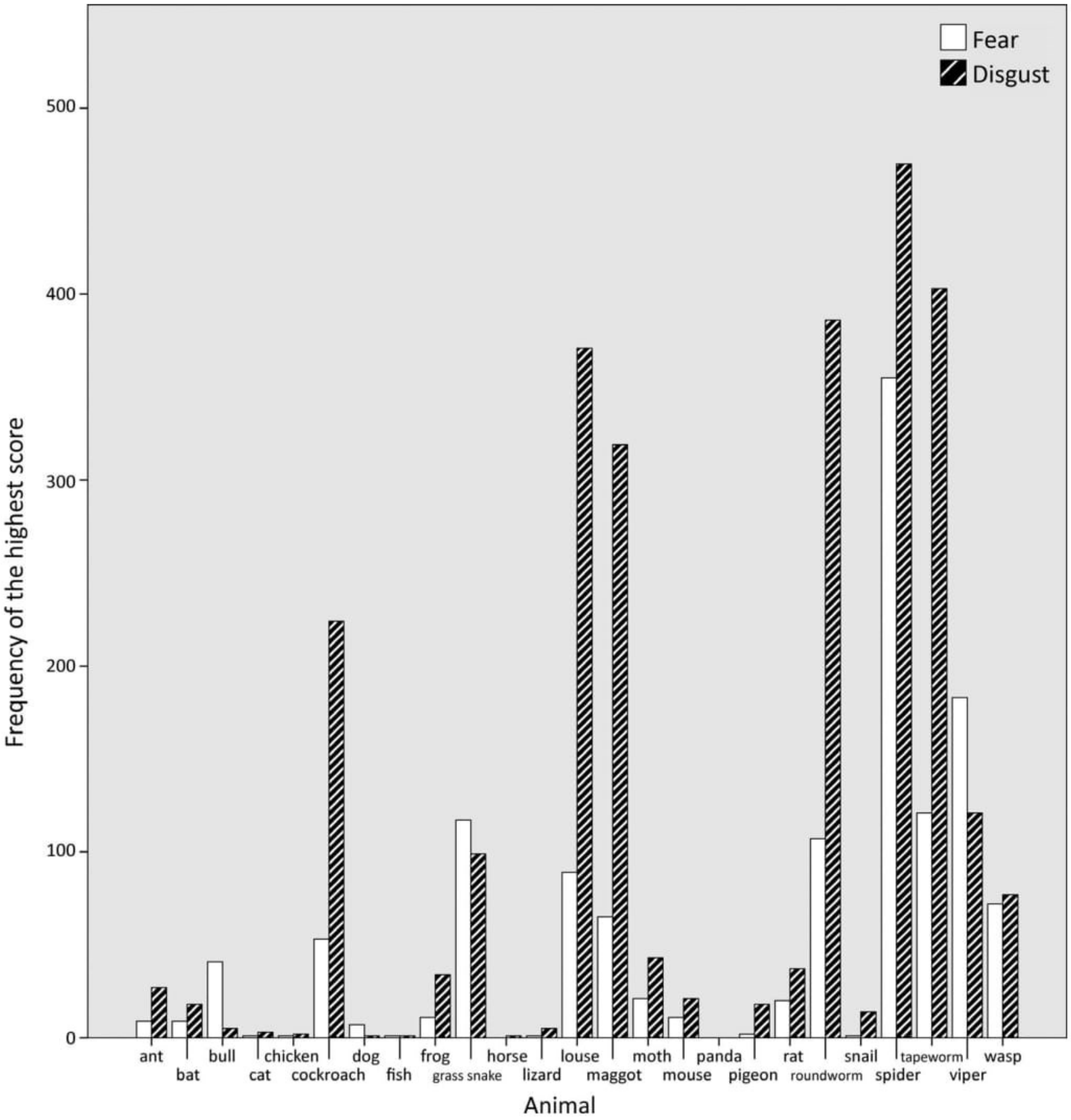

Figure 2. Frequency of the highest fear and disgust rating (7) given to each animal in the set

Factor analysis of fear and disgust of animals

The Kaiser–Meyer–Olkin measure of sampling adequacy (fear: 0.92; disgust: 0.90) and Bartlett's test of sphericity (fear: $\chi^2 = 19507.96$, $p < .001$; disgust: $\chi^2 = 23141.56$, $p < .001$) confirmed that the item structure of the data set warranted a factor analysis. The parallel analysis performed separately for fear and disgust ratings revealed that in both emotions only the first five eigenvalues extracted from the real data exceeded the 95th percentile of those based on the simulations of raw data sets. As for fear, the five factors together explained 47.99% of the total variance, most of which pertained to the first factor (29.01%) while the remaining four clusters were considerably weaker (7.54%, 3.68%, 3.76%, and 3.99% of variance, respectively). For disgust, the five-factor model explained 52.52% of the total variance with the following percentage of total variance explained for each factor: 28.47, 8.76, 5.67, 6.10, and 3.52, respectively (see Tables 2 and 3 with factor loadings for fear and disgust). There were significant correlations between the subscale scores calculated for each factor and the questionnaire scores (see Table 4).

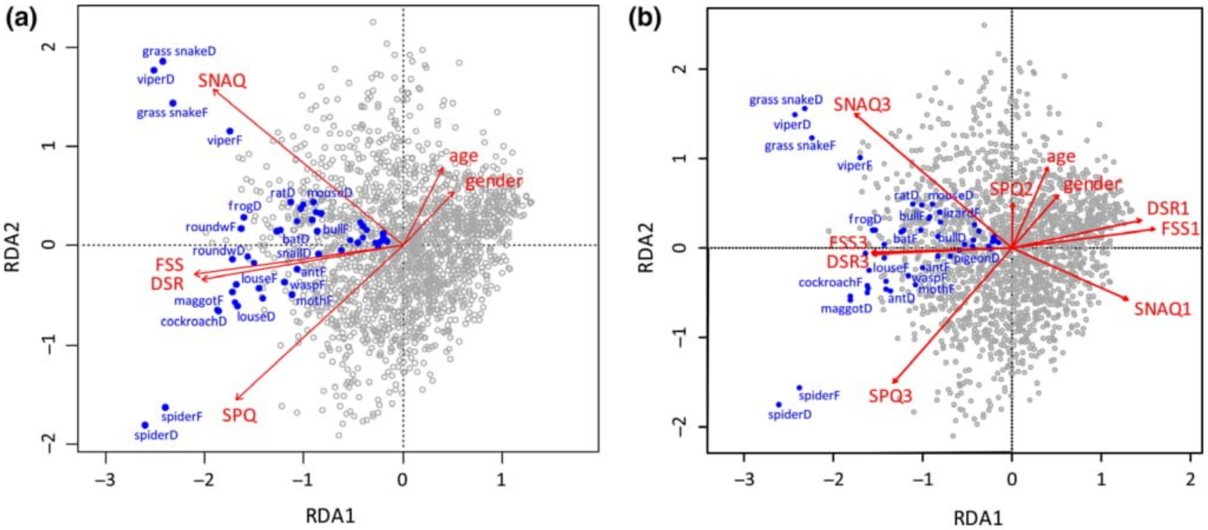

Figure 3. Redundancy analysis visualization of the effect of questionnaire scores (treated as either [a] a continuous variable or [b] when categorized based on quartiles as low [1], medium [2], or high [3]), gender, and age of the respondents on fear (F) and disgust (D) ratings of the tested animals. Eigenvalues of RDA1 and RDA2 axes are 20.45 and 4.71, respectively. Mean fear/disgust ratings of two snake pictures according to how the respondent scored on the Snake Questionnaire (SNAQ): fear of viper, low: 3.41, medium: 4.11, high: 5.86; $F(2, 1{,}848) = 396.81$, $p < .001$; disgust of viper, low: 1.49, medium: 2.38, high: 5.28; $F(2, 1{,}848) = 1000.45$, $p < .001$; fear of grass snake, low: 1.97, medium: 3.04; high: 5.37; $F(2, 1{,}848) = 685.50$, $p < .001$; disgust of grass snake, low: 1.24; medium: 1.98; high: 4.90; $F(2, 1{,}848) = 1172.25$, $p < .001$. Mean fear/disgust ratings of the spider picture according to how the respondent scored on the Spider Questionnaire (SPQ): fear of spider, low: 2.43, medium: 4.21, high: 6.40; $F(2, 1{,}816) = 966.50$, $p < .001$, disgust of spider, low: 2.16, medium: 4.33, high: 6.67; $F(2, 1{,}816) = 1141.50$, $p < .001$.

Effect of individual characteristics on fear and disgust evaluation

We also computed a GLM with the respondent's gender, size of town, and negative experience with animals (scratched by a cat, bitten by a dog, and attacked by another animal) as fixed factors and age as a covariate on the overall mean fear and disgust rating. The mean fear score was significantly influenced by the gender, $F(1, 1{,}737) = 23.67$, $p < .001$; age, $F(1, 1{,}737) = 4.30$, $p = .038$; dog bite, $F(5, 1{,}732) = 5.38$, $p < .001$; and cat scratch, $F(5, 1{,}732) = 2.57$, $p = .025$; but not the size of town, $F(5, 1{,}732) = 0.96$, $p = .443$; nor another animal attack; $F(1, 1{,}737) = 2.73$, $p = .099$. Women reported significantly higher fear of the tested animals than men, and the mean fear rating only very slightly decreased with age ($r = -.064$). We also found a strong negative association between the mean fear rating and severity of a dog bite or cat scratch in the past; that is, people with no or little experience of being bitten by a dog or scratched by a cat gave higher fear ratings than people who had been seriously injured by these pet animals in the past.

The mean disgust score was affected by the gender, $F(1, 1{,}736) = 21.74$, $p < .001$; age, $F(1, 1{,}737) = 25.91$, $p < .001$; and dog bite, $F(5, 1{,}732) = 3.99$, $p = .001$; but not the size of town, $F(5, 1{,}733) = 1.60$, $p = .158$; cat scratch, $F(5, 1{,}732) = 1.93$, $p = .086$; nor another animal attack, $F(1, 1{,}736) = 1.55$, $p = .213$. As with fear, women reported significantly higher disgust than men and the mean disgust rating decreased with increasing age ($r = -.132$). Having been bitten by a dog also decreased the mean disgust rating and the more serious the injury, the lower the rating was. Finally, in a separate

Table 2. Factor loadings for fear evaluation of the tested animals

	Factor				
	1	2	3	4	5
Moth	**0.693**	0.040	0.005	0.043	−0.025
Cockroach	**0.655**	0.010	−0.033	−0.247	0.015
Ant	**0.553**	−0.048	0.032	−0.065	0.132
Maggot	**0.538**	−0.003	−0.011	−0.402	−0.105
Spider	**0.514**	−0.074	0.246	−0.066	−0.056
Wasp	**0.440**	−0.127	0.031	−0.076	0.268
Lizard	**0.326**	0.220	0.322	0.063	0.004
Frog	**0.317**	0.245	0.270	−0.061	−0.025
Snail	0.296	0.122	−0.002	−0.063	−0.050
Fish	0.258	0.136	0.041	0.034	0.062
Mouse	−0.039	**0.863**	0.039	−0.053	0.019
Rat	−0.062	**0.787**	0.040	−0.107	0.139
Bat	0.272	**0.331**	0.224	0.018	0.147
Grass snake	0.056	0.040	**0.820**	−0.023	−0.057
Viper	−0.109	−0.033	**0.749**	−0.110	0.186
Tapeworm	−0.043	0.046	0.037	−**0.832**	0.003
Roundworm	−0.023	0.054	0.074	−**0.820**	0.008
Louse	0.359	−0.017	−0.015	−**0.528**	0.079
Horse	−0.024	−0.049	−0.009	0.003	**0.708**
Dog	−0.088	0.006	0.035	−0.011	**0.685**
Bull	−0.055	−0.004	0.212	−0.086	**0.605**
Rooster	0.255	0.065	0.011	0.036	**0.416**
Panda	0.069	0.210	0.099	0.048	**0.401**
Cat	0.040	0.183	−0.023	−0.009	**0.322**
Pigeon	0.138	0.166	−0.050	−0.089	**0.314**

Factor loadings >0.30 are in boldface.

analysis we have also calculated the effect of those variables on the five fear and disgust subscale scores as derived from the factor analyses (see Table S3 for more details).

Discussion

We demonstrated in this study that in fact only a few animals associated with specific phobias elicit intense fear or disgust within the general population. Most of the tested species scored relatively low on both emotions, while two smaller groups of highly fearful (viper, wasp, snake, and bull) and repulsive animals (roundworm, tapeworm, maggot, louse, and cockroach) were formed on the other end of the axis with the spider in between. Interestingly, the fear and disgust ratings strongly correlated and were positively associated with scores on the administered scales. The mean fear and disgust score was also affected by the gender, age, and bad experience with dogs. Finally, a five-factor solution was found for categorizing the animals based on both fear and disgust ratings separating snakes, small non-slimy invertebrates (including the spider), mice with rats and bats, endo- and exoparasites, and big mammals into coherent clusters.

Table 3. Factor loadings for disgust evaluation of the tested animals

	Factor				
	1	2	3	4	5
Grass snake	**0.948**	0.035	−0.003	−0.030	0.012
Viper	**0.894**	0.070	0.000	−0.045	0.043
Lizard	**0.399**	−0.073	0.160	0.319	0.043
Tapeworm	0.055	**0.876**	0.038	−0.107	0.045
Roundworm	0.084	**0.870**	0.026	−0.050	0.065
Louse	−0.067	**0.680**	0.028	0.281	−0.003
Maggot	0.016	**0.567**	0.010	0.415	−0.114
Rat	0.041	0.068	**0.908**	−0.050	−0.036
Mouse	0.045	0.022	**0.882**	−0.078	0.023
Bat	0.162	−0.043	**0.365**	0.331	0.108
Pigeon	−0.112	0.066	0.277	0.210	0.216
Moth	−0.037	−0.002	0.095	**0.696**	−0.028
Ant	0.016	0.052	−0.088	**0.672**	0.058
Cockroach	−0.036	0.399	0.073	**0.538**	−0.068
Spider	0.151	0.156	−0.035	**0.519**	−0.100
Wasp	0.047	0.078	−0.079	**0.506**	0.158
Snail	0.048	0.060	0.050	**0.470**	0.040
Frog	0.299	0.050	0.192	**0.392**	−0.027
Fish	0.105	−0.031	0.079	**0.345**	0.157
Horse	−0.008	0.015	−0.090	−0.010	**0.709**
Dog	−0.014	0.038	−0.041	−0.045	**0.663**
Bull	0.184	0.020	−0.003	0.135	**0.531**
Panda	0.041	−0.038	0.093	0.025	**0.530**
Rooster	0.038	−0.090	0.080	0.282	**0.399**
Cat	0.004	0.034	0.130	−0.049	0.296

Factor loadings >0.30 are in boldface.

Table 4. Mean subscale scores and correlation coefficients between the subscale scores as identified in the factor analyses and the questionnaire scores

	Factor	Mean	SNAQ	FSS	SPQ	DSR
Fear	1	2.63	0.40	0.58	0.58	0.49
	2	1.95	0.41	0.44	0.22	0.40
	3	3.83	0.68	0.43	0.25	0.37
	4	3.56	0.31	0.51	0.28	0.46
	5	2.00	0.23	0.43	0.09	0.23
Disgust	1	2.25	0.74	0.39	0.29	0.40
	2	4.74	0.31	0.47	0.36	0.55
	3	2.01	0.38	0.37	0.22	0.40
	4	2.69	0.42	0.53	0.62	0.52
	5	1.29	0.31	0.34	0.19	0.26

Tested scales: DSR = Disgust Scale – Revised; FSS = Fear Survey Schedule II; SNAQ = Snake Questionnaire; SPQ = Spider Questionnaire.
All the coefficients are significant at $p < .001$.

Expectedly, the spider and venomous snake (viper), but not a harmless snake (grass snake), were the most feared animals by the majority of respondents in our study. Nearly 19% of subjects reported extreme fear or terror when exposed to the spider picture and 10% of subjects gave the highest fear score to the viper picture. This confirms the general agreement in the literature that snakes and spiders are the most intensively feared animals in humans with the highest prevalence in the general population (Davey, 1994a, 1994b; Davey *et al.*, 1998; Fredrikson, *et al.*, 1996; Merckelbach *et al.*, 1987). It also provides a circumstantial support to Seligman's theory of biological preparedness (1971), which considers snakes and spiders as exemplary species for evolutionary origins of specific phobias that can develop even without a preceding traumatic experience (Fredrikson, Annas, & Wik, 1997). Similarly, Öhman and Mineka (2001, 2003) believe snakes to be prototypical stimuli triggering the fear module hardwired in the mammalian brain. However, as can be demonstrated by our study, not all the snakes are alike and healthy adults, as opposed to phobic subjects, are able to adjust their fear response based on the real threat posed by the particular snake species. Compared to the viper, the picture of an innocuous grass snake was rated considerably lower on the fear scale and only 6% of subjects reported the highest fear, nearly half as frequent as fear of the viper. To our knowledge, this is the first study to show that snake fear much depends on the specific species presented to the subject which should be reflected in future research.

Unlike most of the previous studies of negative emotions towards animals (cf Prokop & Fančovičová, 2010), we have also included disgust evaluation. While the overall intensity of perceived fear and disgust (expressed as a sum of the mean fear/disgust ratings for each animal) was almost identical, the frequency of the highest scores attributed to the stimuli was much higher in the case of disgust (see Figure 2). We hypothesize that this might be attributed to the categorical difference between the two emotions. Disgust, as opposed to fear, can be easier elicited by still images, while fear relies more on the actual context. As Bennett-Levy and Marteau (1984) or Merckelbach *et al.* (1987) argued, fear of animals is associated with the characteristics such as speediness and suddenness of movement which cannot be interfered from the photographs. For example, there is a solid evidence that infants associate snakes with fear only when looking at videos but not still photographs indicating that the snakes' slithering movement is crucial (DeLoache & LoBue, 2009; LoBue & DeLoache, 2011).

As the most disgusting were found the animals that are exo- and endoparasites of humans, such as the louse, tapeworm, or roundworm, which may become vectors of serious life-threatening diseases including epidemic typhus, cysticercosis, or ascariasis, respectively (Macpherson, 2005). Especially intestinal worms represent a huge medical problem as estimated more than 1.5 billion people are infected by soil-transmitted helminths worldwide (WHO, 2018), almost a quarter of the population. This, on the other hand, provides substantial support to the disease-avoidance model of animal phobias (Matchett & Davey, 1991; Oaten, Stevenson, & Case, 2009; Ware *et al.*, 1994) stressing the role of disgust in the behavioural immune system to reflect the strong selective pressure of parasites in human evolution (Curtis, Aunger, & Rabie, 2004; Curtis *et al.*, 2011; Prokop & Fančovičová, 2010). Therefore, all that points to a conclusion that there are two major kinds of animal phobias, one represented by snakes as a prototypical stimulus that are associated with fear and match the presumptions of the biological preparedness concept. The other large group is mostly composed of small slimy or dry invertebrates known as dangerous parasites or vectors of diseases that are avoided through triggering a disgust response and for whom the disease-avoidance model has the highest explanatory power.

Spiders then, as discussed below, share their phobic characteristics with both of these groups.

Interestingly, the spider ranked on disgust right after these parasites and overcame generally highly repulsive animals such as the cockroach, snail, rat, or mouse. Thus, among the most feared and disgusting animals, the spider was the only species scoring equally high on both emotions. This confirms the finding of Gerdes *et al.* (2009) that spiders are special in eliciting significantly greater fear and disgust than any other arthropod. This might reflect emotional fear/disgust ambiguity of the spider stimulus (see also Davey, 1992, 1994b; Gerdes *et al.*, 2009).

It has been hypothesized within the context of disease-avoidance model that spider phobia develops from the convergence of the spiders' disgusting properties and the subjective probability of involuntary physical contact with humans. Indeed, spiders are regarded as highly disgusting by healthy subjects and even more by spider phobics (de Jong & Muris, 2002), potentially due to their quirky 'too-many-legs' body plan. At the same time, they are omnipresent in our homes, often lurking in hidden dark places and capable of fast unpredictable movement. According to de Jong and Muris (2002), spider phobic girls have higher tendency for irrational catastrophic beliefs regarding spiders' intentions and behaviour; specifically, they rather inflate the probability of spiders entering their room, approaching them, and making physical contact or even deliberately causing harm (Arntz, Lavy, van den Berg, & van Rijsoort, 1993). In short, spider phobia stems from fear of physical contact with a disgusting stimulus. A parallel can be found in the case of the cockroach that resembles the spider in its physical appearance and higher fear and disgust status. Interestingly, the cockroach is probably more dangerous to human health than the spider. Cockroaches both defecate and regurgitate on the food that they eat and cause food contamination by spreading highly infectious bacteria *Pseudomonas* and *Salmonella* that are transmissible to humans and cause serious diseases (Cornwell, 1968). Perhaps, the reason why there are not as many cockroach phobias is because these animals are not very frequent in our living space.

Our results suggest that the same mechanism might be at the core of other small animal phobias, especially of parasitic worms and lice. These animals pose a significant disgust status, even greater than the spider. Simultaneously, they are among the most feared animals ranking alongside the wasp or grass snake, prototypical fearful stimuli. This is also corroborated by a significant positive correlation between the respective factor scores and assessments of fear and disgust (FSS and DS-R; see Table 4). One might argue that as opposed to spiders, mainly intestinal helminths lack the ability of active locomotion, and thus fear of involuntary physical contact can be ruled out. However, we hypothesize that this is not the case and in fact several factors typical for human parasites may contribute to development of specific phobia through the same route as for spiders, thus being approached by something highly repulsive.

First, even though some intestinal parasites may grow into impressive body size at adulthood (the pork tapeworm infecting humans can reach up to 4 m in length), due to their life cycle hidden within the host body we nearly never have a chance to see the adult stage. In contrary, humans get typically infected by microscopic, hence invisible, ova or larvae (cysts) that are ingested with undercooked meat or dirtiness from unwashed hands. Second, they may be omnipresent and their distribution is unpredictable. For these reasons, despite being highly repulsive stimuli, we cannot rely on disgust in order to avoid them as neither themselves, the infected meat, nor another person infested with helminths can be recognized at first sight (likewise to lice infestation). Therefore, being as passive passengers not capable of active movement, parasites often use other vehicles to get into our bodies; hence, people fear them as disgusting entities that might get too close without us noticing or having much control over it. In this perspective, the maggot is an interesting animal stimulus that seems to stay half-way to be like a parasite. Even though it is as disgusting as the intestinal worms or lice, the maggot is easier to be spotted and avoided at distance. As a consequence, it does not elicit as much fear as intestinal worms (actually its fear ranking is below average), because the crucial probability of unwanted contact is very limited.

It is noteworthy that the dimension of fear and disgust in this study seemed closely associated (though less profoundly) in other species too as demonstrated by the high correlation coefficient $r = .72$. Therefore, it might also be possible that both emotions elicit similar negative feelings that for many individuals are hard to distinguish, especially in an online testing where no feedback or additional clarification is possible. Emotional intelligence, that is the ability of introspection and correct identification of experienced emotions, has significant interindividual variability and may even be improved through training as some other psychological skills (Mayer & Geher, 1996).

Perhaps, it is maybe more interesting not to ask which animals trigger high fear and disgust but rather which of them do not. Supposing that phobias derive from dysregulation of otherwise normative fears of objects or situations that provoke certain anxiety even in healthy individuals and bearing in mind our picture set should have represented the most common phobic animals, one might expect that the stimuli would all evoke a certain level of fear or disgust in our respondents. Interestingly, out of the 24 animals, only 10 received a mean score above point 3 (i.e. lower than moderate fear/disgust) on either of the scales, i.e. the cockroach, grass snake, louse, roundworm, spider, tapeworm, viper, wasp, and maggot. The remaining 14 animals, e.g., the rat, mouse, lizard, or snail, on average evoked only very little or no fear/disgust that was comparable to the control stimulus, the red panda. Thus, many of the animals that become objects of pathological anxiety do not have any normative fearful or avoidance potential.

We also focused on the association between fear and disgust ratings of animal pictures and scores on standardized questionnaire measuring general fear and disgust propensity (FSS and DS-R) and specific fear of the two most phobic animals, snakes and spiders (SNAQ and SPQ). As revealed in the RDA, high scores on the FSS and DS-R contributed the most to negative evaluation of all the animals according to either fear or disgust, which corroborates previous findings (Davey, 1994a; Matchett & Davey, 1991). Presumably, we have also found a significant association between fear/disgust evaluation of snakes and spiders and the respective fear questionnaire scores, the SNAQ and SPQ. However, it appears that the fear and disgust evaluation of the grass snake picture is a better predictor of the SNAQ score than the viper picture. As discussed above, the viper as a venomous snake representing a serious threat is highly feared among subjects no matter their actual level of snake fear, hence the lower effect of the SNAQ score. On the other hand, people close to phobia scoring high on the SNAQ generalize their fear onto any snake, even a totally harmless one. This has quiet significant implications for clinical practice as responses to innocuous representatives of the feared animal category might be used as a fast screening tool for specific phobias rather than pictures of fierce beasts.

So far, a few studies have focused specifically on non-clinical fears of various animals with the aim to group them into coherent clusters, while others used ad hoc or intuitive grouping instead (Gerdes *et al.*, 2009; Webb & Davey, 1992). There is no clear pattern in the existing literature as to animal fear categorization, because the outcomes are limited by the tested species selection procedure. We argue that the way the previous studies used to devise the stimuli set have been flawed as these often adopted a list by Matchett and Davey (1991) and Davey (1994a) that had been developed based on arbitrary judgement of the authors. Thus, we based our selection on a quantifiable criteria referring to the number of information available for each animal phobia in Doctor *et al.* (2008) which may be considered as a proxy to its prevalence. Second, we have used visual instead of verbal stimuli which are generally considered as more effective in provoking an emotional response. We have also extended the current evidence of a factor analysis of animal disgust evaluation, which allowed us to compare the identified clusters based on both emotions and see whether they overlap or are unrelated.

In this study, five clearly separated factors of fear and disgust evaluations were recognized. The first group comprised mostly small-size animals such as the moth, cockroach, ant, spider, and wasp resembling the so-called low-predatory fear-relevant category (Davey, 1994a; Ware *et al.*, 1994) of dry, non-slimy invertebrates (Arrindell, 2000). The second group was formed of 'mouse-like' animals, that is, the mouse, rat, and bat. It is noteworthy that these animals too are significant transmitters of very dangerous pathogens that can be deadly for humans. Rodents are known to be direct vectors of several zoonotic infections such as leptospirosis, hantavirus, or lassa and haemorrhagic fever (CDC, 2017), similar to bats that carry human-infecting viruses including rabies, SARS, or even may be the original hosts of Ebola and Nipah viruses (Luis *et al.*, 2013). This is in further support of the disease-avoidance model of animal phobias. The third clearly separated factor included the two snakes with a little contribution of the lizard in the case of disgust. The fourth factor grouped together human exo- and endoparasites, that is, the louse, tapeworm, and roundworm, with additional significant loading of the maggot in the case of disgust. And finally, familiar farm or pet mammals and birds, such as the horse, bull, dog, cat, or rooster, belonged to the fifth factor together with the red panda used as a control. This corresponds to the 'farm animals' category found by Arrindell (2000). These animals in general evoked only very low fear and disgust among the respondents.

We have demonstrated that not only the mean overall fear and disgust rating but also some subscale scores composed of items identified in the factor analyses were significantly affected by gender. In general, women self-reported higher fear and disgust towards the animals than men which is a common pattern found in all anxiety-related studies (McLean & Anderson, 2009). Our data show that the most striking differences between the sexes were in fear and disgust evaluation of the group of non-slimy invertebrates and repulsive human parasites. This is again in accordance with the evolutionary theory claiming that women as a sex with higher reproductive cost need to be extra careful of pathogens threatening not only their health but also the one of their children (Tybur, Bryan, Lieberman, Hooper, & Merriman, 2011).

Additionally, we observed rather strong negative associations between fear and pet-related injuries and between disgust and dog-related injuries. Both cats and dogs transmit several important parasites, for example, *Toxoplasma* and *Bartonella*, and contact with pets, and especially sustaining pet-related injuries, has strong impacts on both physical and mental health of the general population (Flegr, 2017; Flegr & Hodný, 2016; 2018 & Balatova, 22018; Flegr & Vedralová, 2017). Our results, namely the negative association between phobias and animal-related injuries, suggest that fear and disgust could protect subjects against harm even in our modern environment.

Limitations

We are well aware of certain limitations of the study. Some of them are associated with the method of data collection. Even though online studies recruiting people through Internet communities can often boast with large sample size that would be hardly achieved in face-to-face research, the data gathered this way are less reliable. Already, self-reports are generally prone to be corrupted by demand characteristics, and moreover, in distant research we have no control over the respondents' behaviour during the test. Indeed, the subjects may be more likely within the anonymous setting behind the screen to provide untrustworthy, randomly fabricated answers that are difficult to be identified. Or, they might have just misunderstood some tasks/items but have no chance of getting a further clarification. Second, under no circumstance can our sample be considered as representative in terms of basic demographic characteristics such as age, gender, or educational level. The average age of respondents in the Facebook group we have used is 34 years with more than twice as many women as men and most of the people with completed high school education or higher. Moreover, the subjects in this kind of survey are self-recruited, therefore a bias towards participants interested in the given topic due to various reasons is expectable.

Another limitation pertains to the selection of the tested animals and administered scales. We aimed to devise a list of the most common phobic animals; however, as real prevalence rates of concrete animal phobias in the general population are unknown, we used the amount of available information in the encyclopaedia of phobias by Doctor *et al.* (2008) as an indicator. Obviously, this method may not necessarily be accurate and it remains questionable how the results (especially the factor analyses) might have changed had another animals been selected. For example, human parasites came out as one group eliciting disgust in this study; however, there is evidence that endo- and exoparasites form two distinctive categories. While the former ones usually enter the host organism through the oral cavity and thus evoke core disgust associated with nausea and vomiting as an effective defence strategy, exoparasites attach themselves to the body surface where feeling sick would not help a lot. Instead, itchiness and grooming behaviour is more appropriate reaction (for a review, see Hart, 1990 and Kupfer & Fessler, 2018). Similarly, we used popular, widespread measures of fear and disgust which had been already standardized in Czech (apart from the FSS and SPQ) and that would allow for drawing comparisons with previous research, although there might have been other appropriate scales providing different outcomes. As suggested by some authors (Cusimano, Royzman, Leeman, & Metas, 2018 or Royzman & Sabini, 2001), it is especially the assessment of disgust that needs careful consideration. Finally, even though we argue that using picture rather than verbal stimuli is an asset in terms of their potential to elicit an appropriate emotional response, there are opposing views pointing out that the depicted particular representatives of the phobic object may be for some reason missing the key features that make it threatening for a given individual (Kindt *et al.*, 2000; van den Hout *et al.*, 1997).

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Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the appropriate institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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Supporting Information

The following supporting information may be found in the online edition of the article:

Table S1. A list of the tested animals.

Table S2. Spearman rank correlation coefficients between ratings of fear and disgust of the tested animals and total/subscale scores on the completed questionnaires.

Table S3. Results of the GLMs for the individual factor scores of fear and disgust as dependent variables and selected demographic or personal experience variables.

animals

MDPI

Article

Human Attitude toward Reptiles: A Relationship between Fear, Disgust, and Aesthetic Preferences

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Simple Summary: Although there are many articles about reptiles, no one has ever studied the human perception of reptiles as a whole, a group that would include representatives of different taxonomic clades. Thus, we designed a study of human perception of all reptiles focusing on the relationship between perceived fear, disgust, and aesthetic preferences. Respondents evaluated various reptile images and the results revealed that people tend to perceive them as two clearly distinct groups based on their similar morphotype—legless reptiles (incl. snakes) and other reptiles with legs. In the case of snakes, the most feared species also tend to be perceived as beautiful. Compared to the most feared reptiles with legs (lizards, turtle, crocodiles), the legless once tend to be perceived as more disgusting. In both groups, species perceived as the least beautiful were the same as those rated as the most disgusting. Thus, reptiles cannot be rated as both beautiful and disgusting at the same time.

Abstract: Focusing on one group of animals can bring interesting results regarding our attitudes toward them and show the key features that our evaluation of such animals is based on. Thus, we designed a study of human perception of all reptiles focusing on the relationship between perceived fear, disgust, and aesthetic preferences and differences between snakes and other reptiles. Two sets containing 127 standardized photos of reptiles were developed, with one species per each subfamily. Respondents were asked to rate the animals according to fear, disgust, and beauty on a seven-point Likert scale. Evaluation of reptile species shows that people tend to perceive them as two clearly distinct groups based on their similar morphotype. In a subset of lizards, there was a positive correlation between fear and disgust, while disgust and fear were both negatively correlated with beauty. Surprisingly, a positive correlation between fear and beauty of snakes was revealed, i.e., the most feared species also tend to be perceived as beautiful. Snakes represent a distinct group of animals that is also reflected in the theory of attentional prioritization of snakes as an evolutionary relevant threat.

Keywords: reptiles; emotions; fear; disgust; beauty

1. Introduction

1.1. Focused on reptiles

Reptilia represents an ancient and diversified group of vertebrates that includes Testudines (turtles, tortoises and terrapins) and Diapsida, which further splits into Lepidosauria (comprising Squamata and Rhynchocephalia) and Archosauria (comprising Crocodylia and Aves). The precise position of

Testudines within Diapsida is uncertain [1]. They may be a sister group of either lepidosaurs [2] or archosaurs [3]. Reptilia is diversified group of animals with unclear phylogeny of major clades, comprising turtles, crocodiles, tuatara, lizards, snakes and birds.

The birds, however, differ so much from the other groups that they are almost always recognized and categorized as a separate category by humans, both in traditional [4] and ethnobiological classification [5]. Because this paper is focused on human perception of these animals, we will use the term "reptiles" in the same manner, i.e., as a paraphyletic group of Reptilia excluding birds and extinct species.

Approximately 10,885 reptile species are currently described, and this number grows each year as others are added. For example, in 2018, 157 new species were described—113 lizards, 39 snakes, 4 worm lizards and one turtle (data valid to 14th November 2018; [6]). Nevertheless, in some aspects, reptiles still represent a neglected group of vertebrates, especially when compared to birds and mammals [7,8]. Because of that, basic information is lacking for a substantial number of species (and not only the newly discovered ones), be it the population size, life-history, or real distribution. These gaps in knowledge also present a complication in the protection of endangered species, because it is not possible to determine whether and by what means a particular species is threatened [9,10].

1.2. Research of Human Relationship to Animals

A similar bias as in our knowledge about reptile species can be found when researching people's relationship to animals. It can be explored from many different perspectives, e.g., in terms of folk traditions, utilitarian reasons, negative attitude, pet keeping or nature protection [11–14]. The whole variety of human interactions with local fauna has been traditionally the subject of ethnozoology (or specifically ethnoherpetology when focused on reptiles), a discipline that has thrived since the 19th century [15]. Recently, there is a growing body of evidence that ethnozoology through studying people's perception of animals is indispensable in sustainable management of natural resources and might, therefore, play a crucial role in conservation of endangered species [16], including reptiles [17–19], protection of which is complicated by the aversion they often elicit in people [20].

Reptile studies are often unbalanced in terms of the choice of stimuli that respondents rate, either as images or words, and the majority of them focus just on snakes in regards to snake fear and phobias (see *Negative relationship to animals*). This can be emphasized especially when compared to studies of human attitude toward other animals (both vertebrates and invertebrates [21,22]). For example, several mammalian species from different families have been selected to study human relationship, e.g., the lion (*Panthera leo*), chimpanzee (*Pan troglodytes*), elk (*Alces alces*) or dolphin (*Tursiops truncatus*) [21,23], although there is nearly half as many mammals as reptiles (5,792 species of mammals are currently recognized [24]). Conversely, a group of reptiles is most often represented by only a single taxonomic category, i.e., the lizards (including snakes), most often further unspecified [22] or represented by the common sand lizard (*Lacerta agilis*) and grass snake (*Natrix natrix*) or some pythons (*Python* sp.) [12,21,23]. Only a few studies also include crocodiles or turtles [22,25]. Thus, the selection of reptilian species in the human-animal relationship research does not adequately reflect their morphological diversity. The only exception can be found in studies investigating the relationship of people to the local fauna, which usually includes the most important reptilian species in the area [13,14,26].

To our knowledge, no one has ever studied the human perception of reptiles in whole, as a category that would include representatives of different taxonomic clades (i.e., turtles and tortoises, lizards, crocodiles, and tuatara) reflecting their large-scale biological diversity. Yet focusing on one particular group of animals can bring interesting results regarding our attitudes toward them and show by what rules evaluation of such animals is conducted. For example, mammals are evaluated mainly by body shape and coat pattern. Animals with a distinctive pattern or longer and denser hair that resemble plush toys are positively perceived. Conversely, people perceive negatively subterranean species with stunted eyes or faintly colored hair. These properties affect the evaluation of mammals across taxonomic groups [27,28]. Similarly, people evaluate birds based on their body shape (head size in relation to the body, tail length, limb length, [29]), and pattern [30]. Colors have minor effect when evaluating birds across all main taxa (families), but affect preferences within some groups, such as parrots [31] or pittas [30].

1.3. Negative Relationship to Animals

Ekman and Cordaro [32] distinguish at least seven basic emotions that are shared between different cultures everywhere, namely anger, fear, surprise, sadness, disgust, contempt and happiness. These basic emotions are described as discrete, automatic answers to important life situations that have helped human ancestors to survive in the past. From an evolutionary perspective, fear and disgust, in particular, represent a biologically adaptive way of responding to situations that may be potentially life-threatening. Fear is triggered in the presence of a predator or other significant fear stimulus, under the influence of the sympathetic nervous system, initiating a specific and rapid defensive behavioral reaction known as "fight or flight [33]. Disgust then acts as a mechanism to protect the body from potential contamination and disease and motivates disease-avoidance behavior [34,35]. Rozin and Fallon [36] and Rozin et al. [37] assume that disgust originated as a mechanism to reject poorly tasting food that could be poisonous, spoiled, or otherwise degraded. Fear and disgust also play a role in anxiety disorders, including specific animal phobias [33,38–40].

Of all reptiles, only certain groups, especially snakes and crocodiles, are really dangerous for humans. Crocodiles may be deadly due to their impressive body size and predatory way of life [41–43]. Certain snakes, on the other hand, can either produce potent venom capable of killing an adult human (Viperidae, Elapidae; [44]) or become dangerous when reaching critical size, especially large constrictors like the reticulated python (*Malayopython reticulatus*, [45]) or green anaconda (*Eunectes murinus*, [46] (p.131–164)). According to some authors e.g., [47,48], humans and snakes have a long predator-prey co-evolutionary history and fatal attacks of venomous and constrictor snakes on our direct ancestors during their early development in Eastern Africa have shaped the relationship to this widely feared group of animals [49]. A significant danger was mainly represented by highly venomous snakes of the viper family (Viperidae, [6]) that lived in the same area of human origins [50,51]. Thus, it was important for early humans to recognize and react appropriately to this threat. There is an extensive line of evidence suggesting that even nowadays, when the risk of snake encounters has much reduced, snakes still represent a significant stimulus for humans attracting increased attention. This phenomenon is supported by studies showing a rapid detection of snakes compared to inanimate objects, such as flowers and mushrooms [52–54] or other animals [55–57], mediated by specific neural mechanisms [58–62]. This was reported in both humans and non-human primates [63,64]. For these reasons, it is rational to believe that snakes, although taxonomically a part of lizards, represent a different cognitive category for humans. As a substantial part of this study, we aimed to examine this specific position of snakes in relation to fear, but also to disgust and beauty (as a positive dimension to contrast with fear).

As for disgust, reptiles do not represent a significant group. Studies have shown that people are particularly repelled by invertebrates or some rodents (mice or rats) [65–68]. Conversely, for humans, reptiles may represent a significant source of food rich in proteins, especially in warmer areas [13,69,70]. Disgust (together with fear) has only been studied in relation to snakes where it may play a significant role in the development of clinical fear in phobics [71,72].

1.4. Positive Relationship to Animals

Animals can also generate positive emotions in humans and be interesting for them from an aesthetic point of view [73]. In literature, terms, such as "beauty", "aesthetic value" or "attractiveness" are often confused or considered as synonymous [74–76]. Still, it is important to correctly define what we are asking about when evaluating animals by humans. For example, the attractiveness of an animal may not always be related to positive assessment. An animal that seems attractive to humans can be somewhat bizarre, atypical or obscure [77]. Thus, with a positive attitude towards animals, the concepts, such as likeness, pleasantness and beauty are more likely to be combined, so the animals evaluated in this way inspire positive experiences [78]. The beauty of animals is an aesthetic value that is perceived consistently between different cultures and ethnicities [30,79] and both sexes at the same time [80].

Aesthetic preferences for animals (i.e., the beauty of animals perceived by humans) were initially examined particularly in relation to the visits of zoos. Results of these studies were to help zoos adapt their concept to the taste of visitors [81–84]. Other research focused on beauty in relation to the conservation of endangered species [85,86], people were more willing to contribute to helping animals if they considered them as more beautiful [87]. In the context of people's willingness to protect beautiful species, further work has focused on the analysis of animals in human care (zoological gardens) and their aesthetic evaluation. In mammals, their beauty has been shown to influence the number of individuals kept [27], the same results were found for parrots [81], turtles [88] and boas (now Boidae and Pythonidae; [89]). Understanding the cues behind people's positive attitudes in a particular group of animals can help in planning conservation programs for endangered species. Beautiful animal species can serve as flag species to support the conservation of a given habitat [90,91]. Conversely, in the case of animals that are not rated as beautiful, it is advisable to use other ways to increase the interest in those species when planning a campaign.

1.5. Aims

Based on the published studies on reptiles and the relationship of people to this group, we asked the following questions:

1. What is the human attitude toward a group of reptiles in terms of positive and negative emotions and does our evaluation rely on basic morphotypes, specifically, are legless snakes perceived differently than the rest of reptiles?
2. What is the relationship between perceived fear, disgust, and beauty of reptiles? Do these evaluations affect each other?

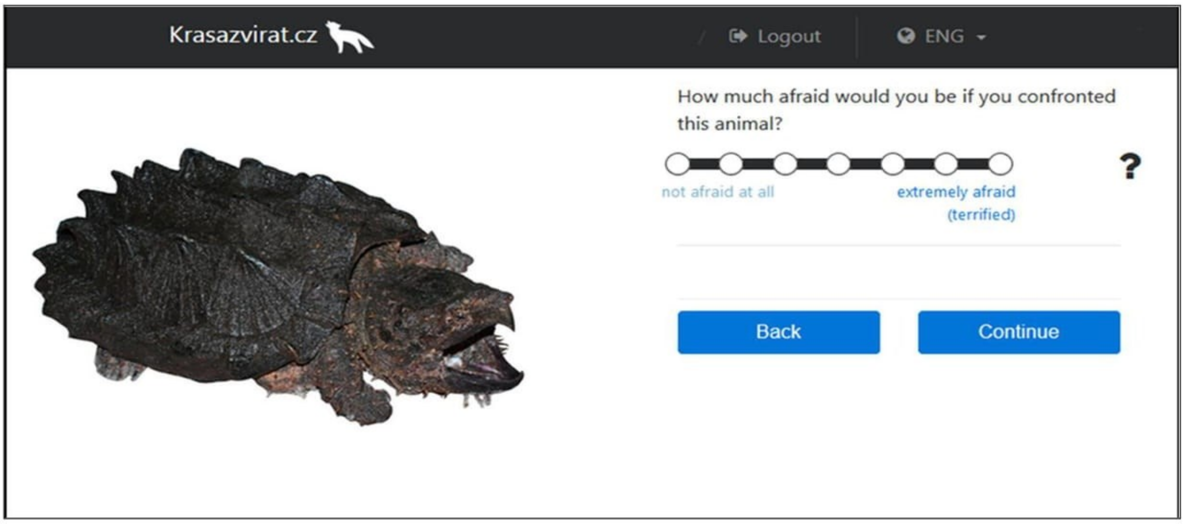
2. Materials and Methods

2.1. Selection and Preparation of Stimuli

To test the relationship of people to reptiles, we have prepared two sets of pictures that cover a wide variability of the reptile morphology: At least one species representing the main lineages was used. These sets were designed to cover the wide variability while retaining a reasonable number of stimuli that could be rated by respondents without substantial tiredness. We selected one representative from each existing reptile subfamily in each set, i.e., 127 stimuli per set (see [92]; the most comprehensive study of reptile taxonomy at the time of experiment planning). For a full list of included species, see Supplementary materials (Tables S1 and S2). The second set containing different species (except monotypic subfamilies) was created to test whether selecting different subfamily representatives will lead to the same results. For each selected species, we found a representative photo of an adult individual on the Internet or among our own resources. Only photos in suitable resolution (at least 800 × 533 pixels) depicting the animal in full body were chosen. We adjusted the photographs to a standardized form, i.e., the animals were placed on a white background, adjusted to a similar position and comparable body size.

2.2. Testing Emotional Response to Reptiles

We uploaded both sets of standardized photos to a special web application available at www.krasazvirat.cz (Figure 1). We had the sets evaluated by Czech respondents (aged 18–88) separately for perceived fear, disgust and beauty on a seven-point Likert scale (7 corresponded to the strongest fear/disgust or the most beautiful species, 1 corresponded to the lowest response; [93]). Before the evaluation, each respondent filled in a short questionnaire (concerning the age, gender, and type of education), was informed about the content of the experiment and provided his/her consent to the processing of personal data (all in the Czech language). Some respondents evaluated the sets by all of the measured dimensions, however, because there was a reasonable time delay between each of the evaluations (several months), we considered them independent. Each of the sets (Set 1 and 2) were evaluated by different respondents: Set 1 evaluated 122 respondents by perceived fear, 126 by disgust, and 157 by beauty; Set 2 evaluated 184 (fear), 143 (disgust), and 188 (beauty) respondents.



How much afraid would you be if you confronted this animal?

Figure 1. Sample of graphic design of web application for evaluating pictures.

2.3. Statistical Analyses

In order to quantify and test the congruence in species ranking provided by different respondents, we adopted a two-way, consistency, average-measures intra-class correlation (ICC; [94,95] computed in R (irr package). Principal component analysis (PCA) was performed to visualize the multivariate structure of the data sets and to extract uncorrelated axes for further analyses. MANOVA was applied to test the effects of independent explanatory variables. Mann-Whitney test was used as a non-parametric alternative for variables deviating from normality (raw scores). Most of the calculations were performed in R [96] and Statistica 9.1. [97].

2.4. Ethical Note

This study was carried out in accordance with the recommendations of Institutional Review Board (IRB), Faculty of Sciences, Charles University approval n. 2013/7. All subjects gave their written informed consent in accordance with the Declaration of Helsinki.

3. Results

3.1. Agreement among Respondents

Results of the ranking procedure revealed considerable congruence among the respondents. Both the reliability of the individual rankings (ICC = 0.562, 0.441, 0.417 for fear, disgust, and beauty rankings, respectively, with all $p < 0.001$) and the ICC for the average-measures were in an excellent range (ICC = 0.994, 0.99, and 0.991 for fear, disgust, and beauty rankings, respectively; [98]. These results indicate that there was a high degree of agreement within the groups of respondents and suggest that the emotions elicited by reptiles and their beauty were rated similarly. The results for Set 2 were comparable; single ratings: ICC = 0.579, 0.416, 0.364 for fear, disgust, and beauty rankings, respectively, and average ratings: ICC = 0.996, 0.99, 0.991 for fear, disgust, and beauty rankings, respectively.

The multivariate analysis of variance (MANOVA) revealed no effect of gender, age, profession, nor their interaction on the rankings of fear and disgust of Set 1. In beauty rankings, small effects of gender (Wilks = 0.0629, $F_{45,127} = 2.23$, $p = 0.0232$) and age (Wilks = 0.0485, $F_{45,127} = 2.94$, $p = 0.0045$) were found. To identify the species that substantially contributed to these differences, we performed Mann–Whitney U tests comparing the raw ranks of each species in male/female and younger (18–30, $n = 85$)/older (31–73, $n = 68$) respondents (Bonferroni-corrected). However, these tests revealed no differences in beauty rankings between both genders, and only one difference in the Chinese butterfly lizard (*Leiolepis reevesii*) that was rated as more beautiful by older respondents.

Similar results were found in Set 2: MANOVA revealed a small effect of gender*age interaction (Wilks = 0.2021, $F_{50,127} = 1.55$, $p = 0.0387$) on the rankings of fear and a small effect of age (Wilks = 0.0173, $F_{9,127} = 4.02$, $p = 0.0137$) on the rankings of disgust, but Bonferroni-corrected Mann-Whitney U tests revealed no differences in rankings between the two age groups (18–30, $n = 106$; 31–88, $n = 37$) in any of the species. In beauty rankings, small effects of gender (Wilks = 0.2180, $F_{54,127} = 1.53$, p = 0.0405) and age (Wilks = 0.1220, $F_{54,127} = 3.06$, $p < 0.0001$) were found. Similarly to Set 1, only two differences between the two age groups (18–30, $n = 111$; 31–73, $n = 77$) were found: Older people ranked the Central American river turtle (*Dermatemys mawii*) and yellow-spotted Amazon turtle (*Podocnemis unifilis*) as more beautiful. Because the differences among respondents of various groups were very small, we decided to pool the data for each ranking of each set in further analyses concerning the means or multivariate axes (PCA) computed from the preference ranks. Both of these methods extract the agreement among respondents and thus further blend the minor effects of gender and/or age.

3.2. Multivariate Analyses of Datasets

In Set 1, PCA based on the fear rankings generated 121 unconstrained axes, 27 of which were of an eigenvalue higher than 1. However, most of the variability was explained by the first axis (69.68%), which was also highly correlated with the mean rankings of fear (Spearman $r^2 = 99.5\%$). Compared to that, the explanatory power of the other axes was much lower (9.98%, 4.41%, 3.27% for PC2, PC3 and PC4, respectively), gradually decreasing down to <0.001% in PC84 to PC121. PCA analyses based on the disgust and beauty rankings, as well as the data from Set 2 showed a very similar pattern (see Table 1). Because of that, we only extracted the scores of the first two axes of each ranking/Set and further analyzed their mutual correlations (Spearman, see Table 2).

Table 1. Summary of the principal component (PC analysis of the datasets).

			Eigenvalue			Proportion Explained by		
Stimuli Subsets	**No. of Axes**	**Eigenvalues > 1**	**PC1**	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**
Set1: fear	121	27	267.18	26.73	10.40	69.68 %	6.97 %	2.71 %
Set1: disgust	125	27	192.71	34.22	9.63	61.28 %	10.88 %	3.06 %
Set1: beauty	126	49	182.98	27.70	15.93	47.86 %	7.25 %	4.17 %
Set1: pooled	126	87	548.17	156.82	43.12	50.74 %	14.52 %	3.99 %
Set2: fear	126	38	388.81	33.04	13.01	70.94 %	6.03 %	2.37 %
Set2: disgust	126	33	229.10	41.94	10.32	61.19 %	11.20 %	2.76 %
Set2: beauty	126	56	188.36	44.20	19.55	42.53 %	9.98 %	4.41 %
Set2: pooled	126	103	696.29	193.68	52.10	51.00 %	14.18 %	3.82 %

Table 2. Spearman correlations of the fear, disgust, and beauty rankings of the (**a**) Set 1 and (**b**) Set 2. Correlations significant at the $p < 0.05$ are marked in bold.

(a) Set 1	mean disgust	mean fear	mean beauty	PC1 fear	PC2 fear	PC1 disgust	PC2 disgust	PC1 beauty	PC2 beauty
mean disgust	**1**	**0.773**	**−0.836**	**0.786**	**0.369**	**0.995**	0.002	**0.859**	**−0.423**
mean fear	**0.773**	**1**	**−0.458**	**0.995**	−0.136	**0.796**	**−0.529**	**0.494**	**−0.682**
mean beauty	**−0.836**	**−0.458**	**1**	**−0.468**	**−0.471**	**−0.807**	**−0.333**	**−0.998**	0.030
PC1 fear	**0.786**	**0.995**	**−0.468**	**1**	−0.104	**0.808**	**−0.537**	**0.505**	**−0.711**
PC2 fear	**0.369**	−0.136	**−0.471**	−0.104	**1**	**0.354**	**0.408**	**0.475**	−0.031
PC1 disgust	**0.995**	**0.796**	**−0.807**	**0.808**	**0.354**	**1**	−0.043	**0.831**	**−0.454**
PC2 disgust	0.002	**−0.529**	**−0.333**	**−0.537**	**0.408**	−0.043	**1**	**0.296**	**0.719**
PC1 beauty	**0.859**	**0.494**	**−0.998**	**0.505**	**0.475**	**0.831**	**0.296**	**1**	−0.082
PC2 beauty	**−0.423**	**−0.682**	0.030	**−0.711**	−0.031	**−0.454**	**0.719**	−0.082	**1**
(b) Set 2	mean disgust	mean fear	mean beauty	PC1 fear	PC2 fear	PC1 disgust	PC2 disgust	PC1 beauty	PC2 beauty
mean disgust	**1**	**0.774**	**−0.797**	**−0.791**	**0.419**	**−0.988**	0.154	**0.853**	**0.423**
mean fear	**0.774**	**1**	**−0.421**	**−0.996**	−0.055	**−0.800**	**−0.346**	**0.504**	**0.724**
mean beauty	**−0.797**	**−0.421**	**1**	**0.428**	**−0.416**	**0.748**	**−0.451**	**−0.989**	0.041
PC1 fear	**−0.791**	**−0.996**	**0.428**	**1**	0.025	**0.817**	**0.353**	**−0.514**	**−0.744**
PC2 fear	**0.419**	−0.055	**−0.416**	0.025	**1**	**−0.421**	**0.402**	**0.425**	−0.064
PC1 disgust	**−0.988**	**−0.800**	**0.748**	**0.817**	**−0.421**	**1**	−0.095	**−0.811**	**−0.476**
PC2 disgust	0.154	**−0.346**	**−0.451**	**0.353**	**0.402**	−0.095	**1**	**0.374**	**−0.695**
PC1 beauty	**0.853**	**0.504**	**−0.989**	**−0.514**	**0.425**	**−0.811**	**0.374**	**1**	0.071
PC2 beauty	**0.423**	**0.724**	0.041	**−0.744**	−0.064	**−0.476**	**−0.695**	0.071	**1**

As the next step, we performed a principal component (PC) analysis of the pooled data set of fear, disgust and beauty rankings, separately for Set 1 and 2 (for the numbers of axes, eigenvalues and explanatory power, see Table 1). Plotting the species scores onto PC1 and PC2 axes yielded very interesting results (see Figure 2): The reptiles are divided into two clearly separate groups, one consisting of snakes, legless lizards, and worm lizards (“legless reptiles”), and the other of lizards, turtles, and a tuatara (“other reptiles”). Notable genera are *Larutia* and *Lygosoma*, which possess visible legs with a long, snake-like body, and thus are seen and ranked by human respondents as something “in between” the legless and other reptiles. These results show that snakes, together with other legless reptiles, are indeed special and are ranked differently by humans: They evoke higher fear and disgust than other reptiles.

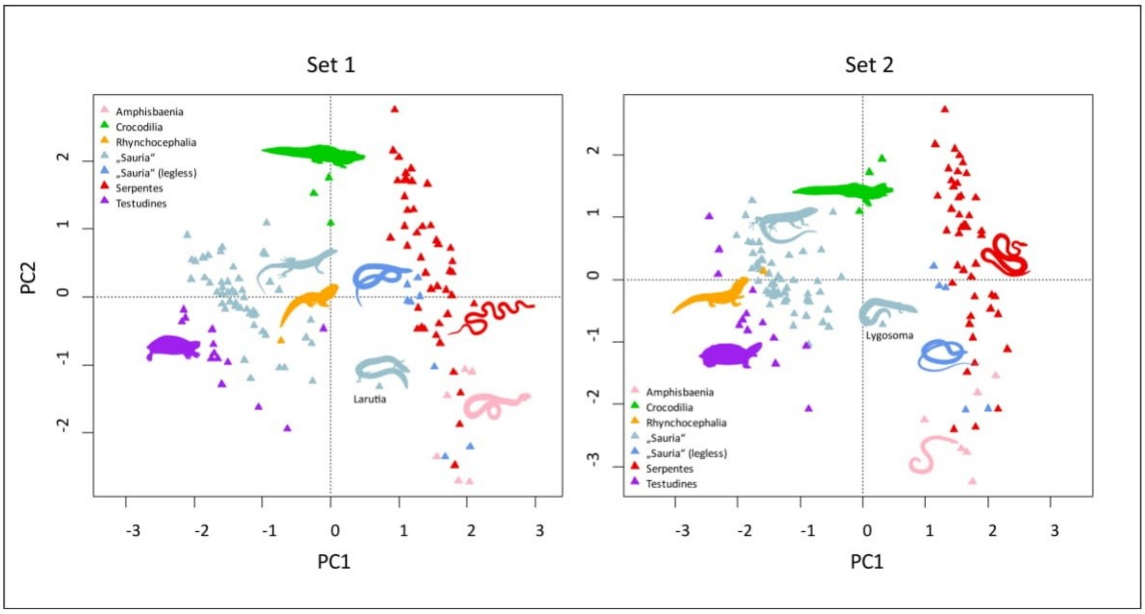


Figure 2. Plotting the species scores onto PC1 and PC2 axes, for Set 1 and Set 2 separately.

Similarly, when we plotted the species scores onto PC1 and PC2 axes of the PC analyses done separately for fear, disgust, and beauty rankings (see Figure 3), the pattern followed the segregation into the two main groups as described above, with a few exceptions specific for the particular ranking types. The most pronounced difference was that in the case of fear, crocodiles formed a distinct group. Moreover, the Komodo dragon (*Varanus komodoensis*, Set 2) split from the main group of “other reptiles” and joined closer to the crocodiles. The alligator snapping turtle (*Macrochelys temminckii*, Set 1) split off from the other Testudines and joined closer to the crocodiles, but still remained within the main group of “other reptiles”. In the case of disgust and beauty, the crocodiles became a part of the “other reptiles” group, suggesting that they mainly evoke fear, but are not exceptional animals when considering disgust and/or beauty.

3.3. Mutual Correlation of the Fear, Disgust, and Beauty Ranks

To see the mutual relationship between the rankings, we plotted the correlations of the mean ranks. To examine whether snakes follow a different pattern, we did these analyses separately for snakes (Serpentes) and other reptiles (see Figure 4). We found that in both cases, disgust and beauty rankings closely negatively correlated (snakes—70.32% and 80.18% in Set 1 and 2, respectively; other reptiles—80.24% and 80.06%). Interestingly, correlations involving fear (fear x disgust, fear x beauty) in snakes differed from those in other reptiles: Their positivity/negativity was inverted. The correlation of fear and beauty was negative in other reptiles (34.06% and 31.26%), but positive in case of snakes

(34.94% and 39.64%). Correspondingly, the correlation of fear and disgust was positive in other reptiles (57.34% and 50.30%) and negative in snakes (21.41% and 28.51).

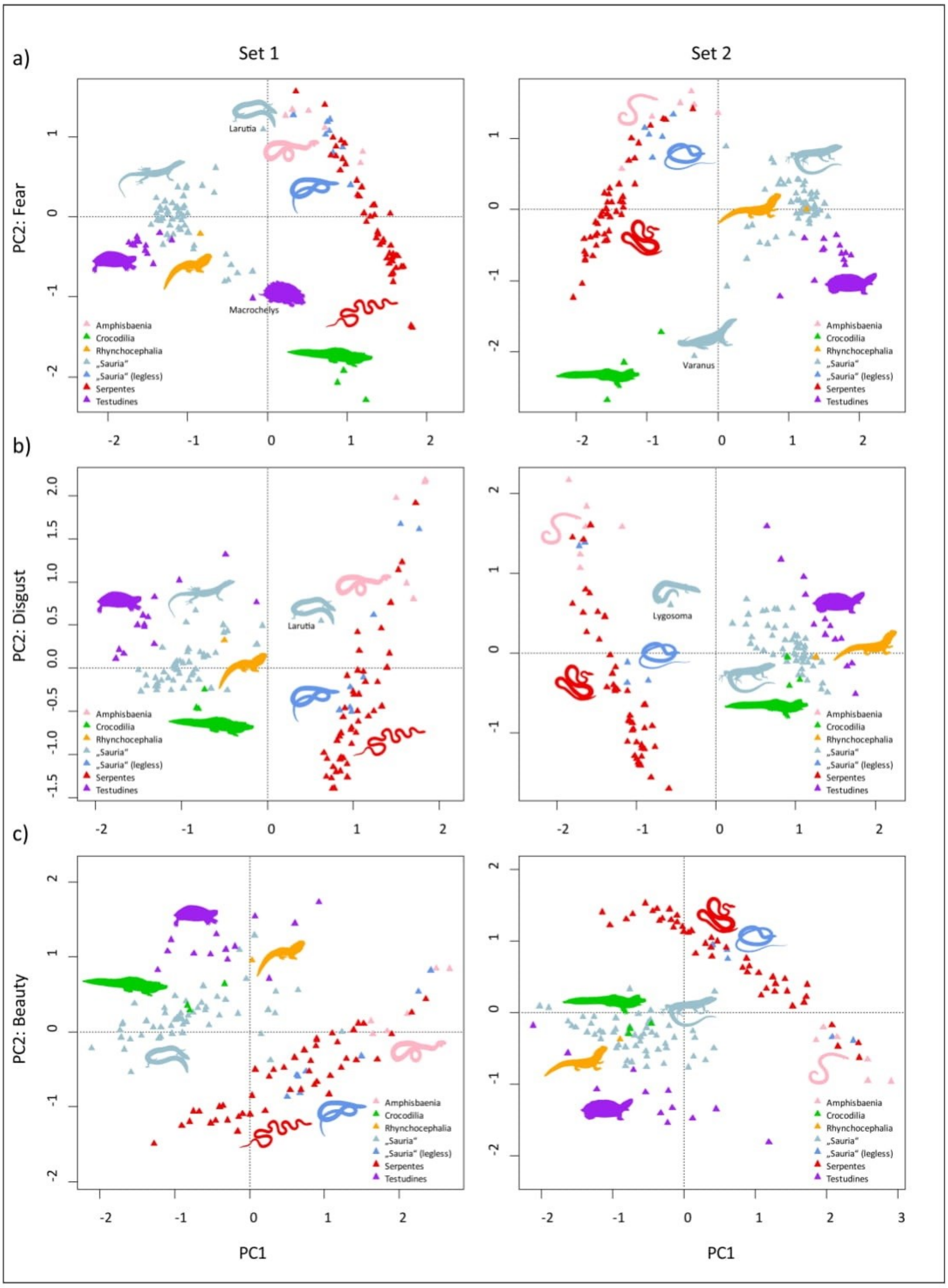


Figure 3. Plotting of the species scores onto PC1 and PC2 axes of the PC analyses, separately for (**a**) fear, (**b**) disgust, and (**c**) beauty rankings. In all cases, PC1 axis closely correlates with the respective mean values (e.g., PC1 fear correlates with mean fear), and the correlations are positive in Set 1 a, b, and negative in Set 1 c and Set 2 a, b, c. Please note that the positivity and negativity of the values of the PC axes are arbitrary and thus not fully comparable across the individual projections. For direct comparisons, please heed the colors that mark the specific taxa/groups and the distance of single points (triangles) and the groups they form from the other groups.

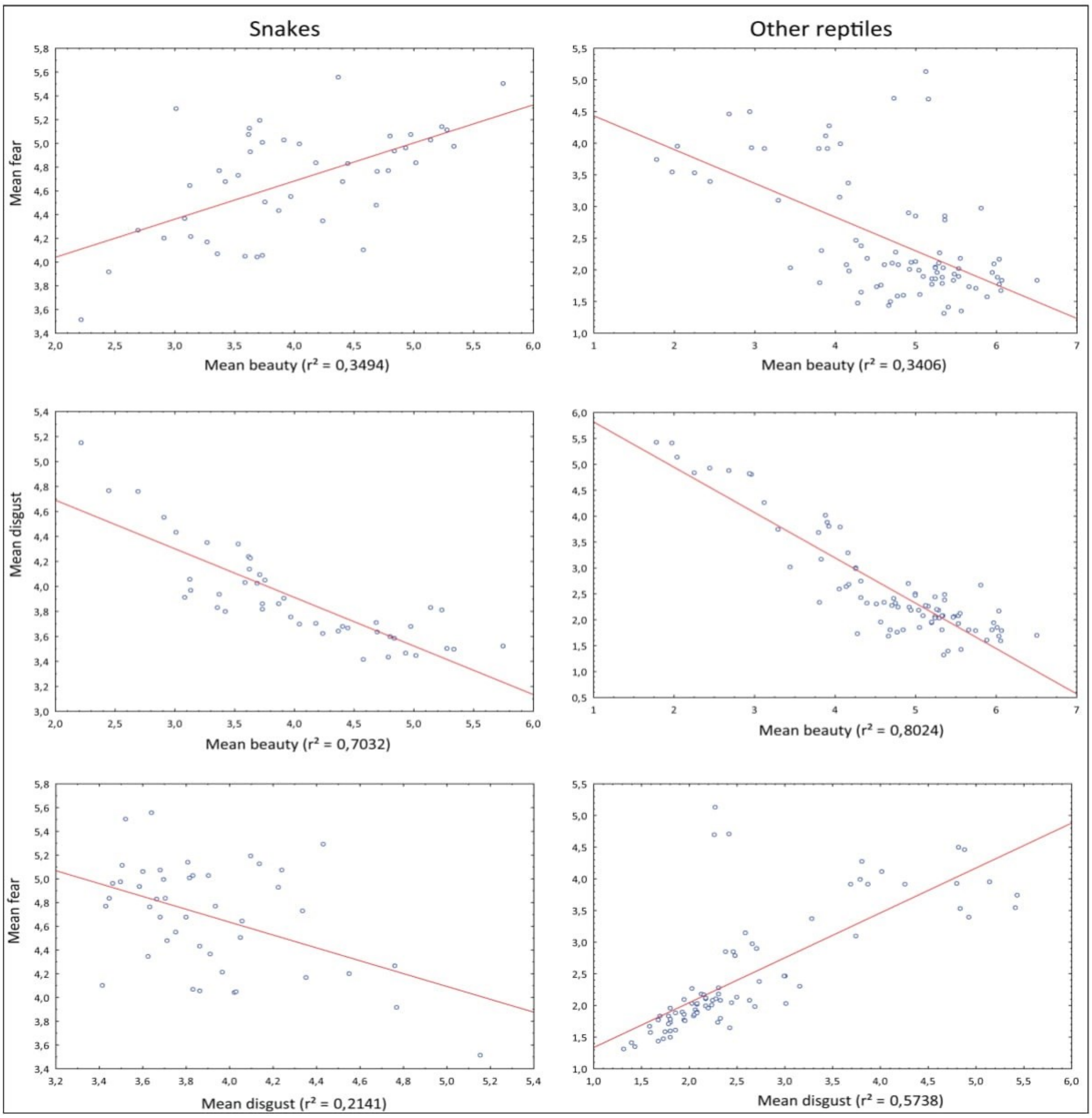


Figure 4. The correlations of the mean ranks for fear and beauty, disgust and beauty, fear and disgust; separately for snakes and other lizards.

4. Discussion

4.1. Relationship to Reptiles as a Group

Our results confirmed that people tend to separate snakes and legless lizards from other Sauria and the rest of the reptiles, i.e., the turtles, tuatara, and the crocodiles. This pattern was present on all examined dimensions; i.e., the respondents separated snakes from other reptiles when evaluating fear, disgust, and beauty. Interestingly, lizards with a snake-like body shape and visible, though very short limbs (*Larutia* and *Lygosoma*), form a transition between the two groups (see Figure 2). Thus, we may hypothesize that people discriminate reptiles into snakes and legless lizards on one side and other species on the other solely based on their external resemblance. As previously shown in a study by Alves et al. [26], when evaluating a set of pictures of local snakes and three worm lizards, the subjects called the whole set as "snakes", disregarding the worm lizards as another taxonomic group. Thus, in human eyes, snakes represent a distinct group of animals, which is also reflected in the theory of attentional prioritization of snakes as an evolutionary relevant threat [47,48,99]. Moreover, people tend to extend this group even to other animals that are not snakes per see, but at least look like them. This is not so much surprising as in terms of survival, it is always better to respond with fear to an otherwise harmless animal that resembles a snake, than to underestimate a potentially serious threat.

4.2. Evaluation of Perceived Fear, Disgust, and Beauty

When reptiles are evaluated on specific dimensions (fear, disgust, and beauty), the two previously mentioned groups are almost always formed. The only exception is the evaluation of fear, in which crocodiles form a separate group. Morphologically, they fall within the category of other lizards with legs, but compared with them, crocodiles trigger more intense fear in humans. Such a result fits well with the fact that crocodiles together with snakes are the only reptilian predators capable of killing a human [41–43,100]. There is also the alligator snapping turtle (*Macrochelys temminckii*) and Komodo dragon (*Varanus komodoensis*), which may be potentially dangerous for humans considering their large body size, although attacks from these species are very rare and the inflicted injuries are mostly manageable [101]. In fact, contrary to crocodiles or large constrictors, both the snapping turtle and Komodo dragon do not consider humans as prey. It is thus possible that these animals evoke high fear in the respondents not due to their real dangerousness, but rather due to their physical appearance, which may include large body size, sharp edges, and dark color.

The shape of an animal allometrically changes with changes in the body size. Because of this, human respondents are able to estimate size [27–31,79,80] and age (on the level of young/adult; [102]) of animals even when presented on pictures standardized for size. A similar effect was observed in this study. Larger reptile species were evaluated as more frightening, including the Komodo dragon. Moreover, as shown on snake studies, the posture of the animal can affect both rapid detection [103] and evaluation of fear [30]. In this study, the alligator snapping turtle was pictured with an open mouth, showing its sharp beak, which might have elicited a feeling of a threat within the respondents. Another explanation might be that the turtle was rated as frightening because of a general perceptual bias towards sharp objects; it has been reported in the literature that people rate sharp objects as more dangerous [104] and also activate a greater neural response in the amygdala when watching sharp objects [105].

Within the group of reptiles with the snake-like body form, we can notice that even though the worm and legless lizards morphologically belong to snakes, they are evaluated as less frightening, similarly to harmless snakes, e.g., the Madagascar blind lizard (*Xenotyphlops mocquardi,* nowadays synonymized with *Xenotyphlops grandidieri*, [106]).

Disgust ratings do not lead to a separation of another special category. In this case, crocodiles, snapping turtles, and Komodo dragons are grouped together with the other reptiles. Again, we can identify two species, the three-banded Larut skink (*Larutia trifasciata*) and banded supple skink (*Lygosoma haroldyoungi*) that, given their morphotype, may fall between the two groups. All worm lizards and legless lizards together with snakes possessing a worm-like body form were evaluated as the most disgusting ones within the snake group. These animals may remind people of some invertebrates (earthworms, larvae, parasitic worms) that usually elicit great disgust [68,107].

Based on perceived beauty, the discrimination of reptiles into two separate groups is similar to that of disgust. Surprisingly, the least beautiful species within the group of other reptiles was a turtle. Turtles are generally considered as popular animals, and this is also reflected in the number of turtle species kept in the zoos [88]. In our study, it was two representatives of the same subfamily Trionychinae, specifically the Malayan soft-shelled turtle (*Dogania subplana*) and Peacock soft-shelled turtle (*Nilssonia hurum*), which is remarkable by its atypical soft-shell carapace that deviates from usual turtle morphotype. Within the snake group, species perceived as the least beautiful are the same as those rated as the most disgusting. This points to the conclusion that reptiles cannot be rated as both beautiful and disgusting at the same time (see below).

4.3. Mutual Relationship of the Ranks

Intuitively, one might assume a negative correlation between negative emotions (such as fear and disgust) and beauty, which is closely related to the positive emotion of joy [108,109]. Our results show that this is true in the case of the beauty x disgust correlation: In both snakes and other reptiles, there is a close negative correlation of disgust and beauty. These results suggest that both ranks form two opposite sides of one axis; a lizard or snake that is ranked as beautiful cannot simultaneously evoke disgust in respondents [30,88,110]. Similarly, a negative correlation can be found between fear and beauty, but only in the case of non-snake reptiles. In snakes, this relationship is inverted, and snakes that evoke high fear are simultaneously ranked as partially beautiful/less disgusting. One reason behind this may be that dangerous snakes often possess saturated or aposematic coloration, which is perceived as beautiful [30,88,111]. Another explanation is that the snakes ranked as non-dangerous, i.e., evoking low levels of fear, may resemble earthworms and/or parasitic worms in appearance, thus evoking disgust [68,111]. Either way, snakes represent an exceptional group in terms of human perception.

5. Conclusions

Firstly, snakes are such important and specific animals that they are completely separated from the other reptiles as regards our perception of them, especially fear. We hypothesize that it is their peculiar legless body plan that guides the human categorization process. Moreover, the same pattern expands onto other species resembling snakes, the worm lizards (Amphisbaenia) and legless lizards.

Secondly, disgust and beauty together form one negatively correlated axis which is common to all reptiles. It is practically impossible for an animal to be both beautiful and disgusting at once. For fear, it is different. Fear correlates with other scales only partly and is independent on disgust and beauty forming a separate axis. Moreover, the polarity of the correlation of fear with beauty is inverted for snakes and non-snakes. Thus, a snake can be beautiful and dangerous at the same time, e.g., the Jerdon's pitviper (*Protobothrops jerdonii*). Conversely, it is possible to find a non-snake reptile that is both disgusting and fearful, such as Borneo earless monitor *Lanthanotus borneensis*.

Thirdly, our results might be used in conservation biology efforts invested in the management of reptile populations threatened by extinction. It has been previously shown that especially in the case of reptiles, human perception and attitude plays a significant role in the effectivity of local conservation programs. Reptiles, as opposed to other vertebrates, such as mammals or birds, are not very popular and aversion they trigger might be a barrier to their protection. Here we show that a particular species with the snake-like body form are associated with intense fear and disgust and therefore, this group might be susceptible to more human attacks and lesser conservation efforts. Previous research has shown that these negative emotions reflected in aversive attitudes might be overcome through various educational programs targeted on people living in the specific locality.

Supplementary Materials: The following are available online at http://www.mdpi.com/2076-2615/9/5/238/s1, Table S1: Species in Set1, Table S2: Species in Set2.

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Snakes Represent Emotionally Salient Stimuli That May Evoke Both Fear and Disgust

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Humans perceive snakes as threatening stimuli, resulting in fast emotional and behavioral responses. However, snake species differ in their true level of danger and are highly variable in appearance despite the uniform legless form. Different snakes may evoke fear or disgust in humans, or even both emotions simultaneously. We designed three-step-selection experiments to identify prototypical snake species evoking exclusively fear or disgust. First, two independent groups of respondents evaluated 45 images covering most of the natural variability of snakes and rated responses to either perceived fear ($n = 175$) or disgust ($n = 167$). Snakes rated as the most fear-evoking were from the family Viperidae (*Crotalinae*, *Viperinae*, and *Azemiopinae*), while the ones rated as the most disgusting were from the group of blind snakes called Typhlopoidea (*Xenotyphlopinae*, *Typhlopinae*, and *Anomalepidinae*). We then identified the specific traits contributing to the perception of fear (large body size, expressive scales with contrasting patterns, and bright coloration) and disgust (thin body, smooth texture, small eyes, and dull coloration). Second, to create stimuli evoking a discrete emotional response, we developed a picture set consisting of 40 snakes with exclusively fear-eliciting and 40 snakes with disgust-eliciting features. Another set of respondents ($n = 172$) sorted the set, once according to perceived fear and the second time according to perceived disgust. The results showed that the fear-evoking and disgust-evoking snakes fit mainly into their respective groups. Third, we randomly selected 20 species (10 fear-evoking and 10 disgust-evoking) out of the previous set and had them professionally illustrated. A new set of subjects ($n = 104$) sorted these snakes and confirmed that the illustrated snakes evoked the same discrete emotions as their photographic counterparts. These illustrations are included in the study and may be freely used as a standardized assessment tool when investigating the role of fear and disgust in human emotional response to snakes.

Keywords: snakes, fear, disgust, affective stimuli, self-reported emotion, emotional response

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INTRODUCTION

Due to a long co-evolutionary history with snakes, both humans and non-human primates evolved specific neural mechanisms for rapid snake recognition (Isbell, 2006; LoBue and DeLoache, 2008; Öhman et al., 2012; Van Le et al., 2013; Baynes-Rock, 2017). Among evolutionarily irrelevant (neutral) stimuli, snake pictures act as strong distractors (Soares et al., 2009a) and are detected faster

(LoBue and Deloache, 2011; Soares et al., 2014) than, for example, flowers and mushrooms, but not faster than stimuli of modern threats such as guns (Fox et al., 2007; Zsido et al., 2018b). Moreover, EEG studies show that neural processing of snake stimuli is prioritized when compared to other animals such as spiders and birds (van Strien et al., 2014).

LoBue and Deloache (2011) provide evidence that it is the distinctive coiled snake morphology that attracts prioritized human attention. However, recent research has shown that the pattern of snake scales is also important. The human brain reacts much faster to pictures of snake skin than similarly, colored bird feathers (van Strien and Isbell, 2017). Moreover, some naturally occurring shapes and patterns are perceived negatively, and processed faster than other patterns, such as sharp edges (Guthrie and Wiener, 1966; Bar and Neta, 2006, 2007), zig zag patterns (Üher, 1991), or strong contrasting patterns in general (Näsänen et al., 2001). Souchet and Aubret (2016) proposed that venomous snakes adopt this phenomenon and use contrasting patterns and morphology with sharp edges as an aposematic signal to deter enemies and communicate their dangerousness. The ability to recognize danger presented by a snake by only a pictured skin detail was also observed in Vervet monkeys (Isbell and Etting, 2017), and Capuchin monkeys were able to recognize whether the presented snake was dangerous or harmless only based on the skin pattern (Meno et al., 2013). On the other hand, Prokop et al. (2018) showed that aposematic coloration did not play a crucial role in eliciting high fear of snakes as both black-and-white and color images of aposematic and cryptic snakes evoked a similar level of increased fear.

Both the typical snake body shape and color pattern seem to be important elicitors of neural mechanisms for rapid snake detection, although it remains unclear what is the typical snake pattern that elicits these reactions. Nowadays, as much as 3 709 snake species from 25 families (Uetz et al., 2018) are described. Many of them differ in ecology, size, skin pattern, behavior, and other aspects. Similarly, snakes vary as to the dangerousness they present to humans, including the efficiency of venom and its delivery system, the snake's size, aggressiveness, and the probability of human encounters. Deadly venomous species can be found within all snake types, i.e., ground, arboreal, fossorial, and aquatic. However, the highest risk is related to two types of snakes (Kasturiratne et al., 2008). First, the venomous vipers or viper-like species are passive predators that use an ambush strategy for hunting. Their dangerousness lies in the unexpected risk, such as the possibility to step on the snakes by mistake (though some species actively warn potential enemies using demonstrative attacks or various acoustic signals such as hissing or rattling). The second type of snakes posing a high risk for humans are the elapids. No less venomous than the vipers, these active predators are much more mobile. They also rely on acoustic or visual signals (e.g., the typical cobra stance) as well as their high speed, which allows them to actively avoid an unwanted confrontation with humans or other enemies (Valenta, 2008). In Africa, the continent of human origin (Grine et al., 2009), the highest number of death by snakes is caused by vipers (Trape et al., 2001), especially the West African carpet viper (*Echis ocellatus*) and Gaboon viper (*Bitis gabonica*; Chippaux, 1998). Each of these snakes is characterized by specific morphological traits that can be easily recognized, e.g., the viperids possess a triangular-shaped head and sharp, visually discrete scales. Many deadly snakes have contrasting (aposematic) skin coloration patterns, by which they make themselves clearly visible. It is possible that humans do not perceive all snake species as one, generally threatening stimulus, but rather distinguish among the snakes that are deadly and react appropriately to the actual threat.

Most studies focusing on snake fear ignore the enormous variability of snakes. However, little is known about the actual effect of particular morphology of snakes on human emotional reactions. Traditional assumptions in psychology research is that the primary emotion involved in ophidiophobia is fear (Öhman and Mineka, 2001, 2003; Soares et al., 2009b), however, our recent studies show that disgust is involved in emotional evaluation of snakes and other vertebrates as well (Polák et al., submitted; Frynta et al., unpublished; see also Prokop and Fančovičová, 2013). Similarly Davey (1994) has shown that snakes are rated as fear-evoking as a result of elevated disgust sensitivity levels, and it is possible that some snake morphotypes may elicit a primary emotion of disgust. Disgust is also of prior interest to clinical researches as increased propensity (i.e., individual tendency to experience disgust) and sensitivity to disgust (i.e., negative appreciation of experiencing disgust) has been demonstrated to play a significant role in etiology of various psychological disorders ranging from specific animal phobia (e.g., arachnophobia: de Jong and Merckelbach, 1998; Woody et al., 2005; Muris et al., 2008; Olatunji et al., 2011) and blood-injection-injury phobia (Sawchuk et al., 2000; Cisler et al., 2009b). Therefore, it may also be involved in the onset and maintenance of snake phobia (Klieger and Siejak, 1997).

Both fear and disgust are considered to be basic emotions, with a universal distinctive facial expression and physiological response among humans and non-human primates (Ekman, 1992). Furthermore, some authors argue that fear and disgust could have opposing effects on sensory perception and attention (Buck et al., 2018). From a biological perspective, the two emotions are similar, as their purpose is to induce an adaptive reaction to life-threatening stimuli, increasing the chances of survival. However, fear arises in cases of immediate threat, which appears suddenly, unexpectedly, and presents a direct risk of injury or death. The resulting physiological reaction leads to activation of the sympathetic nervous system and a cascade of events, including rapid heart and respiratory rates, increased blood pressure, dilated pupils, muscle contraction, and increased perspiration (Barrett et al., 2016). In contrast, disgust is a reaction to stimuli perceived as potential sources of contamination or pathogens (Curtis et al., 2004; Curtis, 2011). The threat is not imminent, but rather takes effect after a prolonged period of time. The physiological reaction to a disgusting stimulus is more variable. Compared with fear, the parasympathetic pathways are activated (de Jong et al., 2011), leading to either an increase or decrease in skin conductance and blood pressure (Stark et al., 2005) and reduced heart rate and respiration (Gilchrist et al., 2016). The reason for this may be the fact that disgust is much more variable emotion than fear; thanks to this pre-adaptation, it evolved into a number of other functional circuits, fundamentally different from its original purpose. Disgust is thus linked to various other triggers such as violation of social norms, political beliefs, sexual orientation, and people from other social groups, etc. (Rozin et al., 1999).

The elicitors of fear and disgust also differ in many aspects. Specific characteristics of an animal can trigger specific emotions, and these characteristics can differ even within an animal group otherwise positively evaluated by humans. A good example is frogs and other amphibians, a vertebrate class which generally is thought to elicit disgust (Angyal, 1941; Davey, 1994; Tomažič, 2011; Prokop et al., 2016). Among them, frogs are listed as one of the animals that are very often objects of specific phobias associated with strong disgust feelings (Doctor et al., 2010). However, only a few frog species with specific characteristics are ranked as disgusting. These characteristics include a round, chunky body shape, small eyes, warts, drab colors, pink color, and white light reflection that gives the impression of a slimy object (Frynta et al., unpublished). Moreover, even mammals, generally a very popular and well-perceived group of animals, contain species with characteristics that make them look dangerous or disgusting. For example, underground-dwellers of a small body size, round shape, and reduced eyes, e.g., mole rats (Bathyergidae), marsupial moles (Notoryctidae), and moles (Talpidae) are often seen as ugly or disgusting (Landová et al., 2018b; see also Frynta et al., 2013 for the rankings of "beauty" and "ugliness"). In contrast, mammals who are thought to be the most dangerous and capable of evoking the highest fear are generally of large body size, such as big cats (although these can also elicit positive emotions at the same time; Landová et al., 2018b; see also de Pinho et al., 2014).

Furthermore, when an animal has a combination of characteristics, the animal can elicit mixed emotions. A snake can be rated as beautiful (Marešová et al., 2009a,b; Frynta et al., 2011; Landová et al., 2012), i.e., eliciting positive aesthetic emotion (Schindler et al., 2017), and fear-eliciting at the same time (Landová et al., 2012, 2018a). It is easy to imagine that a mix of negative emotions, i.e., fear and disgust, could be elicited at the same time as well. Thus, to study emotions triggered by snakes correctly, one must choose the right experimental stimuli and mind the differences between various morphotypes.

When studying human-perceived emotions elicited by snakes, one must not forget that respondents with different susceptibility to snake fear or general disgust and/or anxiety may answer differently. A great amount of literature exists that describes differences in behavior of snake-fearful or phobic respondents in comparison to controls (see, e.g., Öhman and Soares, 1994; Öhman et al., 2001; Schaefer et al., 2014). Given all these differences between phobics and healthy controls, one might also expect variation between these groups in fear and disgust evaluation of snake pictures. Therefore, it is necessary to first test the responses of healthy subjects to fear-eliciting and disgust-eliciting snake images and subsequently administer the same images to snake phobics for a comparison. The participation of each emotion and the relationship between them is crucial when we try to better understand the different line of evidence for involvement of these emotions in causing specific animal phobias (Woody and Teachman, 2000; Cisler et al., 2009a).

There is a lot of picture databases with known evaluations of self-reported emotional responses (usually valence, arousal, and dominance, supplemented with emotional categories that include fear and disgust), e.g., IAPS (Lang et al., 1988; Mikels et al., 2005; Libkuman et al., 2007), NAPS (Marchewka et al., 2014; Riegel et al., 2016), SFIP (Michałowski et al., 2017), DIRTI (Haberkamp et al., 2017), or GAPED (Dan-Glauser and Scherer, 2011). However, these databases consist of pictures with very varying properties including background, colors, lightness, focus on detail, etc. The last mentioned database even includes a separate category of snake pictures, but again the pictures portray the animals in very different contexts and environments, including human hands grabbing the snakes. Moreover, the snakes lack taxonomic description and species identification (e.g., the GAPED database even includes one glass lizard among the snakes). And although these pictures may evoke the particular emotions, it is not known which part of the picture is the main elicitor – is it the snake itself, its particular appearance/position, or something else such as its interaction with the background? It is well known that even basic characteristics of pictures such as the color, luminance, and shape structure affect human evaluation of emotion or preference (Üher, 1991; Bar and Neta, 2006; Silvia and Barona, 2009; Lišková and Frynta, 2013; Lišková et al., 2015; Ptáčková et al., 2017; Landová et al., 2018b; Rádlová et al., 2018). Moreover, such stimuli may be suitable for usage in experiments measuring self-reported or physiological response to a single picture, but are inappropriate for studies requiring block-type design (such as fMRI or EEG), because the stimuli are too variable and could elicit different reactions within a block.

Without a precise selection of well-characterized and standardized stimuli, further studies focused on the variability among respondents may result in misinterpretations. Thus, the main goal of this study was to examine the pattern of variability among various snake stimuli and to develop one homogenous set eliciting fear and another homogenous set eliciting disgust. We are very aware that individual differences in snake fear and general disgust propensity may influence the evaluation of snake species. To examine the differences among the respondents in terms of snake-elicited fear and disgust, we collected additional data about the participants including questionnaires such as the SNAQ (Polák et al., 2016, see also Zsido et al., 2018a for its shorter version) and a self-reported response based on a method more suitable for this kind of experiment. However, due to length limitation, these data will be published in a separate article (in prep.) as this paper is mainly focused on the differences among the picture stimuli. In other words, in this paper, we aim to study the effect of different stimuli on the respondents and to create categories of snake stimuli based on exclusive reactions.

More precisely, the general aims of this study were to (1) examine the full morphological variability of snakes in terms of human emotional responsiveness and to analyse the specific characteristics contributing to the human perception of fear and/or disgust. Then, based on the results, to (2) create two sets of visual snake stimuli that would evoke exclusively fear or disgust in human respondents. Finally, we aimed to (3) confirm the results of Experiment 2 on a reduced set of illustrated stimuli that could be make freely available for download and for usage in experimental studies of human-perceived emotions elicited by snakes.

EXPERIMENT 1. FULL MORPHOLOGICAL VARIABILITY OF SNAKES

Materials and Methods

Selection and Preparation of Stimuli

In case of snakes, subfamilies represent the optimal taxonomical unit that reflect the most distinctive differences between the groups. Thus, we randomly selected one species from each of the extant snake subfamilies (45 in total; see Pyron et al., 2013), inhabiting various parts of the world. To avoid over-representation of a particular genera, we randomly selected a genus and then one of its species.

For each of the selected species, we searched a representative picture of an adult individual on the Internet. It has been shown in our previous study that relative fear rankings of photos and live snakes highly correlate ($r = 0.78$), thus using picture stimuli may provide valid results regarding human responses to snakes (Landová et al., 2012). Our search criteria included photos that were of a good quality and publicly available, i.e., licensed under the Creative Commons license or a written permission was given to us by the authors (For a full list of included pictures, see **Supplementary Material 1**). After collecting the pictures, we modified them to create a standardized setting (using GIMP 2.8, Kimball et al., 1995): we placed the snakes on a unified white background, scaled and rotated them to similar relative size and position with each snake facing the same direction (see **Figure 1**). The total of 45 picture stimuli (one for each of the selected species) was printed on matte 10 × 15 cm cards.

Testing Emotional Response to Snakes

To test the emotional response to snakes by human respondents, we adopted a widely used method of sorting picture stimuli according to a given scale (e.g., Marešová et al., 2009a,b; Lišková et al., 2015; etc.). The reason for which we chose this method is because the main aim of this paper is to examine the variability among the snake species in terms of human-perceived fear and disgust. In other words, we ask whether different snake species/morphotypes affect the respondents differently. For this kind of study, the sorting method is optimal as it maximizes the differences among species. However, as the acquired rankings for each stimulus are only relative, this method is not a good choice for studies focused on the variability among the respondents (e.g., whether snake-fearful respondents rank the snakes differently). For such kind of study, a different ranking method would be more suitable, such as the VAS, Borg, or Likert-type scale (Likert, 1932; Grant et al., 1999). Note that we also collected this kind of data, the results of which will be published in a separate article.

All respondents ($n = 342$) were Czechia residents (aged 19 – 67; mean age = 28.18; $SD = 9.29$). Sample included students and other respondents that volunteered based on informational pamphlets. Other volunteers were recruited using the snowball sampling method (Goodman, 1961; Biernacki and Waldorf, 1981). Our aim was to keep the ratio of respondents with biological and humanities education balanced.

FIGURE 1 | Examples of picture stimuli used in Experiments 1 **(A)** and 2 **(B,C)**. The snake species are as follows, from left to right: **(A)** Rough-tailed Sand Boa (*Eryx conicus*) and Madagascar Tree Boa (*Sanzinia madagascariensis*), both photos by O. Šimková, used with a permission; Coral Cylinder Snake (*Anilius scytale*), photo by Eduardo Santos via Wikimedia Commons, modified. **(B)** Fear-eliciting snakes: Orlov's Viper (*Vipera orlovi*), photo by Venom Tales via Flickr, modified; Ottoman Viper (*Montivipera xanthina*), photo by Benny Trapp via Wikimedia Commons, modified; Eastern Diamondback Rattlesnake (*Crotalus adamanteus*), photo by Pierson Hill, used with a permission. **(C)** Disgust-eliciting snakes: Southern Blind Snake (*Anilios australis*), photo by Stephen Zozaya, used with a permission; Northern Rubber Boa (*C. bottae*), photo by Gary Nafis, used with a permission; Brahminy Blind Snake (*Indotyphlops braminus*), photo by Alexandre Roux via Flickr, modified.

First, each of the respondents filled a personal questionnaire about their age and gender, and signed an informed consent. In addition, each respondent provided us with a rank of their self-perceived affiliation toward snakes on a seven-point Likert scale (1 = I like snakes very much, I would like to keep one as a pet; 4 = neutral affiliation; and 7 = I dislike/hate snakes very much, I fear them; Wuensch, 2015). This variable is further referred to as "affiliation."

Then, we distributed all 45 snake cards on a well-lit table in a random order. The respondents were asked to imagine the depicted snakes as real animals. Their task was to pick up the picture of a snake that was most fear-evoking, then to pick up the second most fear-evoking snake, until they picked up the least fear-evoking snake on the table. In total, 97 women and 78 men sorted the picture set according to perceived fear. Additional 167 respondents (94 women, 73 men) sorted the same picture set according to perceived disgust. Then, because the highest rank obtained this way (i.e., the 45th snake) corresponded to the lowest emotional response, we multiplied the ranks by −1 to obtain more intuitive results.

Explanatory Variables

To analyze the effect of morphometric characteristics of the snake species on the human responses, we measured the following variables on the snake photos using the ImageJ 1.40 g (Rasband, 1997): total body length, body width (also referred to as body size), head size (length from the tip of the nose to the end of the jaw), eyes size, neck size (in the thinnest part), and tail width (width of the tail base next to the cloaca). The number of pixels were transformed to centimeters relative to the picture size printed on a 15 × 10 cm card.

To examine the effect of colors on the respondents' ranking, we used Barvocuc (Rádlová et al., 2016) to extract specific information about hues, lightness, and saturation of each of the stimulus pictures converted to the HSL colorspace. For a detailed description of the Barvocuc software, see Lišková and Frynta (2013) and Lišková et al. (2015). Colors were pre-defined to visually correspond to the snake pictures as accurately as possible: red < 330°; 15°), orange (corresponding to brown in all of the snakes) < 15°; 37°), yellow < 37°; 60°), green < 60°; 200°), blue < 200°; 240°), and violet-rose < 240°; 330°). Further, the red color was divided into two colors as in some snakes it corresponded to reddish brown, while in others, it corresponded to bright red. Three achromatic colors were defined on the basis of the saturation (S) and lightness (L) values, which covered the interval 0–1: black ($L < 0.27$), white ($L > 0.8$), and gray ($S < 0.1$). Mean S and L were also included as explanatory variables. The white background of the stimuli was set to transparent and was excluded from the calculation.

Additionally, we included two more variables extracted from Barvocuc: the pattern, computed using the edge detection method (Sobel, 1978), and opaque pixels, which is the sum of all non-transparent pixels. The latter variable also corresponds to the overall robustness of the depicted snake species. In order to improve normality, the portion of colors, mean S, pattern, and opaque pixels were square-root arcsine transformed prior to the analysis.

Statistical Analysis

To quantify and test the congruence in species ranking provided by different respondents, we adopted the Kendall's Coefficient of Concordance. Significance of differences in mean rank among species was calculated by *post hoc* Friedman–Neményi test as implemented in R-package PMCMR. Prior to analyses, the raw ranks were transformed as follows: each value minus 1 was divided by the number of evaluated species minus 1 (44) and square-root arcsine transformed to achieve a normal distribution. A Principal Component Analysis (PCA) was performed to visualize the multivariate structure of the data sets. A Mann–Whitney U test was used as a non-parametric alternative for variables deviating from normality (raw sores). MANCOVA was applied to test the effects of independent explanatory variables. Contribution of the explanatory variables (constrains) to the rankings of the snakes was examined in the Redundancy Analysis (RDA) as implemented in the R package vegan (Oksanen et al., 2017). RDA is a multivariate direct gradient method. It extracts and summarizes the variation in a set of response variables (subjective evaluation of fear and disgust evoked by snakes) that can be explained by a set of explanatory variables. This analysis permits to plot both response and explanatory variables to a space defined by the extracted gradients and enables detection of redundancy (i.e., shared variability) between sets of response and explanatory variables. Statistical significance of the gradients was confirmed by permutation tests. Calculations were performed in R Development Core Team (2010) and Statistica 9.1 (StatSoft Inc., 2010).

Results

Agreement Among Respondents

The overall agreement among respondents on the snake fear (Kendall's Coefficients of Concordance $W = 0.254$) and disgust rankings ($W = 0.293$) was somewhat low. To correct for potential incongruence caused by an unequal effect of snakes that were ranked as the top, we retested the responses after we divided the set into two halves, i.e., the first half containing 11 snakes rated as the least and 11 as the most fear/disgust-evoking (mean values), and the other half containing 23 snakes in the middle results showed a slight improvement in the agreement on the position of these species (fear-scale extremes $W = 0.332$, middle $W = 0.091$; disgust-scale extremes $W = 0.409$, middle $W = 0.119$). *Post hoc* tests revealed high proportion of significant comparisons among mean ranks of examined stimuli (see **Supplementary Material 2a**). This confirmed that the congruence among respondents was high enough to extract a reliable order of stimuli according to the examined emotions.

RDA analysis of the fear ranks, which included gender, age, and affiliation toward snakes, revealed that these variables explained only 3.1% of the full variability. Sequential "Type I" ANOVA (n permutations = 10 000) confirmed that only the effect of affiliation was significant: affiliation: $F_{1,171} = 2.272$, $p = 0.0188$; gender: $F_{1,171} = 1.728$, $p = 0.0724$; and age: $F_{1,171} = 1.461$, $p = 0.1315$). A reduced model, which included only the affiliation, explained 1.29% of the full variability (ANOVA: $F_{1,173} = 2.257$, $p = 0.0214$). Similar results were found in case of the disgust ranks, although the full model explained more variability (7.57%): affiliation: $F_{1,163} = 10.715$, $p < 0.0001$; gender: $F_{1,163} = 1.2665$, $p = 0.2091$; age: $F_{1,163} = 1.3744$, $p = 0.1553$. Reduced model explained 6.08% variability; ANOVA affiliation: $F_{1,165} = 10.673$, $p < 0.0001$. Since there was no significant effect of age nor gender, the data from both genders were pooled for all further analysis.

Factors Determining Fear and Disgust Rankings

We employed RDA to examine the contribution of various explanatory variables to the rankings of fear evoked by snakes. We used the automatic model-building feature based on both the Akaike criterion and permutation P-values. Both methods agreed on inclusion of the following variables into the reduced model, which were confirmed as significant by the sequential "Type I" test (n permutations = 10 000): head size ($F_{1,39} = 12.095$, $p < 0.0001$), red color ($F_{1,39} = 4.778$, $p = 0.0029$), pattern ($F_{1,39} = 3.952$, $p = 0.0070$), body size ($F_{1,39} = 4.096$, $p = 0.0038$), and blue color ($F_{1,39} = 2.615$, $p = 0.0306$). The RDA model has generated five constrained axes, which explained 41.39% of the full variability (**Figure 2A**).

The same procedure was used to find out which variables affect disgust rankings. The final model included the body size ($F_{1,38} = 6.871$, $p = 0.0002$), green color ($F_{1,38} = 6.353$, $p = 0.0002$), eyes size ($F_{1,38} = 5.316$, $p = 0.0009$), red color ($F_{1,38} = 4.570$, $p = 0.0015$), pattern ($F_{1,38} = 4.549$, $p = 0.0019$), and yellow color

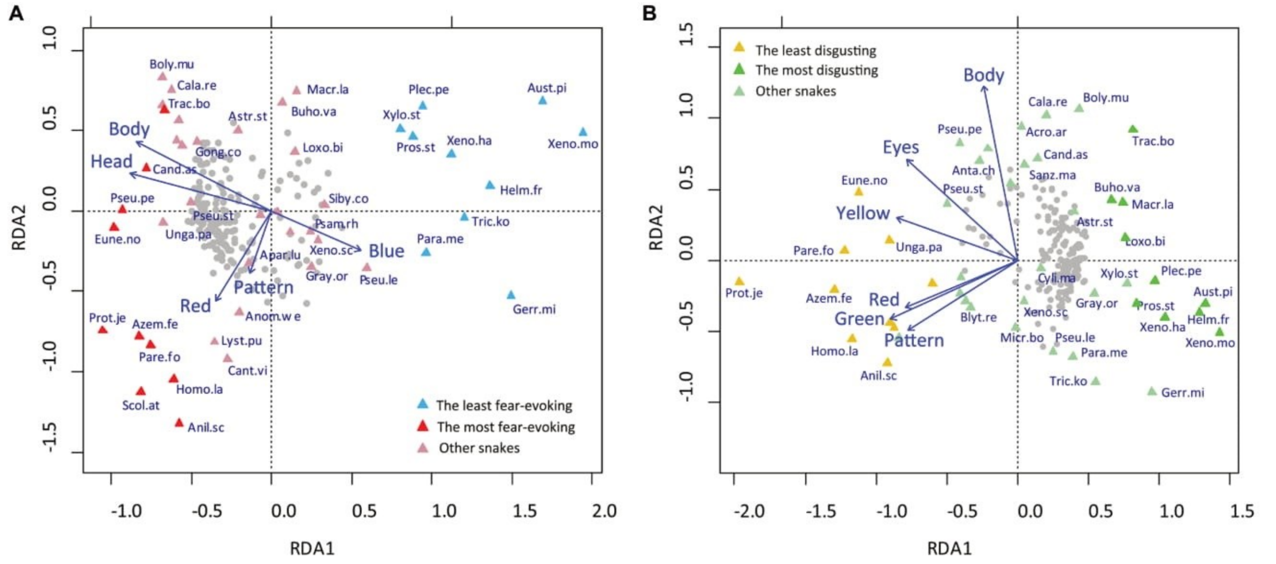

FIGURE 2 | Redundancy Analysis (RDA) of the characters determining the ranks of fear and disgust elicited by snake stimuli used in Experiment 1. **(A)** Analysis of the fear ranks. The model explained 41.39% of the full variability, RDA1 = 0.2784% of variability and RDA2 = 0.0714% of variability. **(B)** Analysis of the disgust ranks. The full model explained 44.77% of the variability, RDA1 = 24.75% of variability, RDA2 = 10.76% of variability. For a better visualization of the fear/disgust ranks polarity, 10 species with the largest and lowest mean ranks of fear/disgust are mapped onto the pictures. For the description of the snake species abbreviations, see **Supplementary Material 1**.

($F_{1,38}$ = 3.148, p = 0.0150). The six constrained axes explained 44.77% of the full variability (**Figure 2B**).

Scores of the first axes on the RDA visualization of fear (**Figure 2A**) and disgust (**Figure 2B**) rankings correspond to the mean rankings of the respective emotions; RDA1 scores x mean fear: r^2 = 95,4%; RDA1 scores x mean disgust: r^2 = −95,8%. The results show that similar characteristics affect the rankings of fear and disgust, but in the opposite directions. Big brightly red-colored snakes with an expressive head and complex scale pattern were ranked as the most fear-evoking, but the blue color present on some snakes in form of a light reflection caused them to be perceived as non-fearful. On the contrary, bright green, red, and yellow colors, large size, big eyes, and a complex pattern characterized snakes perceived as the least disgusting.

Discussion

Most participants agreed on the position of snakes that were ranked as the most fear- or disgust-eliciting, and also on the snakes who are least fear- or disgust-eliciting. The reason behind this may be that the snakes "in the middle" of the scale may either evoke none of the studied emotions at all, or evoke both emotions at the same time, hence the disagreement. Contrastingly, the respondents agreed on the snakes placed at the extreme ends, which suggest that these snakes unambiguously either evoke the given emotion, or do not evoke it at all. The RDA analysis revealed the characteristics specific for snakes ranked as the most fear-eliciting – these included the large body size, bright red coloration, body shape with a distinctive head (as compared to the non-fear eliciting snakes with a small, almost indistinguishable head), and complex pattern. This pattern may include both contrasting ornaments and/or distinctive, raised scales, typical for some groups such as the vipers.

The results suggest that the same characteristics determine whether the snake will be rated as highly fear-evoking or disgusting, only in the opposite direction. This really applies to a number of characteristics: bulky, red, textured snakes are fear-evoking, while thin snakes with low red coloration and smooth texture are disgusting. This overlap of characteristics leads into a partial overlap (correlation) of the fear and disgust axes (r^2 = 38.39%, p = 0.00001). However, each emotion can also be elicited by other specific characteristics, e.g., small eyes and dull coloration in the case of disgust-eliciting snakes. In Landová et al. (2018a), certain snake characteristics are associated with high fear rankings, including a short body length, wide head, and overall darkness. Moreover, the characteristics specific for disgust and fear elicitation are not mutually exclusive and can be present on one snake, e.g., the Northern Eyelash Boa (*Trachyboa boulengeri*) obtained high ranks of both fear and disgust. This snake has dull, brown coloration and a chunky body with sharp, distinctive scales, and represents a good example showing that when specific characteristics mix, the snake can evoke a combination of emotions.

Our findings concur with recent descriptions that European respondents fear the viper and viper-like snakes (Landová et al., 2018a), in which we showed that the evaluation of vipers as the most dangerous snakes is shared across people from Europe and Near East. As the only dangerous snakes in Europe (and adjacent Asian areas) are the vipers, these results may not be that surprising. However, we obtained similar results from studies in sub-Saharan Africa (Frynta, in preparation), where people also mainly fear vipers, even though there are deadly elapids present.

One explanation can be that the vipers, being ambush predators, want to warn others of their presence and thus use specific characteristics, such as sharp edges and contrasting patterns, as aposematic signalization to deter enemies (Souchet and Aubret, 2016). Another explanation may be that the vipers are rather very cryptic and unseen (wanting to merge with the background to ambush a prey), but humans, being often unintended victims of encounters with vipers, perfected attentional mechanisms to effectively recognize and avoid these snakes. More research is needed to resolve this. Moreover, position of the snake plays role in human emotional response. Snakes in a striking posture with a coiled body and S-shaped contracted neck ready to attack are detected faster (Masataka et al., 2010) and trigger more intensive fear (Schaefer et al., 2014).

In most cases, the snakes ranked as the most disgusting were small, harmless species of blind snakes (Typhlopidae) living underground. As these species pose no danger to humans (both in terms of bite and possible contamination; O'Shea, 2018), we can assume that they evoke disgust only due to their close resemblance to phylogenetically unrelated, but morphologically very similar species (such as maggots or parasitic worms causing diseases; Muller and Wakelin, 2002). These animals share slimy look, pale pink coloration, little to no eyes and visually undefined (indistinguishable) head and tail, i.e., characteristics identified as disgust-evoking in this study.

EXPERIMENT 2. SNAKES EVOKING DISCRETE EMOTIONS

Materials and Methods

Selection and Preparation of Stimuli

Picture sets used in this experiment consisted of 40 individual snakes for each discrete emotion (40 fear/40 disgust, further referred to as sets F and D). The sets F and D were printed and mixed into one large set consisting of 80 picture cards. They were constructed by identifying the subfamilies that were ranked as the most fear-evoking and disgust-evoking in Experiment 1 and selecting closely related subfamilies/species with similar morphology (see **Supplementary Material 1**). The subfamilies ranked as the most fear-evoking, i.e., Crotalinae, Viperinae, and Azemiopinae, all belonged to the family Viperidae. We selected morphologically defined species from these groups that corresponded to the results of Experiment 1: snakes with large body size, expressive scales with contrasting patterns, and bright coloration (**Figure 1B**).

The subfamilies Xenotyphlopinae, Typhlopinae, and Anomalepidinae of the Typhlopoidea group (blind snakes) were ranked as the most disgust-evoking. Snakes from these groups live usually underground and are rarely seen which made it difficult to complete a 40-picture set. To complete the set, we added species from the subfamilies Leptotyphlopinae (Typhlopoidea) and Chariniinae (Boidae) that morphologically correspond to the most disgusting snakes and their characteristics as analyzed in Experiment 1: species with thin bodies, smooth texture, small eyes, and dull coloration. We then searched for as many different pictures of each of the selected species/groups as possible on the Internet and modified them in the same way as in Experiment 1 (**Figure 1C**).

Testing Emotional Response to Snakes

The emotional response to snakes on these pictures was measured using the same method as in Experiment 1. However, unlike in Experiment 1, all respondents (n = 172, 118 women, 54 men; mean age = 25.23; SD = 9.43) sorted the set twice, once according to perceived fear and the other time according to disgust, while the order of sorting was balanced. The data about gender, age, and affiliation toward snakes of each respondent were collected, similarly as in Experiment 1. Additionally, we collected the results of the SNAQ (Polák et al., 2016) and DS-R questionnaires (Haidt et al., 1994; modified by Olatunji et al., 2007) from 155 respondents. However, due to a limited focus of this article, results concerning these data will be published in a separate article. The SNAQ score nevertheless highly correlated with the "affiliation toward snakes" variable (r = 0.6683; $p < 0.0001$). This simplified measure of self-assessed "snake fear" can thus be considered a suitable replacement for the needs of this article that is mainly focused on the variability among the stimuli.

The distribution and median of SNAQ and DS-R in our sample was comparable to the sample of respondents used in previous studies (SNAQ n = 594; DS-R n = 1006; Polák et al., 2016, 2018).

Explanatory Variables

Similarly to experiment 1, various data regarding the characteristics of snakes included in the large set were extracted. However, since their selection was mainly based on morphological similarity of the species with extreme rank values, we omitted the body length measurements and only analyzed color and pattern characteristics using Barvocuc: red < 350°; 18°), orange (corresponding to brown in all of the snakes) < 18°; 45°), yellow < 45°; 63°), green < 63°; 170°), blue < 170°; 270°), violet-rose < 270°; 350°), black ($L < 0.25$), white ($L > 0.8$), gray ($S < 0.15$), mean S, mean L, pattern, and opaque pixels. Transformation of the data was the same as in the Experiment 1.

Statistical Analysis

See Experiment 1. Additionally, for each respondent, we counted how many species from set F received a rank > 40. This value (further referred to as disagreement count) quantifies disagreement of the ranking performed by a particular respondent with grouping the snake stimuli into D or F. Moreover, the data were analyzed by a Cluster Analysis (CA). Manhattan distances (non-standardized) were selected as metrics and unweighted pair-group average UPGMA as a clustering method.

Results

Agreement Among Respondents

In the case of F and D photo sets (ranked together as one large set), RDA analysis of the fear ranks included gender, age, affiliation, and order of the task. The full RDA model explained

3.16% of the full variability among the respondents. Sequential "Type I" ANOVA (n permutations = 10 000) confirmed that only the effect of affiliation was significant: affiliation: $F_{1,167} = 2.056$, $p = 0.0062$; gender: $F_{1,167} = 1.139$, $p = 0.2784$; age: $F_{1,167} = 1.341$, $p = 0.1442$; task order: $F_{1,167} = 0.913$, $p = 0.5504$. A reduced model, which included only the affiliation, explained 1.19% of the full variability (ANOVA: $F_{1,170} = 2.051$, $p = 0.005$). In case of the disgust ranks, the full model explained 3.89% of the full variability: affiliation: $F_{1,167} = 2.7576$, $p = 0.0011$; gender: $F_{1,167} = 1.611$, $p = 0.0560$; age: $F_{1,167} = 1.262$, $p = 0.1948$; task order: $F_{1,167} = 1.132$, $p = 0.2798$. Reduced model explained 1.58% variability; ANOVA affiliation: $F_{1,170} = 2.7414$, $p = 0.0009$. The data from both genders (separately for set D and F) were pooled for all further analysis.

Agreement among the respondents on the snake's position within the particular set supports the distinctiveness of both emotions evoked by snakes from each set. When the respondents sorted the mixed sets according to evoked fear, the fear-evoking snakes were positioned among the first 40 places, while the rest (the disgust-evoking snakes) occupied the 41st to 80th place by 96 out of 172 respondents (55.8%). Additional 49 respondents showed only marginal disagreement (1–4 counts), thus 84.3% of respondents disagreed in the case of less than 10% of stimuli. Similar but opposite effect was found when sorting the sets according to evoked disgust, full-agreement in 80 (46.5%) and marginal disagreement in 53 out of 172 respondents (30.8%).

Consequently, when the respondents sorted the mixed sets according to evoked fear or disgust, Kendall's Ws were high, 0.725 and 0.643, respectively. However, when we computed Kendall's W for snakes from just one of the sets, the agreement was quite low; set F sorted by evoked fear: $W = 0.076$; set D sorted by evoked disgust $W = 0.220$. This means that within the F set, all stimuli were equally fear-evoking, and within the D set, all stimuli were equally disgust-evoking. Similarly, there was low agreement on disgust evoked by snakes within the F set ($W = 0.113$), as these snakes apparently do not evoke such emotion. In contrast, agreement on fear evoked by disgust-evoking snakes (set D) was exceptionally high ($W = 0.503$). We also expected a low W value in this case, but this high value suggests that there is still some variability among this group of stimuli. However, since all other analyses (PCA and CA) support exclusiveness of the disgust-evoking snakes, this agreement is presumably an artifact. Due to the respondents' effort to solve a non-sensical task, they might have used a different guide when sorting the pictures.

Examination of Fear Rankings of Disgusting Snakes

To explore which characteristics affect fear rankings of the disgusting snakes within the D set, we performed a GLM analysis. The initial full model included all the explanatory variables as described within the section 3.1. After reduction using the Akaike Information Criterion (AIC; Akaike, 1998), the model explained as much as 90.93% of variation in the rankings ($p < 0.0001$). The white ($F_{1,32} = 36.81$, $p < 0.0001$), reddish brown ($F_{1,32} = 44.31$, $p < 0.0001$), and violet-rose color ($F_{1,32} = 77.81$, $p < 0.0001$) affected the fear rankings negatively, while orange brown ($F_{1,32} = 129.39$, $p < 0.0001$) and the opaque pixels ($F_{1,32} = 107.38$, $p < 0.0001$) affected them positively. The blue color and pattern stayed in the model but remained insignificant.

Categorization of Snakes Based on Fear and Disgust Evaluation

To further confirm distinctiveness of the snake groups, we performed a PCA based on the fear rankings, which generated 79 unconstrained axes. However, the eigenvalues of all but the first one (15.295) were lower than 1. The first principal component axis (PC1) accounted for 70.82% of variation in fear rankings and corresponded to the partition of snakes ranking as fear-evoking and "harmless" (evoking no fear; see **Figure 3A**). PCA based on the disgust rankings generated similar results. The analysis also resulted in 79 unconstrained axes, with eigenvalues higher than 1 in only the first two (14.0147 and 1.36652 for PC1 and PC2, respectively). In this case, the first axis accounting for 64.89% variation corresponded to the disgust-fear diversification of the two picture sets (**Figure 3B**). The second axis accounted only for 6.33% of variation in the disgust rankings. It is unknown which factor feeds this axis, but its effect is small compared to the effect of the set type (PC1).

Post hoc comparisons among the mean ranks of individual species revealed that all comparisons between fear-evoking and disgust-evoking stimuli were significant (see **Supplementary Material 2b**). This further confirms the distinctiveness of these categories of stimuli regarding the evaluation of both fear and disgust.

Subsequent cluster analyses based on the (a) fear and (b) disgust rankings of all 80 snakes confirmed these results. Both trees confirmed strict distinctiveness of the F and D sets, regardless of the type of ranking (fear or disgust). Thus, when ranking the mixed F and D sets according to perceived fear, the respondents clearly divided the sets, ranking the F set as more fear-evoking than the D set. When ranking the sets according to the perceived disgust, the results were the same but opposite – the D set snakes were all rated as more disgusting than the F snakes (**Figures 4A,B**).

Discussion

Based on the results of the first experiment, we created two groups of snakes, each consisting of snakes similar to those rated as the most fear- (F) or disgust-evoking (D). The respondents strongly agreed on the overall position of these snakes: they were able to cluster together snakes from each pre-defined group, sorting the D-snakes together as more disgusting and the F-snakes as more fear-evoking. This is noteworthy considering the fact that the variability in this new set has been considerably reduced compared to Experiment 1, making the task harder for the respondents. However, there was low to no agreement within the particular set. F-snakes evaluated according to fear and disgust were ranked in a random order, which means that there was no meaningful variability within the set in the perceived fear: all the snakes within the fear category evoked fear equally. A similar effect was observed when the participants evaluated disgusting snakes according to perceived disgust. Interestingly, the D set evaluated according to perceived fear was an exception, as the respondents fairly agreed on the relative snakes' fearfulness

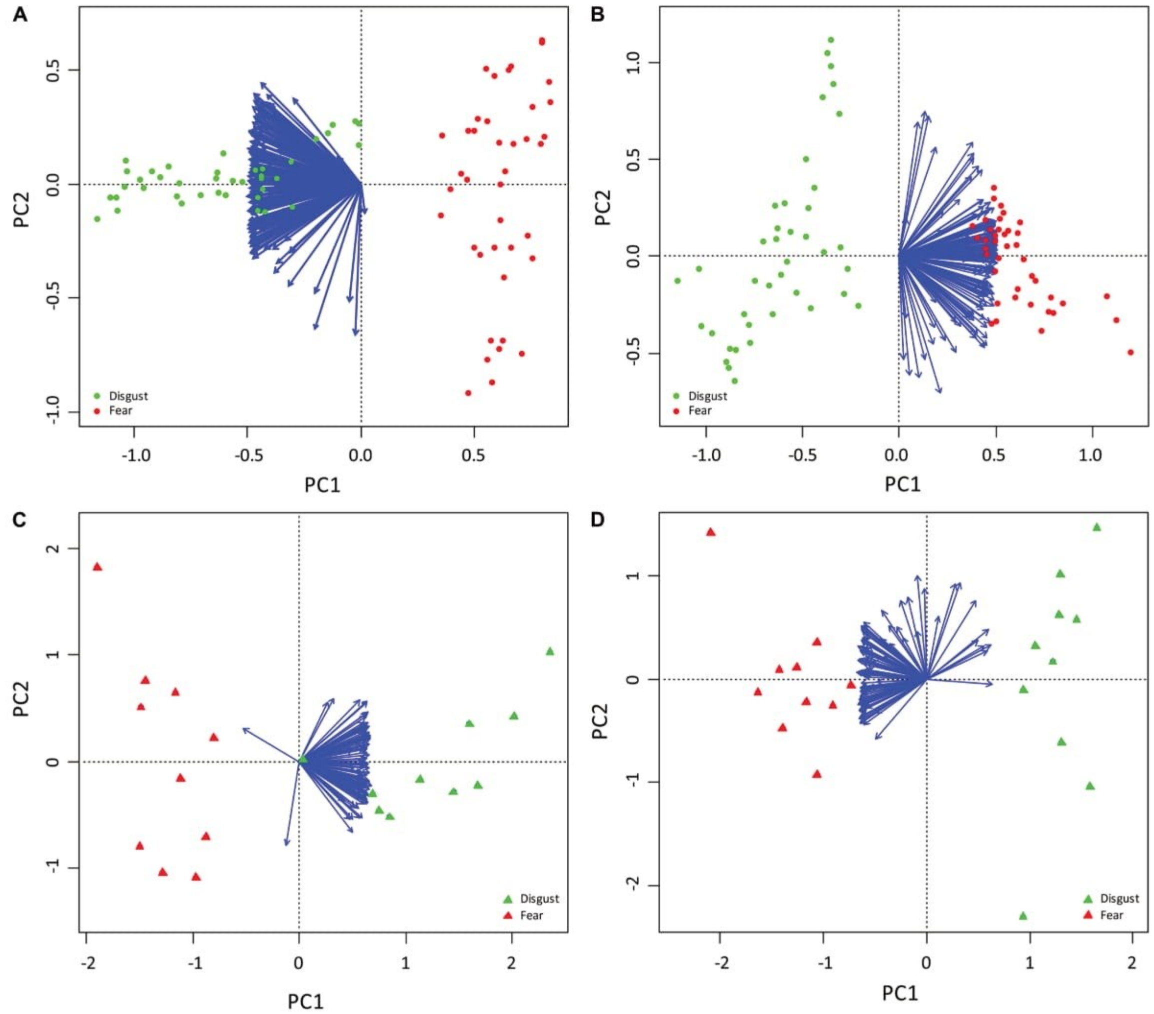

FIGURE 3 | PC Analyses of the fear **(A,C)** and disgust **(B,D)** ranks in the Experiments 2 **(A,B)** and 3 **(C,D)**. The arrows correspond to the respondents, the dots and triangles represent the snakes. In all pictures, PC1, which explains 70.82, 64.89, 68.72, and 59.8% of the full variability in the **A–D** cases, respectively, clearly corresponds with the separation of the snakes from two pre-defined distinct categories, one consisting of only fear-eliciting snakes (shown in red) and other of only disgust-eliciting snakes (shown in green).

($W = 0.503$). The results of a subsequent analysis show that most of the variability (90.93%) can be explained by a few factors: large (bulky) brown snakes were evaluated as fear-evoking, while light, reddish-brown, and pink-purple snakes were evaluated as less fear-evoking.

A possible explanation of this observation can be that we failed to select the morphotypes exclusively evoking disgust. The CA (see **Figure 4A**) suggests a separation of the *Charina-A. bibronii* complex, i.e., brown bulky snakes. Bulky snakes were evaluated as fearful also in another study (in form of the wide head and tail, Landová et al., 2018a). Although this study suggests that this *Charina-A. bibronii* complex is equally disgusting as other snakes within the D set, we cannot rule out the possibility that they also evoke more or less fear. Another study based on the physiological measurement of the emotional response would be needed to resolve this. However, neither brown color nor bulkiness were the factors to affect the evaluated fear of the full snake set (in Experiment 1), which hints for another explanation of this observation.

Another explanation can be that the disgusting snakes do not evoke fear at all and thus the task to sort the stimuli according to perceived fear was non-sensual. Thus, the respondents either used another (unknown) scale (e.g., beauty/valence in general), or just categorized the snakes according to the residual morphological variability (i.e., bulkiness and color), which was their only lead [similarly, to the unsupervised categorization as described by Pothos and Chater (2002) or Pothos and Close (2008)]. The CA of the fear ranks of the D snakes show that the data form three main groups: the brown bulky snakes (*Charina-A. bibronii* complex), pink snakes, and dark snakes. The respondents agree on the order of these groups, i.e., the supposedly "most fearful" are the *Charina-A. bibronii*, then the dark snakes, and the least "fearful" are the pink snakes, but there is no agreement on the order within the sets (dark snakes

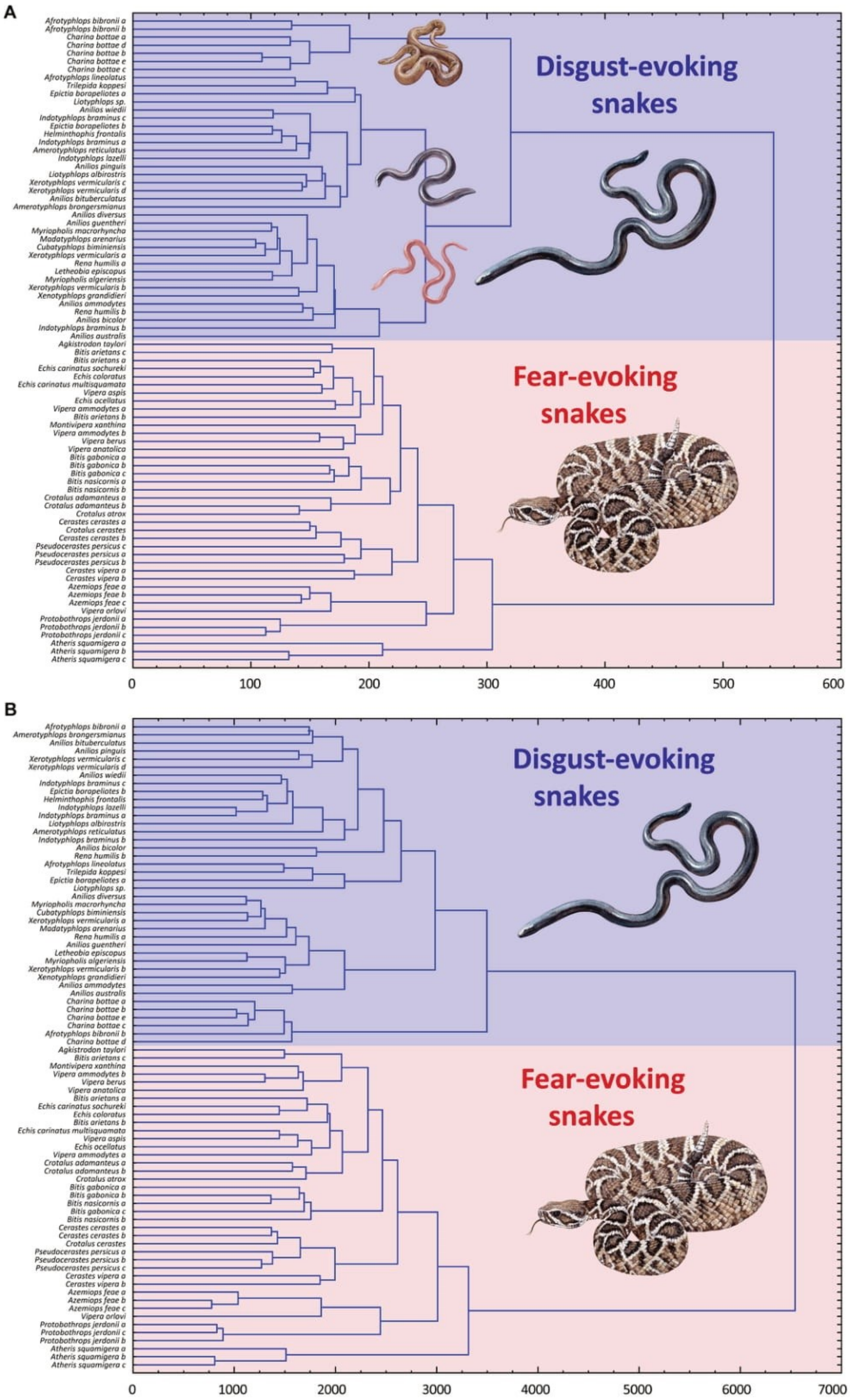

FIGURE 4 | Cluster analysis (CA) of the fear **(A)** and disgust **(B)** ranks of the snakes from the Experiment 2. Both pictures show a separation of the snakes from the two pre-defined distinct categories, one consisting of only fear-eliciting snakes and other of only disgust-eliciting snakes. In case of the fear ranks **(A)**, the respondents also identified three different groupings of the disgust-eliciting snakes set. This, however, might be a result of a non-sensual task as there might be no actual variability in fear of snakes that evoke little to no fear.

$W = 0.142$; pink snakes $W = 0.145$). However, it is possible that the respondents do not really experience the fear emotion. Instead, they are able to estimate the degree of "fearfulness" based on these characteristics, which belong to the fear-inducing ones and which would really evoke fear in a different context or in the presence of other fear-inducing characteristics. The dark color (lightness) was responsible for the evaluation of snakes as more fear-inducing and pink as less fear-inducing in another study (Landová et al., 2018a). To resolve that, another study focused on this issue would be needed.

For future research of human responses to snakes, it is important to purify the image stimuli within each set targeted at triggering certain emotion, e.g., fear or disgust, to make sure that all the images within the given set elicit the desired emotional response only. This is especially crucial in studies monitoring continuous brain stimulation using functional neuroimaging methods.

EXPERIMENT 3. ILLUSTRATION OF SNAKES EVOKING DISCRETE EMOTIONS

Materials and Methods

Selection and Preparation of Stimuli

The problem with photos found on the Internet is that each photo is taken under different conditions, is of a different quality, etc., and full standardization is nearly impossible. Additionally, copyright restrictions usually make it difficult to gather a full set of needed species for a wide use above the scope of a single experiment; especially if some species are rare and hardly ever photographed. Thus, our aim was to create a set of fully standardized illustrations to be available for further research. We randomly selected 20 species from sets D and F (10 from each) and commissioned painted illustrations of these species by a freelance artist. These photographs are publicly available for download at the Mendelay Data Repository (see section 8; 10 × 15 cm at 600 dpi, PNG picture files with transparent background).

Testing Emotional Response to Snakes

The set of 20 illustrated snakes was handled the same way as in Experiment 2: 104 respondents in total (78 women, 26 men; mean age = 33.93; *SD* = 14.85) sorted the snake illustrations according to both perceived fear and disgust. The order of both tasks was counter-balanced. The data about gender, age, and affiliation toward snakes of each respondent were collected similarly, as in Experiment 1.

Statistical Analysis

Similar to Experiment 1.

Results

Agreement Among Respondents

RDA analysis of the fear ranks included gender, age, affiliation, and order of the task. The full RDA model explained 5.65% of the full variability among the respondents. Sequential "Type I" ANOVA confirmed that only the effect of affiliation was significant: affiliation: $F_{1,99} = 2.161$, $p = 0.0089$; gender: $F_{1,99} = 1.148$, $p = 0.2982$; age: $F_{1,99} = 1.137$, $p = 0.2963$; and task order: $F_{1,99} = 1.481$, $p = 0.1056$. A reduced model, which included only the affiliation, explained 2.06% of the full variability (ANOVA: $F_{1,102} = 2.145$, $p = 0.0098$). In case of the disgust ranks, the full model explained 11.26% of the full variability: affiliation: $F_{1,99} = 7.097$, $p < 0.0001$; gender: $F_{1,99} = 1.396$, $p = 0.1807$; age: $F_{1,99} = 2.757$, $p = 0.0198$; and task order: $F_{1,99} = 1.308$, $p = 0.2149$. Reduced model, which included affiliation and age, explained 8.83% variability: RDA1 = 7.21% (corresponding to the fear of snakes; $F_{1,101} = 7.048$, $p < 0.0001$) and RDA2 = 1.62% (age; $F_{1,101} = 2.738$, $p < 0.0230$; see **Figures 5A,B**).

A relationship between affiliation toward snakes and miscounts in fear and disgust categorization of snakes was positively correlated only in the case of disgust (Spearman $r = 0.264$, $p = 0.0067$), but not fear evaluation (Spearman $r = 0.328$, $p = 0.0007$).

The pattern of agreement on the position of disgust- vs fear-evoking snakes confirmed the results of Experiment 2. *Post hoc* comparisons among the mean ranks of the individual species revealed that all comparisons between the fear-evoking and disgust-evoking stimuli were significant (see **Figure 6** and **Supplementary Material 2c**). When the respondents sorted the mixed sets according to fear, the fear-evoking snakes occupied the top 10 places, while the rest (i.e., the disgust-evoking snakes) occupied the 11st to 20th place by 61 out of 104 respondents (58.7%). Additional 27 (26%), 7 (6.7%), 4 (3.8%), and 3 (2.9%) respondents showed only marginal disagreement of one, two, three, and four miscounts (when fear-evoking snakes were placed among the disgust-evoking snakes), respectively. One respondent did seven and another one eight miscounts. Similar but opposite effect was found when sorting the sets according to evoked disgust, full-agreement in 71 (68.3%) and marginal disagreement in 19 out of 104 respondents (18.3%).

Similarly, agreement as expressed by the Kendall's W also replicated the pattern seen in Experiment 2: for all illustrated snakes sorted by fear: $W = 0.698$; for disgust: $W = 0.437$, for fear-evoking snakes sorted by fear: $W = 0.104$; for disgust-evoking snakes sorted by fear: $W = 0.433$; for fear-evoking snakes sorted by disgust: $W = 0.118$; and for disgust-evoking snakes sorted by disgust: $W = 0.025$.

Categorization of Snakes Based on Fear and Disgust Evaluation

The PCA also firmly repeated the pattern seen in Experiment 2. The PCA based on the fear rankings generated 19 unconstrained axes, the eigenvalues of seven of which were higher than 1. The first axis (eigenvalue of 71.46) explained 68.72% of variability and corresponded to the partition of snakes ranking as fear-evoking and "harmless" (see **Figure 3C**). All other axes explained a very small portion of variability (5.13% and lower) when compared to the first axis. The PCA based on the disgust rankings generated similar results: 19 unconstrained axes with the eigenvalues of 62.18 and 10.46 PC1 for PC1 and PC2, respectively. Also in this case, the first axis accounting for 59.8% variation corresponded to

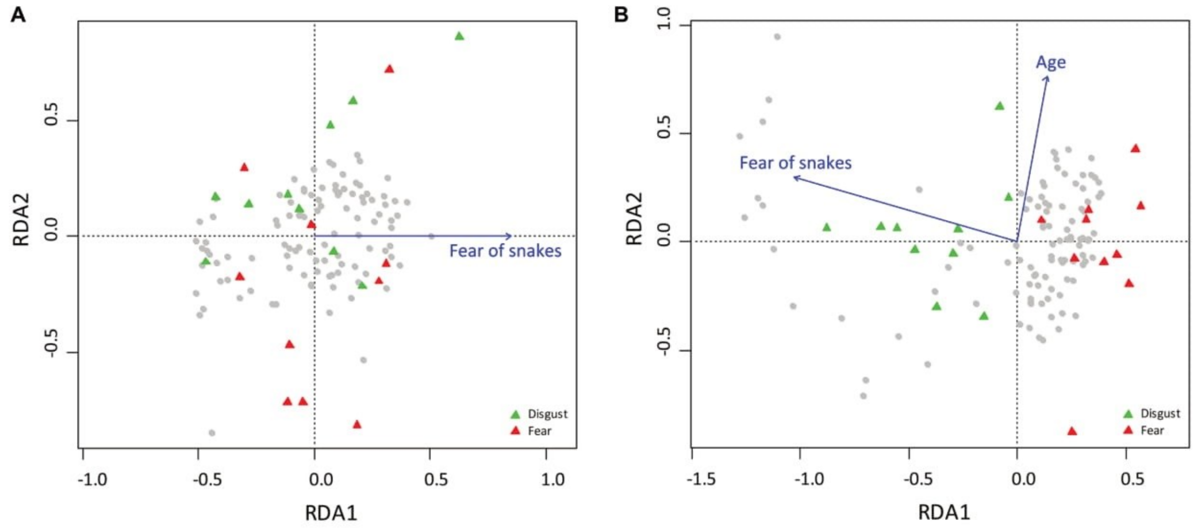

FIGURE 5 | Redundancy Analysis of the characters determining the ranks of fear and disgust elicited by snake stimuli used in Experiment 3. **(A)** The model (RDA1) explains only 2.06% of the full variability, but it does not explain the separation of the disgust- and fear-eliciting snake categories. **(B)** Analysis of the disgust ranks. RDA1 explains 7.21% of the full variability and corresponds to the separation of the two snake groups. RDA2 (corresponding to age) explains 1.62% of the full variability, but does not contribute to the variability explaining the category separation.

the "very disgusting – not disgusting at all" diversification of the two picture sets. The second axis accounted for 10.06% variation in disgust rankings (**Figure 3D**).

The subsequent CA based on the fear and disgust rankings of all the 20 snakes confirmed these results. Both trees confirmed strict distinctiveness of the fear- and disgust-evoking clusters, regardless of the ranking type (**Figure 7**).

Discussion

The aim of the final experiment was to develop a standardized set of pictures that could be used in future research of snake phobia. Ideally, such stimuli should unambiguously evoke either fear or disgust of snakes. Therefore, to acquire comparable, standardized pictures available for use, we commissioned professionally painted illustrations of 20 selected species, ten from each category, and we re-tested their emotional valence to validate their potential to trigger a discrete emotional response.

Previous work has shown that photographs may be substituted for live snakes with no change in the quality and intensity of perceived emotion (Landová et al., 2012). However, we have demonstrated here that illustrations as well have fear- and disgust-evoking properties similar to photographs. This has been confirmed by various exploratory statistical approaches, all showing that the stimuli again formed two separate clusters (see **Figures 3C,D**, **5**, **6**). Although this categorization is highly significant, it is not absolute. A majority of the stimuli were categorized as expected following Experiment 2, however, (and similarly, to Experiment 2), the respondents sometimes misplaced a few species into the other category (e.g., *Charina bottae*). In case of disgust rankings, 12 respondents even inverted the scale, placing the snakes from the disgust category as less disgusting in average than the fear-eliciting ones. To examine the reason behind this observation, we decided to take a closer look on the characteristics of the respondents.

To minimize the effect on underlying snake phobias, we tested only healthy subjects (i.e., excluding clinically detected snake phobics). However, variability among the respondents in terms of snake-induced fear sensitivity and overall affiliation toward these animals was still present within the sample. Interestingly, even though this measurement of the subjective affiliation toward snakes was simple, it helped to explain the variability in the disgust rankings of the illustrated set that skewed the overall agreement when compared to the rankings of fear. The RDA analysis also revealed that this factor affected the structure of the disgust categorization into the two groups (**Figure 5B**). When compared to the pictures evaluation according to fear, the effect of the snake fear variable was small and did not contribute to the separation of the fear-disgust categories, although it was also revealed as significant (**Figure 5A**).

In summary, we found that a portion of the respondents with an overall negative affiliation toward snakes (probably high fear) rank the F-snakes as more disgusting than the D-snakes. This suggests that the illustrated F-snakes, which we consider fear-inducing, appear as much stronger negative stimuli to the respondents with high snake fear, regardless of the emotional categorization. This may also hint for a higher involvement of the disgust emotion (in addition to fear emotion) in the evaluation of snakes in people with strong negative affiliation toward snakes (and possibly in snake phobics). These findings are generally in line with current existing literature (Klieger and Siejak, 1997; Woody and Teachman, 2000; Smith and Davidson, 2006). Another explanation of this phenomenon might be that the respondents with high fear of snakes might perceive all snakes negatively, independently on their appearance. However, if this was the case, the

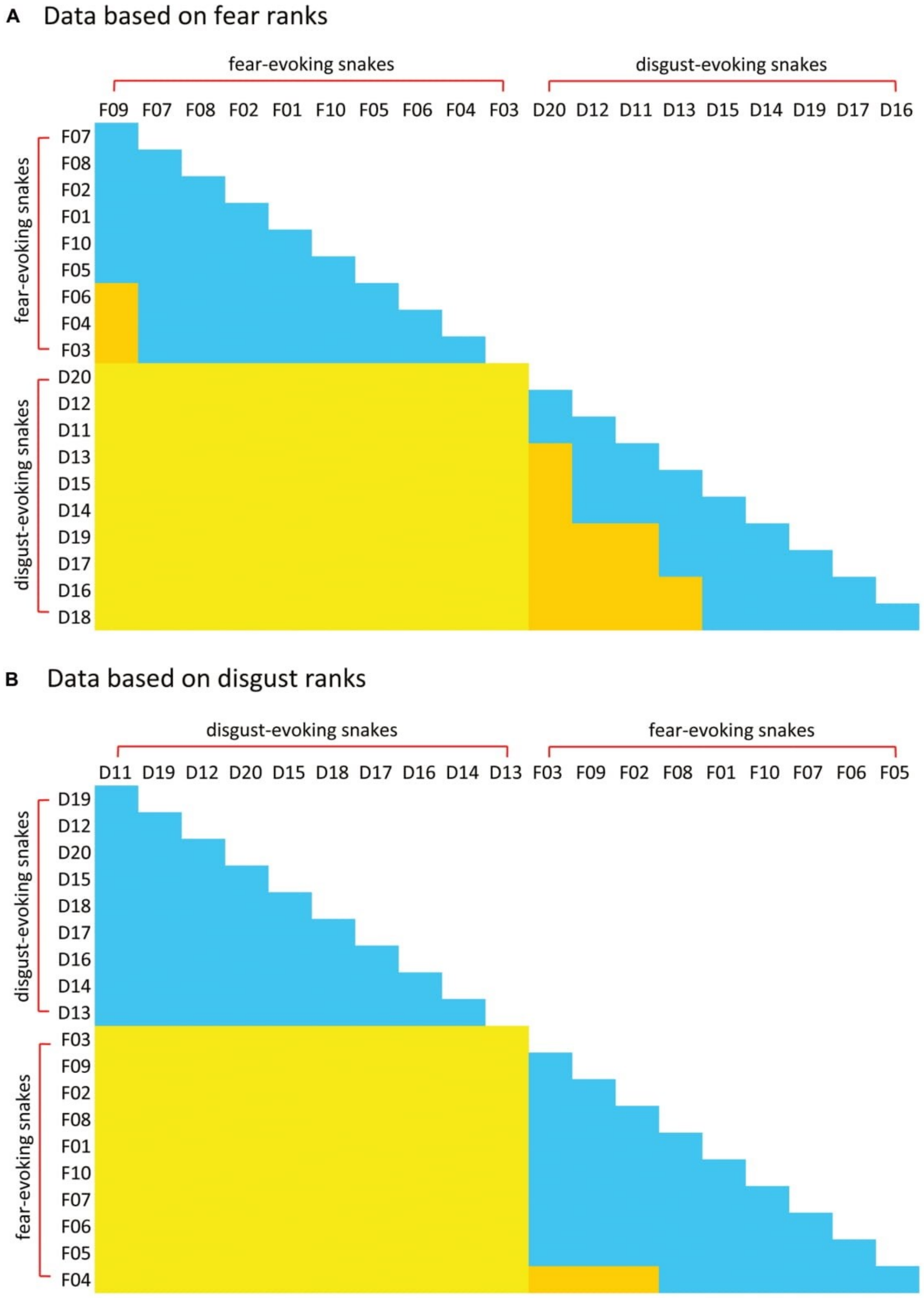

FIGURE 6 | Matrix of *post hoc* Friedman-Neményi comparisons among the rankings of individual snake stimuli in Experiment 3. Species are arranged in an ascending order according to their mean rank of **(A)** fear and **(B)** disgust. Friedman test of the entire matrix was highly significant. Significant comparisons ($p < 0.05$) are marked yellow (comparisons between fear-evoking and disgust-evoking snakes) or orange (comparisons within groups) colors. Non-significant comparisons are denoted by blue. For mean ranks and *P*-values, see **Supplementary Material 2**.

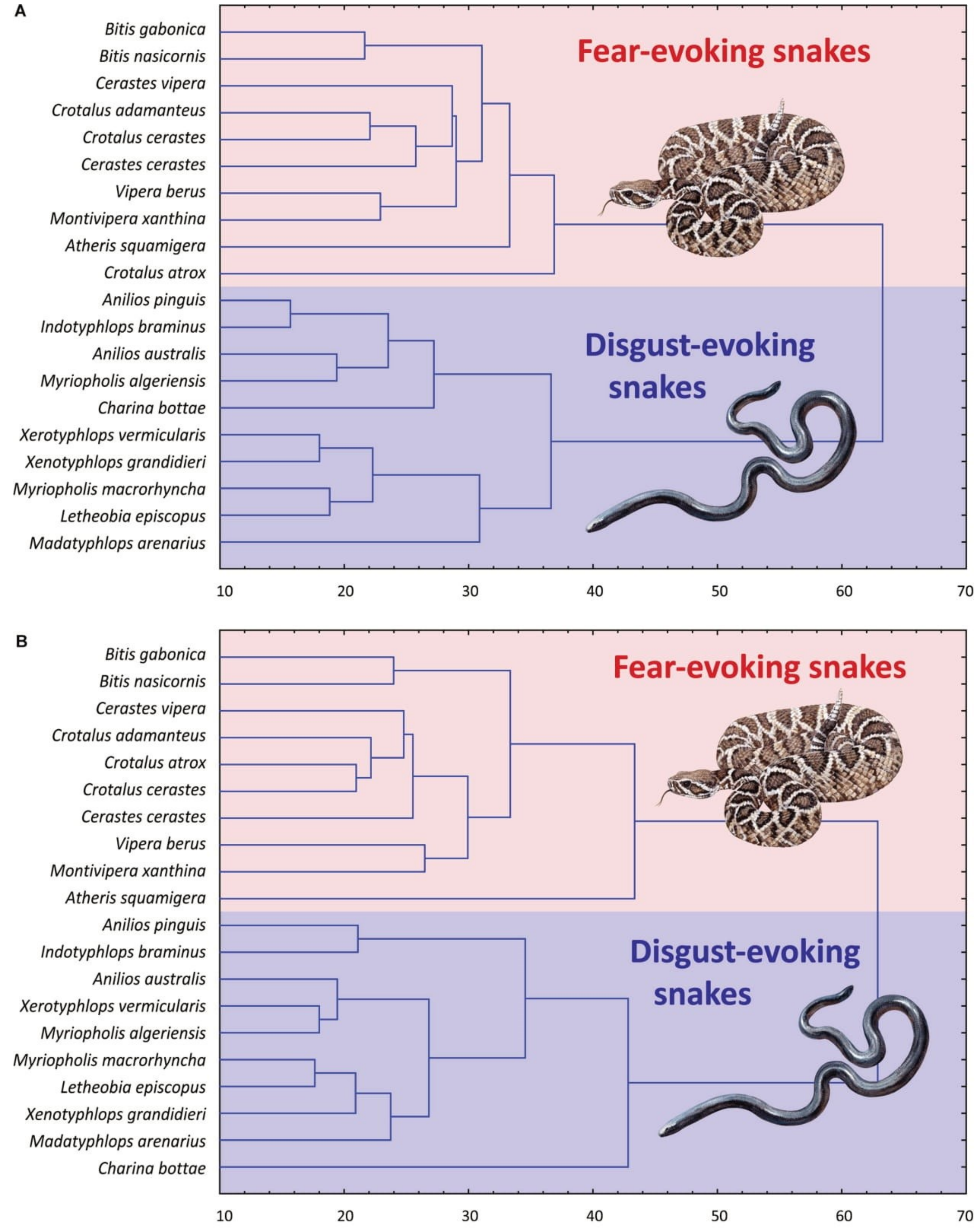

FIGURE 7 | Cluster analysis of the fear **(A)** and disgust **(B)** ranks of the snakes from the Experiment 3. Both trees confirmed strict distinctiveness of the fear- and disgust-evoking clusters, regardless of the ranking type.

categorization would be also distorted during the fear evaluation, which was not found.

LIMITATIONS OF THE STUDY

This study was designed to analyze differences among stimuli, not among people. That is why it used the rank–ordering method instead of the Likert scale. This method is optimal for evaluating relative differences in mean ratings of the stimuli, but, on the other hand, it reduces the inter-respondents effect. Thus, it measures with high resolution the relative difference between stimuli, for example when we try to find out if the viper is perceived as more fearful than the grass snake. It is for this reason that the models incorporating the effect of sex, age, or affiliation to snakes can explain only a very little of the total variability (usually just 2–7%), because in fact they only evaluate differences in the relative order of the species.

Conversely, the absolute evaluation made on a Likert scale is more related to differences in experiencing emotions among respondents, e.g., when fear sensitive respondents attribute higher scores to both the viper and grass snake compared to less fearful subjects. This cannot be well inferred from our type of data, which is a limitation of the study. Nevertheless, we are fully aware of this issue and therefore, we have also collected the Likert scale data which will be analyzed in the next manuscript.

This might also explain the fact why at this time we did not give that much consideration to the questionnaires measuring fear and disgust sensitivity of the respondents and rather substituted the SNAQ and DS-R data by a single question of affiliation to snakes on a 7-point Likert scale. However, this only item highly correlates with the SNAQ ($r = 0.6683$; $p < 0.0001$), which we verified in Experiment 2.

CONCLUSION

In this study, we show that "snakes" are not perceived as a single category. Based on their visual appearance, different snakes may evoke different emotions of fear and disgust, and these emotions are not necessarily mutually exclusive. Snakes can also be grouped into categories based on their morphotypes that evoke similar emotion(s). We were able to create sets of snakes that elicit almost exclusively disgust- and fear-response. Additionally, we do not only provide a smaller set of snake pictures with known emotional rankings, we also offer a "know-how" that will allow anyone else to include additional stimuli into each of the categories of "fear-evoking" and "disgust-evoking" snakes simply based on their unique characteristics.

When compared to existing affective picture databases, the variability among the snakes we present in this study is reduced to the actual variability among the snake species. It is thus especially useful in studies of the evolutionary basis of snake-induced emotional response that heeds the properties of snakes, their characteristics, and evolutionary history of the human-snake interaction. Moreover, we confirmed that snakes within the defined category ("fear-evoking" and "disgust-evoking") form a homogenous group. Thus, these stimuli can be utilized in further studies of snake-induced fear in humans (incl. snake phobics) that require a larger number of homogenous pictures evoking discrete emotional response in a block-type design, such as fMRI and EEG.

In conclusion, snakes demonstrate an immense morphological variability with many patterns, and these patterns are associated with specific human reactions. The theoretical implication of this study is that humans do not react on a "snake" *per se* or some kind of its "snake essence," but they can distinguish specific snake categories based on their morphotypes. For future research, it is critical that "snakes" cannot be considered as one homogenous category of stimuli.

DATA AVAILABILITY

The datasets generated during and/or analyzed during the current study are available in the Mendeley repository, http://dx.doi.org/10.17632/xktgm3j4s7.1.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of Institutional Review Board (IRB), Faculty of Sciences, Charles University, approval n. 2013/7, and approval of the Ethical Committee of the National Institute of Mental Health n. 55/16, with the written informed consent from all subjects in accordance with the Declaration of Helsinki. The protocol was approved by the Institutional Review Board (IRB).

AUTHOR CONTRIBUTIONS

EL and DF contributed to the conception and designed the study. MJ, KS, DN, ŠP, and JP organized the database and performed the research. SR, DF, and MJ performed the statistical analysis. SR wrote the first draft of the manuscript. DF, EL, JP, and MJ wrote sections of the manuscript. Contributions of the first two authors (SR and MJ) are equal. All authors contributed to manuscript revision, read and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2019.01085/full#supplementary-material

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Emotional Reaction to Fear- and Disgust-Evoking Snakes: Sensitivity and Propensity in Snake-Fearful Respondents

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This paper continues our previous study in which we examined the respondents' reaction to two morphologically different snake stimuli categories – one evoking exclusively fear and another evoking exclusively disgust. Here we acquired Likert-type scale scores of fear and disgust evoked by the same snake stimuli by a total of 330 respondents. Moreover, we collected data about the respondents' age, gender, education, snake fear [Snake Questionnaire (SNAQ)], and disgust propensity [Disgust Scale-Revised (DS-R)], and we analyzed the effect of these variables on the emotional scores (with special focus on snake-fearful respondents). In addition, we collected the SNAQ and DS-R scores from the respondents tested in the previous study using the rank-ordering method to directly compare the results of these two approaches. The results showed that non-fearful respondents give high scores of fear to the fear-eliciting snakes and high scores of disgust to the disgust-eliciting snakes, but they give low scores of the other emotional dimension (disgust/fear) to each. In contrast, snake-fearful respondents not only give higher fear and disgust scores to the respective snake stimuli, but they also give high scores of fear to the disgust-eliciting snakes and high scores of disgust to the fear-eliciting snakes. Both Likert-scale scores and rank-ordering data show that the clear border dividing both snake stimuli categories dissolves when evaluated by the snake-fearful respondents.

Keywords: disgust, emotional response, DS-R, fear, image rating, self-reported emotion, snake phobia, SNAQ

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INTRODUCTION

Snakes as Evolutionary Threat Triggering Fear and Disgust

In the world of human ancestors, danger in many forms constantly threatening our survival was omnipresent. According to Isbell (2006, 2009), venomous snakes and large constrictors might be considered as one of the most significant predators in the primate and human evolutionary history (cf. Wheeler et al., 2011). Even though the mortality rates attributed to serpents in the prehistoric times cannot be reliably quantified due to the snake highly efficient metabolism leaving no fossil records of their prey (Greene, 1983; Hsiang et al., 2015), some circumstantial evidence suggests that the emergence of snakes must have become a strong selection pressure in the mammalian evolution (Öhman and Mineka, 2003). As a consequence of the risk presented by snakes, human ancestors have developed a complex adaptive system of interconnected fear responses manifested on the psychological, behavioral, physiological, and neural level, which, according to some authors, has been embodied in a specific brain area, the so-called module of fear (Öhman and Mineka, 2001) localized in the amygdala (Öhman, 2005; Öhman et al., 2007; for a recent critical review of the modular theory, see Coelho et al., 2019). In fact, the modular theory has drawn upon the much earlier Seligman's (1971) concept of biological preparedness claiming that most of the clinical fears are triggered by stimuli threatening our survival in the evolutionary past. This became an alternative to the Rachman's (1977) conditioning theory of fear learning according to which people acquire fears directly through classical conditioning, or indirectly through observation or verbally transmitted information. For a long time, there was a dispute in the literature whether snake fear is a universal inherited trait or rather a learned reaction acquired through life (for a review see, for example, Tierney and Connolly, 2013 or Kawai, 2019). However, a growing body of evidence suggests that even though fear of snakes *per se* is not innate (small infants do not fear snakes, Thrasher and LoBue, 2016, but see Hoehl et al., 2017), there is a biological predisposition to rapidly detect snakes and associate them with fear (LoBue et al., 2010).

Intensive fear of snakes has survived until today as for a majority of people, the snake is still among the most frightening animals (Davey, 1994; Polák et al., 2019b) that may trigger phobic fear in as many as 2–3% of population (Klorman et al., 1974; Klieger, 1987; Polák et al., 2016), which accounts for one of the most prevalent specific phobias (Eaton et al., 2018; cf average prevalence of any animal phobia across the world is estimated to 3.8%, Wardenaar et al., 2017). Even higher prevalence of snake phobia, despite local low abundance of snakes, was reported on a Swedish (5.5%, Fredrikson et al., 1996) or Hungarian sample (4.2%, Zsido, 2017 and 3.3%, Zsido et al., 2018). However, due to extensive species diversity with significant variability in appearance within the snake suborder (Serpentes, 3,709 species were recognized by July 2018: Uetz et al., 2019), recent studies demonstrate that besides fear, disgust is also associated with certain snakes (Janovcová et al., 2019; Polák et al., 2019b; Rádlová et al., 2019), thus it needs to be considered when studying human emotional response to these animals. Moreover, according to the influential model of disease-avoidance proposed by Matchett and Davey (1991), some animal phobias (especially those of small species) have not primarily evolved through fear of being attacked, but rather employed disgust as an adaptive mechanism protecting us from the transmission of pathogens. There is an evidence that a causal link exists between experimentally manipulated disgust and reported fear of certain animals (Webb and Davey, 1992; see also Polák et al., 2019b). It is thus reasonable to expect that snake phobia in some cases might not be driven by dysregulated fear but disgust.

Differentiating Propensity and Sensitivity of Fear and Disgust

The latest literature on disgust suggests that it can be separated into two specific concepts, propensity and sensitivity. While the former one refers to the individual's general tendency to respond with the emotion of disgust to various objects or situations, sensitivity is used for the secondary appraisal of disgust, i.e., how negatively the feeling of disgust itself is evaluated by the individual (van Overveld et al., 2006). So far, most of the research on disgust has been focused on propensity, while sensitivity remained overlooked. Nevertheless, it has been shown that both constructs are relevant and may be associated with several anxiety disorders (Olatunji et al., 2007; Nicholson and Barnes-Holmes, 2012), including animal phobias (Cisler et al., 2009), e.g., in predicting avoidance behavior (van Overveld et al., 2010). It is reasonable to expect that this conceptual distinction is not restricted to disgust but might be as well applied to other negative emotions such as fear. Moreover, based on the recent evidence, propensity to react with fear or disgust is associated with different brain activation pattern than sensitivity to these emotions (Mataix-Cols et al., 2008). While the former is positively correlated with activation in the attention-related (parietal and anterior cingulate cortex), and valence/arousal processing regions (orbitofrontal cortex and insula), sensitivity to fear and disgust is exclusively negatively correlated with activation in the areas involved in emotion regulation such as the medial and dorsolateral prefrontal cortex (Schäfer et al., 2009).

Specific Psychology Profile of People With High Fear of Snakes

Differentiating propensity and sensitivity of fear and disgust is important as these constructs may be independently involved in psychopathology. For example, Vernon and Berenbaum (2008) found that fear and disgust propensity may both play their role in spider fear. Similarly, van Overveld et al. (2006) reported that while fear of blood was associated with disgust propensity and sensitivity, spider fear was correlated only with disgust propensity: according to self-report, spider-fearful respondents were more likely to react to spiders with the emotion of disgust. It is thus sensible to believe that similar results may be found in snake-fearful subjects, which differ from non-fearful controls in many aspects. For instance, it has been shown that snake-fearful respondents give more negative and extreme scores to snake stimuli when rating valence and arousal (Miltner et al., 2005) or anxiety, disgust, and pain (Lueken et al., 2011; Haberkamp et al., 2013). Their reaction time to detect snake stimuli is shorter (Öhman et al., 2001; Flykt and Caldara, 2006; Rosa et al., 2011), while their reaction time to detect a target stimulus or a change in a scene is longer when a snake picture is present as a distractor (Lipp and Waters, 2007; McGlynn et al., 2008; see also Waters and Lipp, 2008; Waters et al., 2011, for a comparison of both reaction time procedures). People with high fear of snakes also show increased cognitive interference in the Stroop test when confronted with snake-related sentences (Constantine et al., 2001; Wikström et al., 2004).

Furthermore, high-fear individuals demonstrate higher skin conductance response (SCR) when confronted with a live snake (McGlynn et al., 1973) or just a snake picture (Flykt et al., 2017), even when these are presented unconsciously (Öhman and Soares, 1994). Unconscious presentation of snakes within watched video stimuli attracts attention in form of eye saccades directed toward the areas where the snakes were presented and this effect is again more pronounced in snake-fearful participants (Rosa et al., 2014). Flykt et al. (2017) found an increased vocal response intensity and increased heartrate changes of snake-fearful participants in response to snake picture stimuli. Moreover, the neural response of snake-fearful respondents to snake movies is higher or qualitatively different: according to Lueken et al. (2011), snake-fearful respondents show higher activation within the inferior frontal operculum, middle temporal gyrus, middle cingulate gyrus, pallidum, and the cerebellum. Even their brain morphology differs as the gray matter volume in the left postcentral gyrus is increased when compared to control participants (Hilbert et al., 2015).

Various Snake Species May Trigger Different Emotions

In short, high-fear participants change many aspects of their behavior when confronted with the feared stimuli, regardless of whether these are presented as live specimens or just moving or still pictures. All of the above-mentioned studies considered the presented stimuli as a uniform category, a general form of "snake," or "harmless/non-venomous snake" in studies working with live animals (e.g., McGlynn et al., 1973; Klieger and Siejak, 1997). However, there are many snake species, differing in size, color, shape, texture, and also the actual dangerousness they present to humans (Kasturiratne et al., 2008; see also Rádlová et al., 2019 for a review). Previously, we have shown that human respondents are able to distinguish between various snake morphotypes and that they mostly fear vipers and allies (Landová et al., 2018; Rádlová et al., 2019) while simultaneously evaluating harmless fossorial species as not fear-eliciting at all. These findings raise a further question whether snake-fearful participants distinguish particular snake morphotypes and respond comparably to non-fearful respondents, or evaluate all snakes in general negatively.

In the previous article (Rádlová et al., 2019), we introduced two types of defined, standardized snake stimuli: one set that elicits exclusively fear and another one that elicits exclusively disgust. The stimuli were carefully standardized, reduced to differences between specific snake morphotypes but uniform in other aspects such as the background or posture. Such approach presents a great advantage because it offers well-described and characterized stimuli, free from uncertainties about the effects of other factors such as the body size, environment, background color, or lightness on the rankings given by human respondents. Still, we found that even with this reduced variability, there was a great distinction between the stimuli types as the respondents clearly distinguished and categorized each stimulus into its respective category. However, the snakes were examined using a rank-ordering method, which is optimal for analyzing differences between the stimuli but reduces differences *between the raters* – the main focus of the present study. Here we examine the relationship of fear and disgust ratings using the absolute scale (Likert-type scores), focused on differences between respondents with high and low fear of snakes.

Aims of the Study

In this study, we focus mainly on two aspects linked to snake fear and phobias: a relative contribution of the particular emotion of fear and disgust to enhanced snake fear and generality/specificity of snake stimuli. More specifically, we aimed to test the following predictions (corresponding to alternative hypotheses) pertaining to the effect of snake fear as measured by the Snake Questionnaire (SNAQ):

1) High-fear respondents report high fear of both types of snakes (fear- and disgust-eliciting ones), thus showing increased fear propensity toward various stimuli (as opposed to high disgust propensity found in individuals with high fear of spiders van Overveld et al., 2006). This would mean that high snake fear (and consequently the SNAQ score) is strictly saturated by the fear emotion with no disgust component involved.
2) High-fear respondents report high disgust from both types of snakes (fear- and disgust-eliciting ones). In this case, anxiety provoked by snakes (as measured by the SNAQ) would in fact result from increased disgust propensity and sensitivity which would corroborate the findings of Klieger and Siejak (1997) who argued that some SNAQ items are ambiguous and may tap into disgust.
3) High-fear respondents rate all the snakes as highly fearful and disgusting at the same time, thus showing increased fear and disgust propensity. Such results would, in accordance with the study on spider fear (Vernon and Berenbaum, 2008), suggest that high fear of snakes is composed of negative evaluation in general (i.e., valence; Barrett, 2006) and that high-fear respondents (and potentially phobics) are unable to identify or distinguish between the two emotions while evaluating different snake pictures.

Additionally, we examined the effect of high disgust propensity [as measured by the Disgust Scale-Revised (DS-R)] following the same pattern. All of the above-mentioned predictions would also mean that snake-fearful subjects do not treat various snake morphotypes as distinct categories. Should the contrary be the case, the intact ability to categorize the snakes would be predicted by the following possible outcomes:

1) Although high-fear respondents compared with controls attribute higher scores to snakes, they still report higher fear from fear-eliciting than from disgust-eliciting snakes and, simultaneously, higher disgust from disgust-eliciting than from fear-eliciting snakes.
2) During the rank-ordering task, high-fear respondents do not misplace the snakes from one category into the other more often than control respondents.

MATERIALS AND METHODS

The Stimuli

In the previous study, we introduced two sets of snake stimuli, one consisting of 40 snake pictures rated as exclusively fear-eliciting (further referred to as F snakes) and the other consisting of 40 snake pictures rated as exclusively disgust-eliciting (further referred to as D snakes; Rádlová et al., 2019; please note that the stimuli are available online for free use in research). The sets contained snakes standardized for size and placed on a blank (white) background. In the present study, both F and D snakes were mixed into one 80-picture set and presented to the respondents.

Testing the Emotional Response of the Respondents

A total of 330 respondents (279 women, 51 men, aged 18–65; mean age 30.03; SD = 9.84) participated in the study. First, each respondent provided an informed consent, filled information about his/her age, gender, education (biological/other), and completed the SNAQ (Czech translation: Polák et al., 2016 of the original scale by Klorman et al., 1974) and DS-R (Czech translation: Polák et al., 2019a of the original scale by Haidt et al., 1994; modified by Olatunji et al., 2007). Then he/she proceeded to the task using an online web application at www.krasazvirat.cz, specially designed to test the self-reported response to animal picture stimuli on various bases, including the Likert-type scale (Likert, 1932). The instructions were to first score each stimulus (randomly presented) on a seven-point scale according to elicited fear. Then, the stimuli were presented again, this time to be scored according to elicited disgust (1 = the least fear/disgust-eliciting, 7 = the most fear/disgust-eliciting). Half of the respondents received the task in a counter-balanced order, i.e., their task was to score the set first for elicited disgust and then fear.

The Likert-type scale, which helps to acquire absolute scores for each stimulus, is a very sensitive method when considering differences among respondents. Different respondents tend to use the scale in a different way; they use the full scale only partially, give higher/lower scores to specific stimuli, etc. In contrast, the rank-ordering method, in which the respondents sort all of the stimuli in an ascending or descending order according to a specific dimension (e.g., emotion such as fear), only helps to collect relative ranks of the stimuli. Such a method is optimal for studying different patterns of the presented stimuli in general, but reduces the variability among respondents (Rádlová et al., 2019). To show the difference of the two methods in a direct comparison, we utilized the rank-ordering data of the same mixed (F-D) set from Rádlová et al. (2019), with additional data of the SNAQ and DS-R scores from 154 respondents (107 women, 48 men; mean age = 25.62; SD = 9.88). These data were collected in a very similar manner as those described above, except the evaluation method used was rank-ordering (see Marešová and Frynta, 2008; Marešová et al., 2009a for more details).

Consistently with our previous study, those participants who scored above the 75th percentile on the SNAQ (8 and higher) were then classified as "high-fear" respondents (*n* = 143). Similarly, those who scored above the 75th percentile on the DS-R (44 and higher) were classified as "high-disgust" respondents (*n* = 171). Others were classified as "low-fear" (*n* = 187) and/or "low-disgust" (*n* = 159) respondents, respectively (see **Table 1** for descriptive statistics of the studied sample). By choosing the upper quartile, we could balance between an individual fear level significant enough to discover its potential effect and a statistically sufficient number of subjects within the high-fear category.

TABLE 1 | Descriptive statistics of the study sample. **(A)** Likert-scale data: *n* = 330; high-fear group *n* = 143; high-disgust group *n* = 171; **(B)** Rank-ordering data: *n* = 172; high-fear group *n* = 44; high-disgust group = 71.

(A) Likert-scale data

	All respondents			High-fear respondents			Low-fear respondents			High-disgust respondents			Low-disgust respondents		
	Age	**SNAQ**	**DS-R**	**Age**	**SNAQ**	**DS-R**	**Age**	**SNAQ**	**DS-R**	**Age**	**SNAQ**	**DS-R**	**Age**	**SNAQ**	**DS-R**
Mean	30.01	8.94	43.67	30.66	16.80	46.78	29.50	2.93	41.28	30.08	10.49	54.76	29.93	7.27	31.74
SD	9.64	8.12	14.35	9.67	6.15	14.25	9.61	2.03	14.01	9.57	8.38	9.02	9.75	7.51	8.07
Min	18	0	10	19	8	10	18	0	13	18	0	44	18	0	10
Max	65	30	95	63	30	95	65	7	87	63	30	95	65	28	43

(B) Rank-ordering data

	All respondents			High-fear respondents			Low-fear respondents			High-disgust respondents			Low-disgust respondents		
	Age	**SNAQ**	**DS-R**	**Age**	**SNAQ**	**DS-R**	**Age**	**SNAQ**	**DS-R**	**Age**	**SNAQ**	**DS-R**	**Age**	**SNAQ**	**DS-R**
Mean	25.22	6.10	43.16	25.86	14.27	49.45	25.01	2.86	40.64	26.37	8.24	55.94	24.43	4.30	32.22
SD	9.43	6.10	14.64	12.16	5.44	13.01	8.33	1.82	14.55	10.95	7.07	8.96	8.16	4.45	8.28
Min	18	0	3	18	8	25	18	0	3	18	0	45	18	0	3
Max	79	27	93	74	27	93	79	7	84	74	27	93	79	24	43

Statistical Analysis

Most data were statistically analyzed using multivariate statistics including a multiple regression and MANOVA. In these cases, effect sizes were provided as Pillai's Trace (Pillai, 1955). In order to quantify and test congruence in species ranking provided by different respondents, we adopted a two-way, consistency, average-measures intra-class correlation (ICC; McGraw and Wong, 1996; Hallgren, 2012) computed in R (irr package). Prior to the analyses, the raw order-ranks were transformed as follows: each value minus 1 was divided by the number of evaluated species minus 1 and square-root arcsin transformed to achieve a normal distribution. A principal component analysis (PCA) was performed to visualize the multivariate structure of the data sets. Friedman test and Mann–Whitney *U*-test were used as a non-parametric alternative for variables deviating from normality (raw sores). Effect sizes for the Mann–Whitney *U*-tests were computed as normal approximation z to r (Pallant, 2007; Field, 2013). Pairwise comparisons of the means were done using the *post hoc* Nemenyi multiple comparison test.

Contribution of the explanatory variables (constrains) to the scorings and rankings of the snakes was examined using the redundancy analysis (RDA) as implemented in the R package vegan (Oksanen et al., 2017). RDA is a multivariate direct gradient method. It extracts and summarizes the variation in a set of response variables (subjective evaluation of fear and disgust evoked by snakes) that can be explained by a set of explanatory variables. Statistical significance of the gradients was confirmed by permutation tests. Calculations were performed in R (R Development Core Team, 2010) and Statistica 9.1 (StatSoft Inc, 2010).

RESULTS

Likert-Scale Data

PC Analysis

Principal component analyses of the fear scores generated 80 axes, 12 of which were of an eigenvalue higher than 1. The most variability was explained by the first two axes: PC1 explained 60.28% and PC2 explained 24.99% of the full variability (see **Figures 1A,B**). The second axis clearly separated the stimuli into the two groups of fear-evoking and disgust-evoking snakes. Very similar results were found when analyzing the disgust scores: 80 PC axes, the eigenvalues of 13 of which were higher than 1; PC explained 56.44% and PC2 29.24% of the full variability. Again, the PC2 axes separated the stimuli into the two groups. In both cases, the rest of the axes (3–80) explained <1% variability each.

Agreement Among Respondents

Results revealed considerable congruence among the respondents in fear scores. Although reliability of the individual rankings (Hallgren, 2012) was only moderate (ICC = 0.416, $p < 0.0001$), ICC for the average-measures was in an excellent range: ICC = 0.996, $p < 0.0001$ (Shrout and Fleiss, 1979; Cicchetti, 1994). These results indicate that there was a high degree of agreement within the group of respondents and suggest that the snake stimuli were rated similarly in terms of evoked fear. Similarly, a high agreement for the average measures was found when analyzing the disgust scores (ICC = 0.982, $p < 0.0001$), although the single measures agreement was somewhat lower (ICC = 0.144, $p < 0.0001$).

Variability Among Respondents

We performed a multivariate multiple regression (Type II MANOVA tests) to analyze the effect of age, gender, SNAQ and DS-R scores, education, and order of the task on the scores. In the case of fear scores, only the SNAQ (Pillai's Trace = 0.666, $F_{1,323} = 6.09$, $p < 0.0001$), education (Pillai's Trace = 0.382, $F_{1,323} = 1.887$, $p = 0.0001$), and the task order (Pillai's Trace = 0.406, $F_{1,323} = 2.088$, $p < 0.0001$) were significant. In the case of disgust scores, significant predictors were age (Pillai's Trace = 0.316, $F_{1,323} = 1.411$, $p = 0.0244$), SNAQ (Pillai's Trace = 0.739, $F_{1,323} = 8.64$, $p < 0.0001$), education (Pillai's Trace = 0.379, $F_{1,323} = 1.863$, $p < 0.0001$), and the task order (Pillai's Trace = 0.308, $F_{1,323} = 1.359$, $p = 0.0396$). To identify the species that substantially contributed to these differences, we performed Mann–Whitney *U*-tests comparing the raw ranks of each species in low/high fear respondents, biologists/non-biologists, and respondents first scoring fear/disgust, respectively; the levels of significance were Bonferroni-corrected. The differences in both fear and disgust scores of low versus high fear respondents were strongly significant ($p < 0.0001$) in all cases (all snake species; for more details and effect sizes, see **Supplementary Material 1**). In the case of fear scores, the education affected only the disgust-evoking snakes, which were scored as less fear-evoking by biologists (all $p < 0.0001$). In the case of disgust scores, biologists scored the majority of fear-evoking snakes (30 out of 40) as less disgusting than did the non-biologists, and also three disgust-evoking snakes ware rated as less disgusting. Additionally, the respondents who first evaluated the stimuli according to fear scored 26 of the disgusting snakes as less fear-evoking and three of the fear-evoking snakes as more fear-evoking. For more detailed statistics including effect sizes computed as normal approximation z to r (Pallant, 2007; Field, 2013), see **Supplementary Material 1**. In the case of disgust scores, no snake was significant. We have also performed the same analysis for women only, but this approach yielded comparable results (for more details, please see **Supplementary Material 2**).

It is possible that the effect of gender was not significant because the gender ratio in our sample was very unbalanced (51 men, 279 women). Because of that (and to control for the effect of SNAQ, which was the strongest predictor, see also the RDA analyses below), we randomly selected 51 women from the sample with the corresponding SNAQ scores, pooled them together, and re-analyzed the data. In the case of fear scores, significant predictors were the SNAQ (Pillai's Trace = 0.935, $F_{1,99} = 3.581$, $p < 0.0011$) and education (Pillai's Trace = 0.911, $F_{1,99} = 1.863$, $p = 0.0102$); see **Supplementary Material 2** for more details. The gender

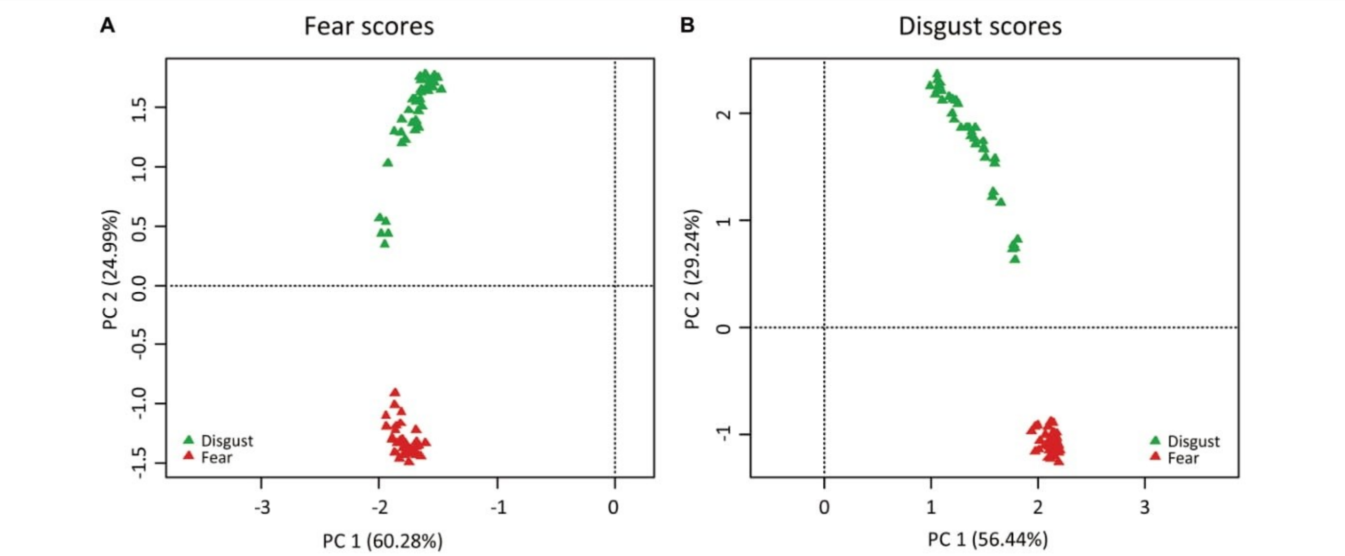

FIGURE 1 | Results of PC analyses of the **(A)** fear scores and **(B)** disgust scores of snake stimuli. The colored triangles refer to the pictures of fear-eliciting snakes (red) and disgust-eliciting snakes (green). In both cases, PC2 axis contributed to the separation of the snakes into their respective categories.

appeared as a single significant predictor only in the case of disgust scores (Pillai's Trace = 0.887, $F_{1,99} = 1.957$, $p = 0.0456$). However, a univariate analysis of the disgust scores revealed that the effect of gender was significant in neither case (snake), and these results were confirmed by Mann–Whitney *U*-tests (Bonferroni corrected). This suggests that no strong effect of certain species contributes to the results, but rather that it is constructed by a combination of a number of small effects. This could be, however, also an artifact of the statistical method.

A redundancy analysis confirmed the results of the regressions. We utilized the automatic model-building feature based on both Akaike criterion (but with permutation tests) and on permutation *P*-values. In the case of fear scores, both methods agreed on the inclusion of the following variables into the reduced model: SNAQ scores, age, education, and order of the task. The reduced model has generated four constrained axes that explained 35.79% of the full variability. Sequential "Type I" ANOVA (n permutations = 10,000) further revealed that the effect of SNAQ scores ($F_{1,325} = 153.151$, $p < 0.0001$), education ($F_{1,325} = 6.756$, $p = 0.0012$), and order of the task ($F_{1,325} = 18.560$, $p < 0.0001$) on fear scores were significant. In the case of disgust scores, only the SNAQ ($F_{1,327} = 169.627$, $p < 0.0001$) and DS-R ($F_{1,327} = 5.440$, $p = 0.0046$) scores were significant. Therefore, we have also tried to recalculate the analysis using scores on three individual DS-R subscales known as core, animal reminder, and contamination-based disgust instead of DS-R total scores. The reduced model revealed again the effect of SNAQ scores ($F_{1,327} = 171.817$, $p < 0.0001$), but out of the three disgust subscales, only core disgust has proved significant ($F_{1,327} = 8.331$, $p = 0.0003$). Interestingly, this model better explained the full variability than the one using DS-R total scores (35.73 vs 34.87%, respectively). For more details, see **Table 2** and **Figures 2A,B**.

Analysis of Mean Scores

Next, we analyzed the effect of dimension (i.e., the emotion according to which the set was scored) and set (D vs F snakes) in relation to snake fear. For each respondent within the high-fear and low-fear category, we computed mean fear scores (fear) and mean disgust scores (disgust) separately for disgust-evoking snakes (D) and fear-evoking snakes (F; these variables are further referred to as fear-D, fear-F, disgust-D, and disgust-F). Friedman tests revealed that the effect of combination of dimension and set on mean scores was highly significant for both high-fear subjects (Friedman chi-squared$_3$ = 123.57, $p < 0.0001$) and low-fear subjects (Friedman chi-squared$_3$ = 234.94, $p < 0.0001$). Furthermore, we performed pairwise comparisons within each

TABLE 2 | PCA and RDA results of the fear and disgust scores and ranks.

	Fear scores	Disgust scores	Fear ranks	Disgust ranks
% Explained				
Constrained%	35.79%	34.87%	2.34%	2.30%
No. RD axes	4	2	1	1
RD1	30.91%	34.21%	2.34%	2.30%
RD2	4.71%	0.66%	–	–
Eigenvalues				
RD1	92.61	118.77	221.83	365.02
RD2	14.11	2.28	–	–
PC1	90.89	101.17	0.38	0.68
PC2	58.40	75.74	0.33	0.45
ANOVA *p*-values				
SNAQ	<0.0001	<0.0001	0.0005	0.0003
DS-R	–	0.0046	–	–
Task order	<0.0001	–	–	–
Education	0.0012	–	–	–
Age	0.0605	–	–	–

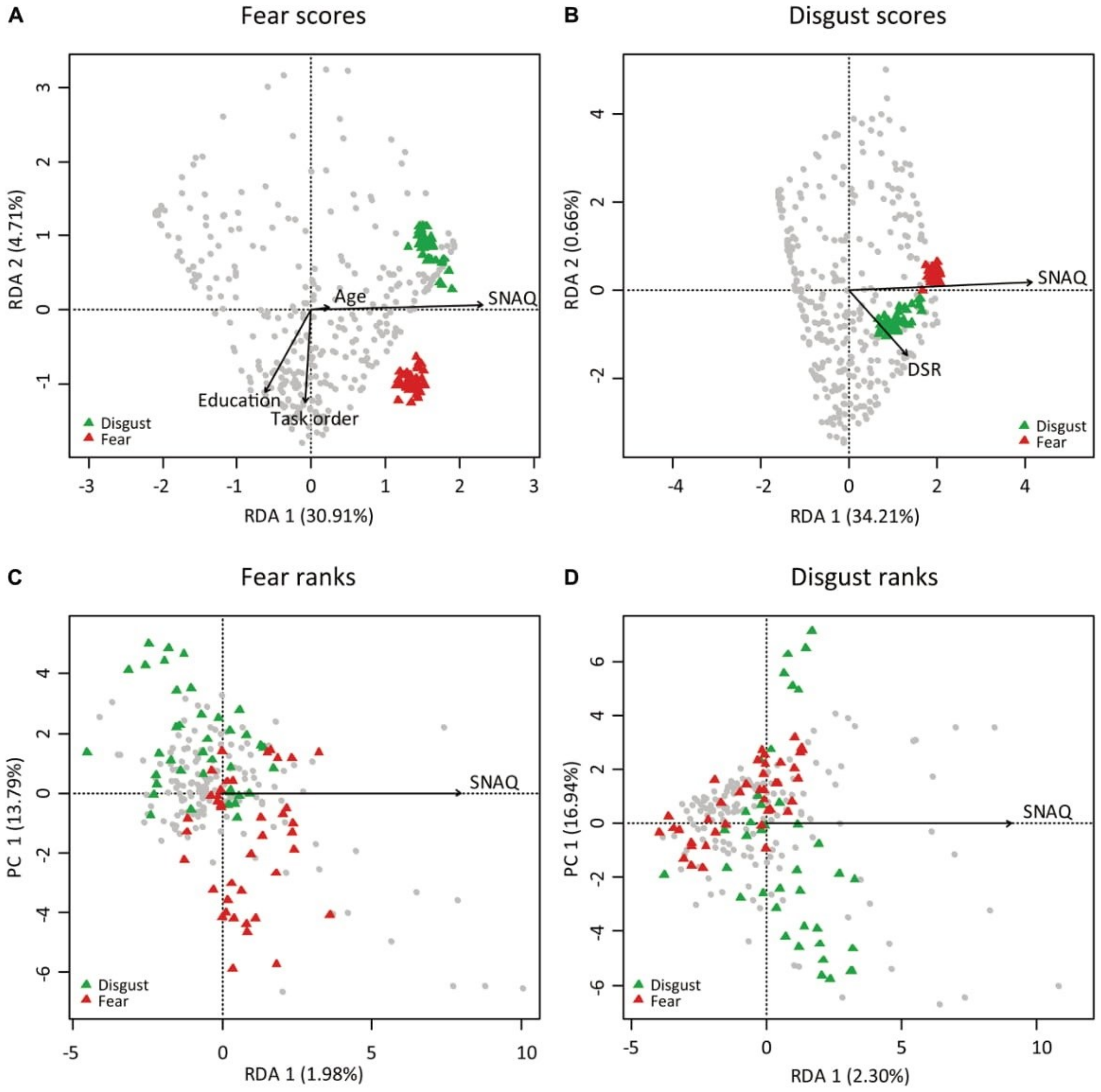

FIGURE 2 | Redundancy analysis (RDA) of the respondents characteristics determining their ratings [scores **(A,B)** and rank-orderings **(C,D)**] of fear and disgust elicited by snake stimuli. The colored triangles refer to the pictures of fear-eliciting snakes (red) and disgust-eliciting snakes (green). In all cases, the effect of SNAQ scores was a significant predictor (ANOVA). However, in the case of Likert-type scoring **(A,B)**, the effect was much higher than in the case of the rank-ordering, because the latter method uses relative ranks and minimizes variability among the respondents. It is thus more suitable for analyses of variability among the stimuli.

respondents' group using the *post hoc* Nemenyi test. Within the low-fear subjects, all comparisons were highly significant (all $p < 0.0001$) except for disgust-D vs fear-F, which was significant at the $p = 0.037$ level, and disgust-F vs fear-D, which was not significant. Within the high-fear subjects, all comparisons were highly significant (all $p < 0.0001$) except for disgust-F vs fear-D and disgust-D vs disgust-F, which were not significant.

We then analyzed the mean scores outside of the groups using the Mann–Whitney U-tests, which revealed that all comparisons were highly significant (all $p < 0.0001$); disgust-F: $U = 3484.5$, $r^2 = 0.402$; disgust-D: $U = 7052.5$, $r^2 = 0.164$; fear-F: $U = 4877.0$, $r^2 = 0.297$; fear-D: $U = 4550.5$, $r^2 = 0.320$). For a graphical summary, see **Figure 3A**.

Rank-Ordering Data

PC Analysis

Principal component analyses of the fear and disgust ranks were also very similar to each other: each analysis generated 79 axes, none of which had the eigenvalue higher than 1. The first and second axes explained 12.55 and 11.31% of the full variability in the case of fear ranks and 16.99 and 12.55% of the full variability in the case of disgust ranks.

Agreement Among the Respondents

In the case of the rank-ordering data, agreement of the respondents was very high in both fear (ICC = 0.997 for average-measure, 0.683 for single-measure) and disgust (ICC = 0.996 for average-measure, 0.606 for single-measure) evaluations (all

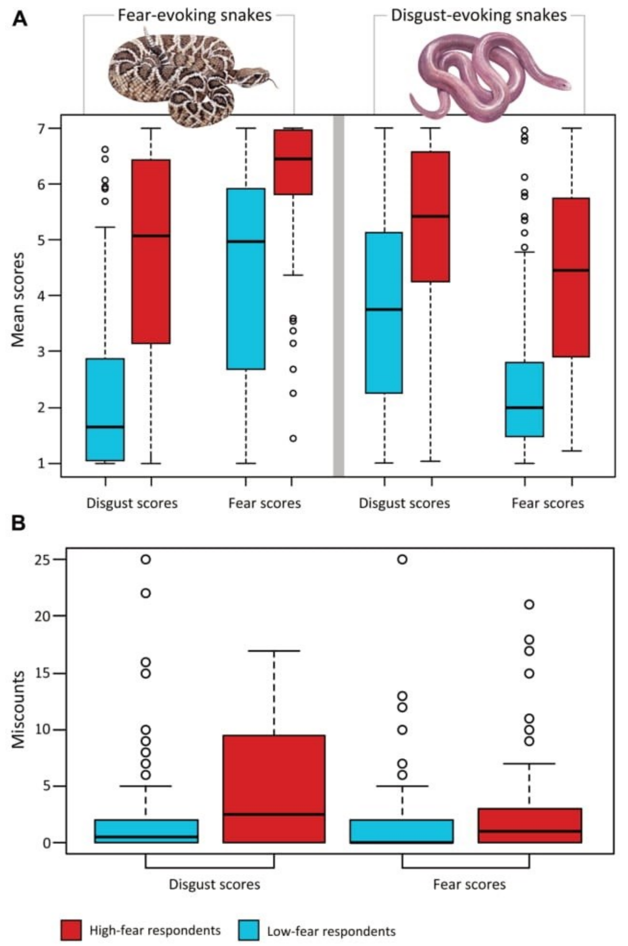

FIGURE 3 | Comparison of snake ratings of high-fear and low-fear respondents. **(A)** The effect of combination of dimension (fear and disgust scores) and set (fear-evoking and disgust-evoking stimuli) on mean scores was highly significant for both high-fear subjects and low-fear subjects (both $p < 0.0001$). A *post hoc* Nemenyi test revealed that within the low-fear subjects, out of six comparisons, only one was not significant (disgust-F vs fear-D, the capital letter marks stimulus category). In the case of the high-fear subjects, disgust-F vs fear-D and disgust-D vs disgust-F were not significant. All comparisons outside of the high-fear and low-fear groups were highly significant (all $ps < 0.0001$). **(B)** Analysis of miscounts: SNAQ scores affected the number of miscounts (i.e., how many times a respondent misplaced snake from one category into the other category; $p = 0.0005$); the high-fear subjects misplaced the snake out of its category more often than low-fear subjects, regardless of the dimension of rank-ordering.

$p < 0.001$). These results are in agreement with the Kendall's coefficients of concordance as provided in Rádlová et al. (2019) and show that the respondents were reliably able to sort the snakes into their respective groups (i.e., sorted most of the fear-evoking snakes as the first most fear-evoking when ranking the set according to the evoked fear, etc.).

Variability Among Respondents

In the analyses, we used data about the age, gender, education, and task order from Rádlová et al. (2019) as well as the newly collected SNAQ and DS-R scores. A multivariate multiple regression analysis of the fear ranks revealed that only the effect of age (Pillai's Trace = 0,659, $F_{1,78}$ = 1.734, $p = 0.0100$) and task order were significant (Pillai's Trace = 0.628, $F_{1,78}$ = 1.516, $p = 0.0389$). Mann–Whitney U-tests revealed that after Bonferonni correction, the significant effect of task order remained in only one snake, the *Austrotyphlops diversus*, which was rated as more fear-eliciting by the respondents that were first to rank the pictures according to elicited disgust (U = 1955.5, r^2 = 0.085, $p = 0.0003$). A corresponding regression analysis of the effect of age, gender, SNAQ and DS-R scores, education, and order of the task on the disgust ranks revealed no significant effect of any of these factors.

A redundancy analysis of the fear and disgust rankings did not confirm the regressions. Only the SNAQ scores significantly explained the rankings, but the effect was very small: the constrained axes explained 1.98% in the case of fear ranks (ANOVA: $F_{1,152}$ = 3.062, $p = 0.0005$) and 2.30% in the case of disgust ranks (ANOVA: $F_{1,152}$ = 3.574, $p = 0.0003$; see **Table 2** and **Figures 2C,D**).

Analysis of Miscounts

Although the rank-ordering task required only sorting the pictures according to the given dimension, the respondents were able to unconsciously categorize the snakes by clustering together the 40 fear-evoking snakes as the top 40 fear-evoking ones and the 40 disgust-evoking snakes as the bottom 40 fear-evoking ones (Rádlová et al., 2019). In the case of disgust dimension, the results were similar but opposite. Whenever the respondent misplaced a snake outside of its place (category), we counted this as a miscount. The total number of miscounts was collected for each respondent and further analyzed. In the subsequent glm analysis, we examined the effect of dimension, SNAQ score, and their interaction to the number of miscounts (quasipoisson model). The results revealed that only the SNAQ scores affected the number of miscounts ($p = 0.0005$); the high-fear subjects misplaced a snake out of its category more often than low-fear subjects, regardless of the dimension of rank-ordering (**Figure 3B**).

DISCUSSION

Generality/Specificity of Snake Stimuli

In the previous study (Rádlová et al., 2019), although uninstructed to do so, the respondents clearly assorted the mixed set of fear- and disgust-eliciting snakes into their respective, distinct categories. And although such results suggested that the fear-eliciting snakes do not elicit any disgust and the disgust-eliciting snakes do not elicit any fear, one could not be entirely sure as the evaluation was done using a relative scale. In this study, we confirmed that this was true for low-fear subjects by asking the participants to score the same set of mixed F-D snake stimuli on an absolute scale. The results showed that the fear-eliciting snakes received significantly much higher scores of fear and lower scores of disgust than the disgust-eliciting snakes, for which the opposite was true. Moreover, the fear scores of the D-snakes and disgust scores of the F-snakes did not significantly differ from each other – both were very low and indicated that the F-snakes elicited no disgust and D-snakes elicited no fear. In comparison, the same scores given by the high-fear respondents also did not differ significantly from each other, but both were significantly higher than those of the low-fear respondents. In other words, high-fear respondents find snakes that usually (i.e., in people with normative fear) evoke no disgust disgusting and snakes that usually evoke no fear fear-evoking (**Figure 3**). These results suggest that both fear and disgust propensity are involved in high snake fear (and possibly phobia). Moreover, disgust elicited by the F and D snakes did not significantly differ, which points out that the high-fear respondents do not distinguish between the two categories of snake types when considering their emotional effect. However, they still distinguish the F snakes as significantly more fear-eliciting than the D-snakes.

Analysis of the number of miscounts from the rank-ordering data also confirmed that the high-fear respondents partially lose the ability to distinguish between the two snake categories as they misplaced the snakes from one category into the other category significantly more often than the low-fear subjects.

Contribution of Fear and Disgust to Snake Fear

Klieger and Siejak (1997) argue that the SNAQ is not a good measurement of snake fear because it is strongly biased by false positives. These authors found out that respondents undergoing a behavioral approach test (BAT) with a live snake often facially expressed disgust, and performed a study examining the relationship between SNAQ scores and disgust determined using various measurements. They showed that many respondents with high SNAQ scores actually approached the live snake during the BAT with no avoidance and their results suggested that it was either because the SNAQ was affected by disgust of snakes or because fear and disgust might be inseparably connected in this case.

In our study, we asked the respondents to rate both fear and disgust of snakes and compared these data with their SNAQ and DS-R scores. The DS-R scores seem to be a good measurement of disgust propensity because it affected only the scores of disgust of snakes. However, the SNAQ scores affected scoring and ranking of both fear and disgust and thus it is in agreement with Klieger and Siejak's (1997) hypothesis that the SNAQ reflects the two emotions elicited by snakes (see also Wiens et al., 2008, where disgust sensitivity correlated with the SNAQ score). Moreover, our results show that when scoring and rank-ordering the snake pictures according to perceived disgust, the high-fear (high-SNAQ) respondents are not able to distinguish between the particular snake morphotypes. This may be due to the fact that high-fear respondents feel strong disgust not only from the disgust-eliciting snakes, but also from the fear-eliciting ones (vipers), otherwise rated as not-disgusting at all by low-fear respondents. Similar results were found in Polák et al. (2019b), where respondents with high SNAQ scores rated both the venomous viper and harmless grass snake as strongly fear- and disgust-eliciting. In comparison, low-SNAQ respondents only rated the viper as fear-eliciting.

Another explanation of this phenomenon is that the high-fear respondents cannot distinguish the emotions and only evaluate the snakes according to negative valence (Barrett, 2006; Barrett and Wager, 2006). It may be possible that simply seeing the snake stimuli made the high-fear respondents feel miserable (cf. core affect, Russell and Barrett, 1999), which in turn affected the overall evaluation negatively, but it was still hard for the respondents to assign a particular emotional label to a single snake.

Are Likert-Scale and Rank-Ordering Data Comparable in Evaluation of Perceived Snake Fear and Disgust?

In this paper, we tested the self-reported emotional reactions toward snake pictures using the Likert scale, and we compared the results with those of the rank-ordering scale used in Rádlová et al. (2019). Each method has its advantages and disadvantages, and should be thus used in purposely designed experiments. The absolute Likert-type scale is sensitive to the differences between respondents and is better to be used in experiments in which differences between two groups of respondents, e.g., low- and high-fear respondents like in this paper, are the main focus of interest. However, when a study uses a block of similar stimuli that is treated and measured as a single condition (e.g., studies involving eye-tracking, reaction time, EEG, fMRI), a thorough examination of the variability among the stimuli is needed to ensure that each stimulus within the block has the same properties of interest. Failing to do so may lead to high noise, skewed results, or even a wrong interpretation. And for this, the rank-ordering method is optimal as it maximizes the variability among the stimuli (Rádlová et al., 2019). However, relative ranks minimize the variability among respondents and are thus unsuitable for studies focused on the factors behind respondents' variability. Here we compare both methods to further illustrate the impact of each of them on the results of respondents' characteristics including the age, gender, SNAQ and DS-R scores, education, and order of the task.

The regression analyses of the rank-ordering data revealed no effect of the respondents' variables on the disgust ranks, and also revealed only the effect of age and order of the task on the fear ranks. However, these effects were not strong enough to survive a different type of analysis: the RDA only revealed the effect of SNAQ in both cases, and it was very small (1.81 and 2.34%). These results point out that there is only a little difference between the respondents on the relative order of the ranked stimuli. Similar results were presented in other studies using the rank-ordering method and analyzing not only snake stimuli (Marešová and Frynta, 2008; Marešová et al., 2009a,b; Matchett and Davey, 1991; Frynta et al., 2011; Landová et al., 2012; Ptáčková et al., 2017), but also other animals (Frynta et al., 2009, 2010, 2013; Lišková et al., 2015). In other words, if a viper is ranked as more fear-evoking than a blind snake, the order stays the same (Landová et al., 2018), even if a high-fear respondent finds both snakes much more fear-evoking than a low-fear respondent. Similarly, in our study, all respondents regardless of age, gender, or order of the task ranked the D-snakes as very disgusting (grouping them together) and the F-snakes as very fear-evoking. However, although the effect of the SNAQ score is small, it still leads to significantly larger number of miscounts in high-fear respondents who tend to rank the F-snakes as more disgusting.

When compared to the absolute scale data, the analyses revealed much higher effect of the respondents' characteristics on both fear and disgust scores: according to the RDA, SNAQ, age, education, and order of the task together explained as much as 35.79% of the full variability of the fear scores and the SNAQ and DS-R together explained 34.87% of the variability of disgust scores. The SNAQ scores, in both cases building the RD1 axis, had the highest effect (**Figure 2**): the high-fear respondents scored all of the snake stimuli much higher than the low-fear respondents. Moreover, respondents with biological education scored the F-snakes as less disgusting and the D-snakes as less fear-evoking. In comparison, Prokop and Tunnicliffe (2008) found the effect of knowledge only on the attitudes toward non-feared animals (bats), but not phobia-related animals such as spiders. The authors argued that public awareness is not enough to improve attitudes toward animals that were associated with danger in human evolutionary history, and Tomažič (2011) found that knowledge of snakes does not affect fear of these animals. However, biologically educated people do not necessarily need to have a higher knowledge than non-biologists (Tomažič, 2011), and it is thus possible that it was rather their higher experience with live animals that affected the scores (Ballouard et al., 2012). This has been recently corroborated by Coelho et al. (in prep.) who reported that people having more experience with snakes and those bitten by a snake show lower snake fear.

When taken together, the results of both methods show not only that the high-fear respondents give overall higher scores to all of the snake stimuli, but also that they treat the D-snakes and F-snakes differently: they tend to rank the F-snakes as more disgusting and the D-snakes as more fear-eliciting than the low-fear respondents do. This difference between snake-fearful subjects and controls might form a new pictorial assessment of snake phobia. Moreover, we found that not only fear but also disgust contributes to high snake fear. Thus, a therapy focused on both of these emotions, not just fear, could lead to better treatment outcomes.

CONCLUSION

The results of this study confirmed those reported in Rádlová et al. (2019): the fear-eliciting (F) snakes received high scores of fear and low scores of disgust, while the disgust-eliciting (D) snakes received high scores of disgust and low scores of fear. Thus, human respondents are apparently able to distinguish these characteristic snake morphotypes (and possibly many others) and respond accordingly to each. Additionally, we found that high-fear respondents gave high scores of both fear and disgust to all snakes, and also miscounted snakes within each category more often than low-fear respondents, partially dissolving the boundaries of both categories. Thus, while it is natural to fear dangerous snakes, high-fear (or phobic) respondents do not only experience more intense fear (and/or disgust), they also attribute a strong emotional charge to stimuli otherwise considered safe. This might suggest that both sensitivity (i.e., high-fear respondents report more intense fear of fear-eliciting snakes than low-fear respondents) and propensity (i.e., high- vs. low-fear respondents are more likely to rate fear-eliciting snakes as highly disgusting and disgust-eliciting snakes as highly frightening) play a role in acquisition and maintenance of snake fear.

Finally, it is noteworthy that our results might have important clinical implications. So far, one of the most recommended therapeutic interventions in snake phobia, a cognitive behavioral therapy, is mostly focused on effective fear management. However, our data provide evidence that individuals with high fear of snakes experience not only elevated fear, but disgust as well, which is partly in agreement with the disease-avoidance model by Matchett and Davey (1991). Therefore, shifting focus by incorporating the disgust propensity and sensitivity component into the treatment model for snake phobics might potentially lead to improved therapeutic outcomes.

LIMITATIONS OF THE STUDY

One of the limitations of the study emerges from the data collection method. It is well known that even though online surveys may collect extensive amount of data in a short time, these are less reliable than data from research conducted in contact with individual respondents that allows for more clarifications or corrections. Furthermore, self-reports may be often biased due to demand characteristics pertaining to the individual tendency to comply with the researcher's expectations or attempts to present oneself in a better light based on social expectations. Therefore, within a distant and anonymous setting of online testing, the subjects with various motives are more likely to provide distorted or randomly fabricated answers that are difficult to be identified.

The second limitation may be related to the unbalanced gender ratio. Sex differences in fear and disgust (not only of snakes) is a trend continuously demonstrated throughout the psychology research. This was also the reason we had the unbalanced gender ratio within our sample, because we selected our respondents *based* on the SNAQ scores. However, when we balanced the gender in a sub-sample based on the SNAQ scores, there was no effect of gender on fear scores of the snake stimuli, and only weak (not very robust) effect of gender on disgust scores. These results mean that even though women have higher SNAQ scores and/or fear snakes more often, women and men with the same SNAQ scores rate the snake stimuli similarly. This is a very important result for further studies in which fear is the main focus, e.g., specific snake phobia (there are also male phobics and they do not differ in their fear pattern from female phobics).

DATA AVAILABILITY STATEMENT

The datasets generated and/or analyzed during the current study are available in the Mendeley repository: doi: 10.17632/ksy5z9z3fh.2.

ETHICS STATEMENT

This study was reviewed and approved by the Institutional Review Board (IRB), Faculty of Science, Charles University, approval n. 2013/7, and by the Ethical Committee of the National Institute of Mental Health n. 55/16. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

DF and EL contributed to the conception and design of the study. MJ, KS, ŠP, SR, and JP organized the database and performed the research. SR and DF performed the statistical analysis. SR wrote the first draft of the manuscript. DF and JP wrote sections of the manuscript. All authors contributed to the manuscript revision, read and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.00031/full#supplementary-material

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Association Between Fear and Beauty Evaluation of Snakes: Cross-Cultural Findings

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According to the fear module theory, humans are evolutionarily predisposed to perceive snakes as prioritized stimuli and exhibit a fast emotional and behavioral response toward them. In Europe, highly dangerous snake species are distributed almost exclusively in the Mediterranean and Caspian areas. While the risk of a snakebite is relatively low in Central Europe, Azerbaijan, on the other hand, has a high occurrence of the deadly venomous Levant viper (*Macrovipera lebetina*). We hypothesize that co-habitation with this dangerous snake has shaped the way in which humans evaluate snake species resembling it. For that purpose, we asked respondents from the Czech Republic and Azerbaijan to rank photographs depicting 36 snake species according to perceived fear and beauty. The results revealed a high cross-cultural agreement in both evaluations (fear $r^2 = 0.683$, $p < 0.0001$; beauty: $r^2 = 0.816$, $p < 0.0001$). Snakes species eliciting higher fear tend to be also perceived as more beautiful, yet people are able to clearly distinguish between these two dimensions. Deadly venomous snakes representing a serious risk are perceived as highly fearful. This is especially true for the vipers and allies (pit vipers) possessing a characteristic body shape with a distinct triangular head and thick body, which was found as the most fear evoking by respondents from both countries. Although the attitude toward snakes is more negative among the respondents from Azerbaijan, their fear evaluation is similar to the Czechs. For instance, despite co-habitation with the Levant viper, it was not rated by the Azerbaijanis as more fearful than other dangerous snakes. In conclusion, agreement in the evaluation of snake fear and beauty is cross-culturally high and relative fear attributed to selected snake species is not directly explainable by the current environmental and cultural differences. This may provide some support for the evolutionary hypothesis of preparedness to fear snakes.

Keywords: attitude to snakes, cross-cultural study of emotions, envenoming, fear of snakes, perception of animal beauty, snakebites, viperidae

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INTRODUCTION

Detection and an appropriate reaction to dangerous animals and other life threatening stimuli were necessary for human survival (Barkow, 1992; New et al., 2007). Even in contemporary humans, animal species receive considerably more attention over other stimuli (Altman et al., 2016; Calvillo and Hawkins, 2016; but see Hagen and Laeng, 2016). For example, people are able to rapidly detect various potentially dangerous animals eliciting fear (Tipples et al., 2002; Yorzinski et al., 2014). Öhman and Mineka (2001) proposed the existence of an evolutionary fear module, a complex system consisting of neural, psychophysiological, and behavioral reactions to potentially life-threatening stimuli, particularly those evolutionary relevant. However, all stimuli evoking emotions, in general, attract attention more than neutral stimuli (Vuilleumier, 2005).

Of all the dangerous animals that human ancestors frequently encountered and feared in their environment, snakes have been used as an example of a prototypical stimulus activating the hardwired neural circuitry of fear (Öhman and Mineka, 2003) and their role as a significant selection pressure seems plausible. Throughout the course of evolutionary history venomous snakes presented a real threat (Öhman and Mineka, 2001; Öhman et al., 2001; Isbell, 2006; LoBue and DeLoache, 2010; LoBue and Rakison, 2013) requiring a rapid detection. This drove human ancestors to evolve attentional bias to snakes and similar survival endangering stimuli (Lipp and Waters, 2007). This has been demonstrated in visual search tasks when both adults, as well as 3-year-old children, visually detected snakes more rapidly than other kinds of stimuli (LoBue and DeLoache, 2011). Interestingly, reactions to snake stimuli are even faster than to spiders (Soares et al., 2009), which are both common phobic objects (Davey, 1994). It is the snake body shape (LoBue and DeLoache, 2011) and bright colors (Hayakawa et al., 2011; Landová et al., 2012) together with other typical snake characteristics (LoBue, 2014; Janovcová, 2015) that enhance the fast and accurate visual detection (LoBue et al., 2014). High attentional bias combined with innate (Weiss et al., 2015) or learned fear of snakes (Mineka et al., 1980; Cook et al., 1985; Cook and Mineka, 1989) in many primates including humans allow for quick associations between snake cues in the environment and an appropriate behavioral reaction to the imminent threat (Van Le et al., 2013; LoBue, 2014).

Tierney and Connolly (2013) note in their comprehensive review that, due to methodological reasons, ontogenetic and comparative studies of snake fear are not conclusive and fully comparable. Thus, we are not certain if snake fear has an evolutionary basis only. However, Van Le et al. (2013) reported the existence of neurons in the medial and dorsolateral pulvinar of macaques that responded faster and stronger to snake stimuli than to monkey faces and other objects. These results further support the evidence that primates (Van Le et al., 2013, 2014) as well as humans (Van Strien et al., 2014; Almeida et al., 2015) possess a neurobiological substrate for a rapid detection of snakes as threatening visual stimuli. They also corroborate the evolutionary perspective that snakes have shaped the evolution of the visual system in the primate lineage (Isbell, 2006). The question remains, however, to what extent these evolutionary based attentional biases coincide with the current level of danger represented by snakes in specific geographical regions and how these both factors influence emotions evoked by snakes.

Some colubroid snakes in Africa and Asia have evolved a potent venom delivery system (Vidal and Hedges, 2002); the highly venomous snakes include viperids and elapids (Fry et al., 2006). Interestingly, this innovation coincided with the appearance of rodents and primates (reviewed in Isbell, 2006). For example, it is now agreed that viperids and anthropoid primates evolved together in the Old World and thus share a long history of co-evolution (Keogh, 1998; Beard, 2002; Miller et al., 2005). The major threat pertaining to snakes is currently the risk of envenoming especially in some regions like South and Southeast Asia and Sub-Saharan Africa (Swaroop and Grab, 1954; Chippaux, 1998). Nowadays, venomous snakebites are still an important cause of human injuries and even deaths in some countries. A global estimate for the occurrence of envenomings per year is 421,000–1,841,000 cases resulting in 20,000–90,000 deaths (Kasturiratne et al., 2008). However, the statistical estimates are based on records reported by doctors or data about compensation for the farming community (various accidents including snakebites). Even if all these factors are taken into account, the data might still be underestimated for developing countries or for regions where no exact information about snakebites epidemiology and subsequent injuries is available. Besides that, constrictor non-venomous snakes were for a long time significant predators of primates and human ancestors and even now may represent a serious danger to humans. It has been shown on Agta Negritos, a preliterate society of hunter-gatherers in the Philippines, that 26% of adult males survived predation attempts by large constrictors, specifically the reticulated python (Headland and Greene, 2011).

The danger of a particular snake species for humans varies with the efficiency of venom and its delivery system, the snake's size, aggressiveness, and the probability of encounter with humans. In North, Central, and Western Europe, only small venomous species of vipers can be found, such as the common European adder (*Vipera berus*, **Figure 1A**). More dangerous is the nose-horned viper (*Vipera ammodytes*), but its distribution is mainly in South-Eastern Europe. Envenoming by the common adder results in tachycardia, dizziness, hypotension, shock, and gastrointestinal symptoms, coagulopathy and neutrophil leucocytosis (Malina et al., 2008). However, in the last 20 years, there has be no reported death caused by this snake in the Czech Republic (Valenta, 2008). Contrastingly, highly dangerous snake species of Europe are distributed almost exclusively at its eastern border, in the Caspian region (Chippaux, 2012). The most important snake species causing the most of envenomings and subsequent deaths in Azerbaijan is the Levant viper (*Macrovipera lebetina*, **Figure 1B**). Bites of the Levant viper are far more dangerous compared to the common adder and provoke serious symptoms such as oedema, hypotension shock, hemorrhage, tissue necrosis, and melanoderma (Göçmen et al., 2006). In Azerbaijan, 106 cases of bites and one death caused by this species were reported since April to October in 2016 (Bakhshaliyeva, unpublished data); for more information about snakes in this region (based on Bannikov et al., 1977; Coborn, 1991; Schultz, 1996; Amr et al., 1997; Khan, 2002; Spawls et al., 2002; Marais, 2004; El Din, 2006; Egan, 2007; Valakos et al., 2008; Stojanov et al., 2011; Wallach et al., 2014) and their dangerousness (based on Brown, 1973; Weiser et al., 1984; Spawls et al., 1995; Mallow et al., 2003; Abdel-Aal and Abdel-Baset, 2010; Weinstein et al., 2011; Nalbantsoy et al., 2012, 2013; Hossie et al., 2013; Yousefkhani et al., 2014; Samy et al., 2015; Steinhoff, 2017) see Supplementary Tables 1, 2.

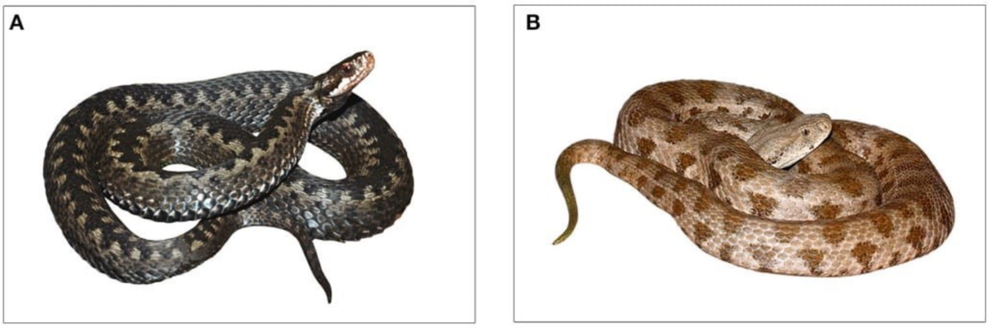

FIGURE 1 | The most dangerous species of venomous snakes in each country: **(A)** the common European adder (*V. berus*) from the Czech Republic, original photo Pavel Kirillov, standardized version; **(B)** the Levant viper (*M. lebetina*) from Azerbaijan, original photo Omid Mozaffari, standardized version. We predict that these snakes should elicit the highest fear in the Czech Republic and Azerbaijan, respectively.

Snakes are an ambivalent stimulus perceived as a source of actual or evolutionary fixed danger that attracts specialized attention and triggers fear. Together with a negative picture caused by the media, this may result in negative attitudes toward snakes in both adults (Pandey et al., 2016) and children (Yorek, 2009; Ballouard et al., 2013), including snake killing (Pandey et al., 2016). It has been demonstrated that more negative attitudes toward snakes may be associated with a higher risk of snakebite in the specific region. In South-Eastern Australia, for example, where most of the snakes are highly venomous, one-third of encountered snakes are killed by local people (Whitaker and Shine, 2000). However, especially children attitudes toward snakes vary in different countries and may be modified by targeted educational programs (Ballouard et al., 2012, 2013). On the other hand, snakes are seen as positive divinities in some countries, a source of meat, or a part of traditional medicine (Alves et al., 2012).

In contrast to the cross-cultural variation in negative attitude toward snakes (Ballouard et al., 2013), evidence shows that humans express a universal, cross-cultural agreement in how they evaluate beauty of some snake species (Frynta et al., 2011) which might be closely connected with positive emotions such as joy (see a meta-analysis by Kühn and Gallinat, 2012). Although perceived beauty and fear of snakes may correlate (Janovcová, 2015), these two form distinct dimensions so beauty of a snake cannot fully explain the level of fear it evokes, as we found in king snakes (Landová et al., 2012).

Here we hypothesize, that despite the evolutionary preparedness model, the risk of a snakebite in a given locality is an important predictive factor modulating negative or positive evaluation of snakes. People living in a region with a low abundance of dangerous snakes might have less negative attitudes toward them and experience fear of snakes differently than people living in a country where venomous snakes are more numerous. Therefore, the relationship between the perceived danger, emotions underlying the evaluation of fear, and attitudes toward snake species in different countries warrant future research. To study this effect, we recruited participants from two countries with a considerably different risk of envenoming. Only five species of snakes live in the Czech Republic, four of them are non-venomous and only one presents a potential though moderate danger to humans. Contrary to that, 32 species of snakes live in Azerbaijan and some of those are deadly venomous.

The aims of this study are as follows:

1. As the risk of a bite by venomous snakes is considerably lower in the Czech Republic compared to that in Azerbaijan (the area with a high occurrence of the deadly venomous Levant viper), we expect that the fear response will also be qualitatively different in these two countries. We hypothesize that co-habitation with the highly dangerous viper in Azerbaijan shaped human fear evaluation of snake stimuli resembling it.
2. Furthermore, some animals may trigger more than one emotion at a time, e.g., fear linked to a potential threat and pleasure associated with the perception of animal beauty (Landová et al., 2012). Both fear and perceived beauty could influence the way we view animals, and therefore, we have decided to include the evaluation of snake beauty as a control task to fear rankings. This would allow us to disentangle these two judgements and identify whether snake fear and beauty evaluations form two separate dimensions or are in any way interlinked through a general categorization process as we have previously found in the king snakes (Landová et al., 2012). Contrary to fear, we expect a high cross-cultural agreement in snake beauty evaluation, similarly to already reported results on boid snakes (Marešová et al., 2009a; Frynta et al., 2011).
3. An important question that remains unstudied is what accounts for human evaluation of specific snake species as fear or beautiful evoking. Here we suggest that specific features of snakes' appearance lead to their evaluation as "dangerous" and more fear evoking while other features are linked to the positive evaluation of snake beauty. In the study reported here, we examined morphological (body form), color, and other visual features of snake photo stimuli that account for specific fear and beauty ranking.
4. Evaluation of animals by humans might be influenced by sociodemographic factors such as formal education and gender or previous personal experience. In this study, we

could analyze the effect of gender and type of education (biological vs. non-biological) on human fear and beauty evaluation of snakes.

5. Finally, as the risk of a venomous bite influences attitudes toward snakes in some countries (Ballouard et al., 2013; Pandey et al., 2016), we also asked our respondents in the Czech Republic and Azerbaijan how much they liked snakes and if they have experienced snake killing. If the attitude was similarly negative in both countries, then we could assume that humans possess an innate "fear module" influencing their mental representation of snakes as dangerous animals, even though some of them (especially the Czech respondents) have never risked a venomous snakebite in their life.

MATERIALS AND METHODS

Participants

In total, 104 individuals (50 men and 54 women) from the Czech Republic (CZ) and 100 individuals (38 men and 62 women) from Azerbaijan (AZ) were included in the study. We recruited the Czech respondents among undergraduate students from Charles University and University of South Bohemia and their families. Similarly, the Azerbaijani participants were recruited among the undergraduate students and staff of Baku State University together with their families. This has been driven by the need for a homogenous and comparable sample of respondents in both countries that would be attentive enough to complete the task (see the Discussion for more details).

The mean age of Czech respondents was 30.00 ± 1.67 and 30.46 ± 1.45 years, for men and women, respectively. Similarly, the mean age of men and women respondents from Azerbaijan was 31.16 ± 2.46 and 20.79 ± 1.67, respectively. More than a half of the respondents completed a bachelor degree in biology (55 Czechs and 78 Azerbaijanis) or another university degree, only 12 Azerbaijani and 28 Czech individuals had a secondary high school education. All subjects gave their written informed consent in accordance with the Declaration of Helsinki and then filled a questionnaire written in their native language (Czech or Azeri) asking for their gender, age, family membership, attitude toward snakes, and experience with them (see Supplementary Table 3 for an English translation of the form and more details below). The study has been approved by the research ethics committee of Charles University and National Institute of Mental Health.

Attitude Toward Snakes

Based on the most frequent spontaneous responses given in our previous research in the Czech Republic and Azerbaijan, attitude toward snakes was measured using a 7-point Likert scale from 1 ("I like snakes, I would like to breed them at home") through 4 (neutral) up to 7 ("I hate snakes/I fear them). We also asked the respondents whether they have ever encountered a real snake and if so, to give more details ("How and where have you met snakes?"). We also asked if they have ever killed a snake or seen someone else killing a snake. The responses were coded as either 1 = Yes or 0 = No.

Stimuli

We examined a list of extant snake species inhabiting Europe, the Mediterranean and Caspian area (Uetz et al., 2015). For this study, we selected 36 species covering the main morphological diversity and all major phylogenetic lineages. The included species belong to 6 families and 29 genera (Pyron et al., 2013; Uetz et al., 2015; for more information about the tested snakes, see Supplementary Table 1). To test perceived fear and beauty, we developed a standardized set of 36 photographs depicting these species, each representing a typical adult individual in a resting position. In addition, we included a control photograph of the Egyptian cobra (*Naja haje*) in a striking posture for a comparison with the resting position picture. The photos were adapted from books and internet sources (for sources and other information, see Supplementary Table 4). We digitally set the pictures of snake bodies on a white background, resized them to a comparable size (regardless of their real size) using GIMP2.8.16 (GNU Image Manipulation Program. Spencer Kimball, Peter Mattis et al., 1995 – 2015), and printed them in a 10 × 15 cm format. It has been previously demonstrated that photos may reliably substitute live snakes (Landová et al., 2012).

Stimuli Ranking According to Fear and Beauty

The respondents were instructed to sort the photographs of live snakes so that the "most beautiful" species would be on the top of the pack, the second "most beautiful" under, etc., until the last selected species at the bottom of the pack. After a short break (∼5 min) they were asked to sort the photographs again, this time according to perceived fear. No time limit was set for performing both tasks. Each photograph's rank in the pack according to fear and beauty provided by the respondents was further examined. The ranks were square-root arcsin-transformed to increase the importance of the distribution tails and to improve normality. Mean values of the transformed ranks were used further as a scale for perceived fear and beauty of snakes (the higher the value the lower the perceived fear or beauty). These fear and beauty scales were calculated separately for the Azerbaijani and Czech respondents and further correlated to assess similarities in the fear and beauty evaluations of snakes in the two countries.

Extraction of Morphological and Color Characteristics

We measured morphological characteristics of the depicted species, specifically the body length, head width and length, tail width, neck width, and the eye diameter, using the software Image Tool 3.1 (Wilcox et al., 2002). All the values were measured in millimeters and log-transformed for further analyses. Color properties of the stimuli, namely the proportional ratio of chromatic and achromatic colors, the mean and standard deviation of lightness and saturation and the complexity of lightness pattern, were extracted using the software Barvocuc (for a more detailed description of the software see Lišková and Frynta, 2013; Lišková et al., 2015; Rádlová et al., 2016).

The hue values (defined in the HSL color space) for chromatic colors were pre-defined using the following angles: red (<330°; 17°), orange/brown (<17°; 39°), yellow (<39°; 67°), green (< 67°; 180°), blue (<180°; 260°), purple (260°; 310°), and pink (<310°; 330°). Values for achromatic colors (with values of 0-1 in the HSL color space) corresponded to the following setting: white ($L > 0.80$), black ($L < 0.28$), and gray ($S < 0.10$). The pattern complexity was computed in Barvocuc using the Sobel operator (Sobel, 1978); minimum 0.2013, e.g., a smooth snake as the European blind snake (*Xerotyphlops vermicularis*), maximum 0.8452, e.g., a snake with a complex pattern with pronounced scales, such as the common European adder or the African puff viper (*Bitis arietans*). For the graphical output from the Barvocuc program, see Supplementary Figure 1. To improve normality, we square-root arcsin-transformed the values of color representations and pattern complexity (both expressed as a proportion of the area covered by the animal in the picture) for further analyses. Furthermore, we extracted the area covered by the animal in the picture (the number of non-transparent pixels transformed to square millimeters and square rooted).

Statistical Analyses

Agreement among the respondents was quantified by the Kendall's coefficient of concordance (W) as implemented in SPSS (Statistical Package for the Social Sciences), version 16.0 (Chicago, IL, USA). Next, the transformed data (square-root arcsin-transformed) were analyzed by the Principal Component Analysis (PCA) to visualize their multivariate structure. We computed two-way, consistency average score Intra-class Correlations (ICC, Hallgren, 2012) to estimate reliabilities of mean transformed ranks (command icc, irr package, in R; R Development Core Team, 2010). The cross-cultural agreement in fear and beauty and a correlation between both evaluations were analyzed by the least square linear regression (Pearson r-squared). To test which respondent's characteristic (sex, age, nationality, attitudes toward snakes and their interaction) influence the evaluation of beauty and fear, we used MANOVA (Multivariate Analysis of Variance); a final reduced model was built from an initial full model by backwards removal of the factors which appeared non-significant.

A different model was used for testing the effect of family membership and respondents' individual characteristics on the attitude itself. We computed a marginal model (command gls as implemented in package nlme in R software), testing the effect of nationality, sex, age, type of education and nationality∗sex interaction. We computed one model with and another one without the random effect of family membership. Subsequently, these two versions of the model were compared using ANOVA. We also performed Canonical Discrimination Function Analysis (DFA, forward stepwise model) for the fear and beauty evaluations to identify those species whose evaluations matched/differed significantly. Next, we performed GLMs (Generalized Linear Models) to analyze the effect of traits of the assessed snakes, i.e., morphological and color characteristics (see above) on their beauty and fear evaluation. To calculate correlations between the fear eliciting evaluation and a specific level of threat to humans we used the Spearman's rank correlation coefficient (Spearman R). All those analyses, if not stated otherwise, were performed in Statistica 8.0 (StatSoft Inc., 2010).

RESULTS

Congruence Among Respondents

First, we evaluated agreement among the respondents for each country and evaluation separately. Kendall's coefficient of concordance (W) showed sufficient agreement among the respondents from the Czech Republic for fear ($N = 104$, $W = 0.341$, $p < 0.0001$) and beauty evaluation ($N = 104$, $W = 0.201$, $p < 0.0001$). The concordance coefficients computed for Azerbaijan respondents were also significant (fear: $N = 100$, $W = 0.180$, $p < 0.0001$; beauty: $N = 100$, $W = 0.263$, $p < 0.0001$). When the picture of the Egyptian cobra (*N. haje*) in the threatening posture was excluded from the datasets, the agreement in fear evaluation remained significant in both Czech ($N = 104$, $W = 0.315$, $p < 0.0001$) and Azerbaijani respondents ($N = 100$, $W = 0.151$, $p < 0.0001$).

In order to estimate reliabilities of mean transformed ranks, we computed average score intra-class correlations (ICC). The resulting population values were high in both Czech [$N_{\text{stimuli}} = 37$, $N_{\text{raters}} = 104$, fear: ICC = 0.983, 95% CI = 0.974–0.990, $F_{(36,3708)} = 59.4$, $p < 0.0001$; beauty: ICC = 0.967, 95% CI = 0.950–0.980, $F_{(36,3708)} = 30.3$, $p < 0.0001$] and Azerbaijan datasets [$N_{\text{stimuli}} = 37$, $N_{\text{raters}} = 100$, fear: ICC = 0.958, 95% CI = 0.936–0.975, $F_{(36,3564)} = 23.8$, $p < 0.0001$; beauty: ICC = 0.975, 95% CI = 0.962–0.985, $F_{(36,3564)} = 40.2$, $p < 0.0001$].

Respondents' Characteristics Affecting Fear and Beauty Evaluation of Snakes

To test for the effect of respondents' individual characteristics (biology education, age, sex, nationality, and interactions thereof) on the fear and beauty evaluations, we employed MANOVA. For fear, there was no significant effect of biology [$F_{(164,35)} = 1.36$, $p = 0.1025$, power = 0.97], age [$F_{(164,35)} = 0.63$, $p = 0.9486$, power = 0.61], nor sex [$F_{(164,35)} = 0.99$, $p = 0.4907$, power = 0.87], however there was a significant effect of nationality [$F_{(164,35)} = 4.65$, $p < 0.0001$, power = 1.00] and nationality∗sex interaction [$F_{(164,35)} = 2.03$, $p = 0.0017$, power = 1.00]. For beauty, we found a significant effect of nationality [$F_{(164,35)} = 4.13$, $p < 0.0001$, power = 1.00], and age [$F_{(164,35)} = 1.68$, $p = 0.0162$, power = 0.99], while biology [$F_{(164,35)} = 1.48$, $p = 0.0551$, power = 0.98], sex [$F_{(164,35)} = 1.13$, $p = 0.2989$, power = 0.92], and nationality∗sex interaction [$F_{(164,35)} = 1.49$, $p = 0.0528$, power = 0.98] were not significant. We further tested the effect of family membership as a random factor on fear and beauty scores in the two most prominent species in both countries, i.e., the common European adder (Vipera) and the Levant viper (Macrovipera). Two versions of a marginal model (command gls as implemented in package nlme in R software) with and without the family factor were compared by ANOVA. It appeared that neither fear nor beauty evaluation was effected by the family membership as having included it into the model did not result in a significant improvement (Macrovipera-fear: likelihood ratio = 1.67, $p = 0.1961$; Vipera-fear: likelihood ratio = 1.21, $p = 0.2720$; Macrovipera-beauty: likelihood ratio = 0.11, $p = 0.7401$; Vipera-beauty: likelihood ratio = 0.65, $p = 0.4213$).

Attitude Toward Snakes and Experience With Killing a Snake in Czech and Azerbaijani Respondents

We tested the effect of individual characteristics (nationality, sex, type of education, and nationality∗sex interaction) and family membership on the attitude toward snakes. Using the same type of analysis as mentioned above, i.e., creating two marginal models with and without the family membership as a random factor and comparing them by ANOVA, it was revealed that the model with the family membership was significantly better (likelihood ratio = 8.72, $p = 0.0033$; AIC of the model with and without the family membership: 816.04 vs. 823.05, respectively). The resulting model further showed a significant effect of nationality [$F_{(1,199)} = 27.44$, $p < 0.0001$] and sex [$F_{(1,199)} = 17.34$, $p < 0.0001$], but not the nationality∗sex interaction [$F_{(1,199)} = 0.75$, $p = 0.3879$] nor biology education [$F_{(1,199)} = 3.29$, $p = 0.0714$].

Different attitude toward snakes in both countries could be further demonstrated by responses on the provided measure. In the Czech Republic, 54% of respondents had a positive attitude toward snakes, 20% neutral, and 26% a negative one. In Azerbaijan, only 14% of respondents had a positive attitude toward snakes, 49% neutral, and 37% a negative one. Interestingly, the incidence of snake encounters was comparable in both countries (99% of Czechs and 89% of Azerbaijanis have met a snake, $p = 0.0023$), even though the number of snake species living in the respective country is strikingly different (see the Introduction).

We also tested the effect of individual characteristics on experience with killing a snake or having seen someone killing one. We computed a GLM model (for binomial data with logit link function) with nationality, sex, nationality∗sex interaction, and biological education as fixed factors. The frequency of killing a snake was influenced only by nationality ($Z = -3.60$, $p = 0.0003$); more respondents in Azerbaijan than in the Czech Republic have killed a snake or have seen someone killing it (49% vs. 14%). Moreover, people in the Czech Republic reported having this experience mostly as a part of veterinary care or road accident.

When using MANOVA to analyze the additive effect of reported attitude toward snakes and experience with snake killing in both countries on fear evaluation, both the nationality ($F = 3.16$, $p = 0.0001$, power = 0.99) and snake killing influenced it significantly ($F = 1.62$, $p = 0.0252$, power = 0.99), but no significance was found for the attitude toward snakes ($F = 1.00$, $p = 0.4834$, power = 1.00). A similar statistical model for beauty evaluation was influenced only by nationality ($F = 2.54$, $p = 0.0001$, power = 0.99), but neither the attitude ($F = 1.15$, $p = 0.0895$, power = 1.00) nor snake killing ($F = 1.48$, $p = 0.0562$, power = 0.98) were significant.

Are Fear and Beauty Two Separate Dimensions?

In the Czech respondents, perceived fear positively correlated with beauty ($r^2 = 0.379$, $p = 0.0001$), however this correlation was insignificant in Azerbaijanis ($r^2 = 0.063$, $p = 0.1415$). Such difference could be explained by the MANOVA results (see section Respondents' Characteristics Affecting Fear and Beauty Evaluation of Snakes above) showing that there was a significant difference in the rankings between men and women, but only in the Azerbaijani sample. Therefore, we analyzed the relationship of perceived fear and beauty for each sex and country separately. In Czech men, the correlation was highly significant and stronger ($r^2 = 0.424$, $p < 0.0001$) than in Czech women ($r^2 = 0.299$, $p = 0.0006$). In Azerbaijani men, the correlation was rather weak, yet significant ($r^2 = 0.170$, $p = 0.0125$). However, in Azerbaijani women, there was no significant correlation ($r^2 = 0.012$, $p = 0.5290$). These results suggest that the correlation between fear and beauty in Azerbaijani respondents is influenced by the different precision in fear rankings (the highest fear/beauty discrepancy was found in the Azerbaijani women, followed by the Azerbaijani men, Czech women, and Czech men) and the difference in experience with snake killing (see above). Nonetheless, when the data from Azerbaijan were analyzed separately, the sexes correlated significantly in both fear ($r^2 = 0.746$, $p < 0.0001$) and beauty evaluation ($r^2 = 0.866$, $p < 0.0001$).

Correlation Between Czechs and Azerbaijanis in Fear and Beauty Evaluation

In section Respondents' Characteristics Affecting Fear and Beauty Evaluation of Snakes, we detected a significant effect of nationality on mean ranks of fear and beauty. Despite that, a comparison of photos ranking in both countries according to a particular evaluation showed a high cross-cultural agreement (Pearson correlation coefficient; fear: $r^2 = 0.648$, $p < 0.0001$, **Figure 2**; beauty: $r^2 = 0.832$, $p < 0.0001$, Supplementary Figure 2). The remaining variability in the data may be explained by the statistical models we have used to analyze the effect of demographic variables and attitude toward snakes. For the complete results of fear and beauty evaluations for particular species, see Supplementary Table 5.

We also performed a canonical discrimination function analysis (DFA) to assess differences/overlaps between the groups of respondents (nationality and gender) in the fear evaluation [Wilks' lambda = 0.36; $F_{(51,548)} = 4.43$; $p < 0.0001$] of selected 17 species, see **Figure 3** for details. Even though the analysis was significant, the classification success was rather low (62.25%), which signifies an overlap between the groups. This analysis showed significant differences between the sexes and countries when comparing the Azerbaijani women to the remaining groups (Azerbaijani men: $F = 8.95$, $p = 0.0031$; Czech men: $F = 33.14$, $p < 0.0001$; Czech women: $F = 39.37$, $p < 0.0001$) and the Azerbaijani men to the Czech respondents (Czech men: $F = 4.87$,

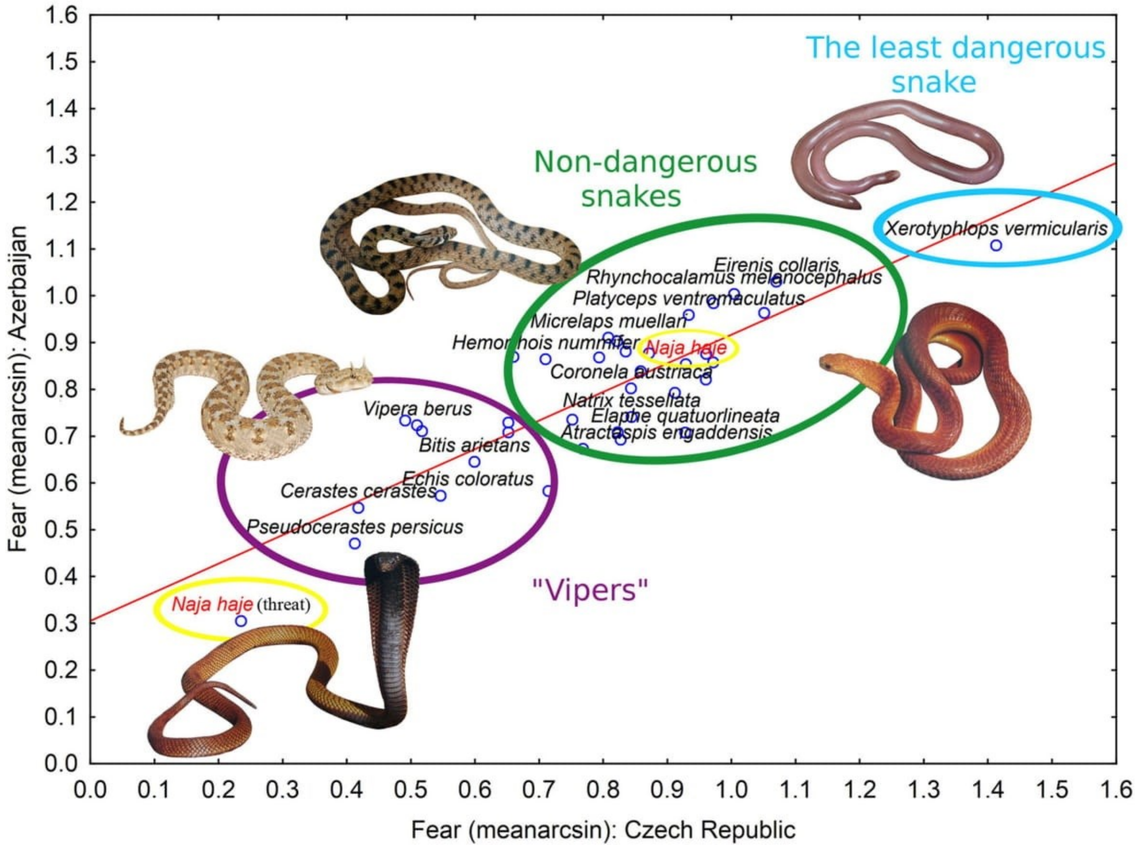

FIGURE 2 | A correlation of fear evaluations from the Czech Republic and Azerbaijan. The graph was calculated from square-root arcsin-transformed data, i.e., the lower the value the more fearful the species is according to the respondents (Pearson correlation coefficient; $r^2 = 0.683$, $p < 0.0001$). The highlighted evaluation of the Egyptian cobra in two positions illustrates different perception of snakes depending on their posture.

$p = 0.0284$; Czech women: $F = 6.70$, $p = 0.0103$). However, there was no significant difference when comparing the Czech men and women ($F = 0.14$, $p = 0.71$). A plot of the first two canonical factors showed a considerable overlap of the groups (see **Figure 3**, loadings are provided in Supplementary Table 6).

Similarly, an analogical analysis was performed to assess differences/overlaps between the groups of respondents (ethnic and gender) in their evaluation of snake beauty [Wilks' lambda: 0.3390, $F_{(108,495)} = 2.00$, $p < 0.0001$, 24 species were included, see Supplementary Figure 3]. The classification success was again rather low (62.75%) signifying an overlap between the groups. As with the analysis of fear evaluation (see above), there was no difference between the Czech men and women ($F = 1.17$, $p = 0.2749$). Contrary to that, the Azerbaijani women were different from all the other groups again (Azerbaijani men: $F = 2.58$, $p = 0.0002$; Czech men: $F = 3.69$, $p < 0.0001$; Czech women: $F = 3.51$, $p < 0.0001$) and the Azerbaijani men differed from the Czech participants (Czech men: $F = 3.70$, $p < 0.0001$; Czech women: $F = 2.58$, $p = 0.002$). Still, a plot of the first two canonical factors showed a considerable overlap of the groups (see Supplementary Figure 3, loadings are provided in Supplementary Table 7).

Explanation of Perceived Fear and Beauty by Physical Traits of Snake Stimuli

Because of the high correlation of snake rankings according to fear and beauty between the Czech and Azerbaijan respondents (see above), we computed a model explaining the influence of snake morphology and color from a combined data set (CZ and AZ respondents pooled together), but separately for beauty and fear rankings. We computed optimal linear models (LM), which we used to analyze the effect of morphological and other perception characteristics (color, pattern, lightness, saturation) of stimuli on the fear and beauty evaluations.

The optimal model (LM) for the perceived fear explained 83.6% of variability. There was a positive effect of the head width, eye width, tail width, and white color on high fear evaluation. We found a negative effect of the overall body length, photograph lightness and pink color that reduce fear evaluation of snakes (see **Table 1**). The optimal model (LM) for the perceived beauty explained 80.7% of variability. We found a positive effect of the pattern complexity, amount of black color, and overall lightness of the photograph that all increase the snake beauty evaluation. On the contrary, white and red colors of snakes had a negative effect and decreased the beauty evaluation. Interestingly, none

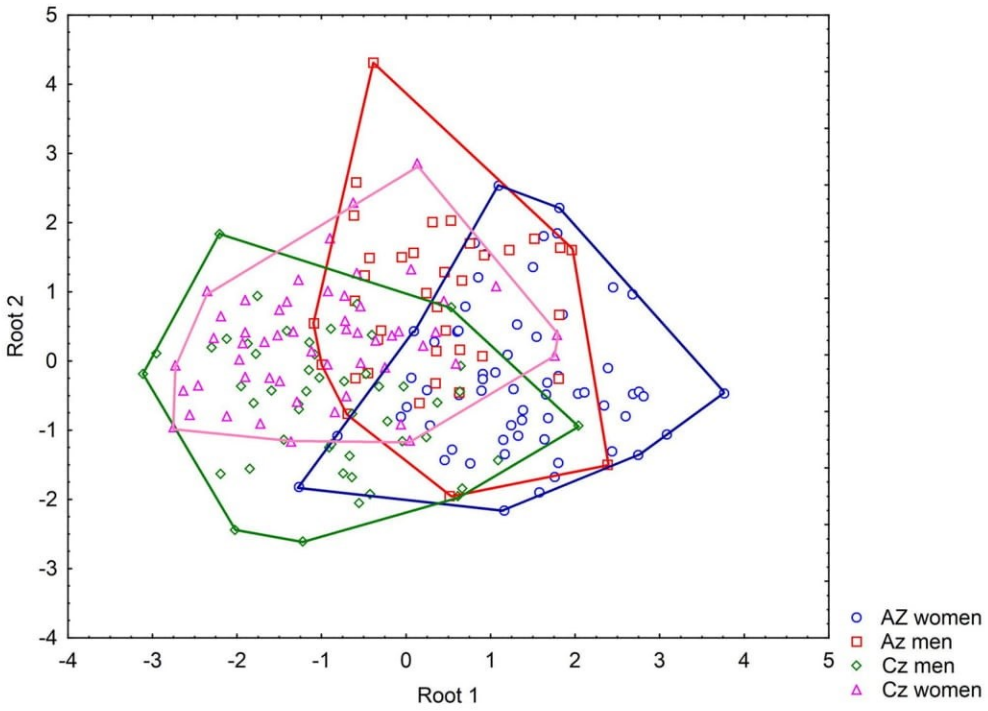

FIGURE 3 | The canonical DFA of fear evaluation. This analysis showed significant differences between the sexes and countries when comparing the Azerbaijani women to all other groups and the Azerbaijani men to the Czech respondents. However, a plot of the first two canonical factors showed a considerable overlap of the groups for elicited fear. The number of included species was reduced by the forward stepwise procedure to just 17 out of 36. Three species, the meadow viper (*Vipera ursinii*; Wilks' lambda = 0.3850, $p = 0.0042$), the coastal viper (*Montivipera xanthina*; Wilks' lambda = 0.3975, $p = 0.0002$), and the Palestine saw-scaled viper (*Echis coloratus*; Wilks' lambda = 0.3898, $p = 0.0014$) had the largest Wilks' lambda and therefore, corresponded the best with the discrimination criteria. Thus, only three of the 36 tested snake species are responsible for the detected differences in fear evaluation.

TABLE 1 | Final reduced model (LM) describing the effects of snake morphology and color on fear ranking.

	Df	*F*-value	Pr(>*F*)	Estimate	SE	*t* value	Pr(>|*t*|)
Intercept				0.171	0.492	0.347	0.7312
Body length	1			0.148	0.070	2.098	0.0458
Tail width	1					−2.546	0.0172
Head width	1	26.99	< 0.0001	29.180	< 0.001	−2.947	0.0067
Eye width	1	10.21	0.0036	11.870	0.002	−2.585	0.0157
Mean lightness	1	18.86	0.0002	1.435	0.296	4.851	< 0.0001
SD lightness	1	0.24	0.6267	1.738	0.529	3.287	0.0029
White	1	29.52	< 0.0001	−1.018	0.220	−4.628	< 0.0001
Purple	1	0.01	0.9078	−1.346	0.699	−1.925	0.0652
Pink	1	5.48	0.0272	0.641	0.274	2.340	0.0272
Residuals	26						

TABLE 2 | Final reduced model (LM) describing the effects of snake morphology and color on beauty ranking.

	Df	*F*-value	Pr(>*F*)	Estimate	SE	*t*-value	Pr(>|*t*|)
Intercept				2.529	0.340	7.449	< 0.0001
Pattern	1	78.53	< 0.0001	−7.422	2.334	−3.180	0.0035
Mean lightness	1	3.04	0.0917	−2.307	0.671	−3.436	0.0018
SD Lightness	1	2.40	0.1320	−2.082	0.661	−3.152	0.0038
White	1	5.41	0.0273	0.998	0.254	3.932	0.0005
Black	1	9.02	0.0055	−0.617	0.220	−2.799	0.0090
Red	1	22.46	< 0.0001	0.345	0.073	4.739	< 0.0001
Residuals	29						

of the morphological characteristics had a significant effect on beauty (see **Table 2**). Dark, short, thick snakes with a wide head and big eyes elicit the highest fear, while snakes with complex disrupted patterns and bright colors are evaluated as the most beautiful. Thus, different sets of morphological and color characteristics influence the fear and beauty evaluation, but only lightness of the snake picture stimuli influences the fear (dark snakes are the most fear eliciting) as well as beauty (brightly colored snakes are the most beautiful) evaluation.

Explanation of Perceived Fear by the Snake's Real Dangerousness

The presented snake species also differ in their dangerousness for humans. We compared the specific level of threat to humans (the dangerousness category, see the Materials and methods and Supplementary Table 2) with the species' fear evaluation. In both the Czech and Azerbaijani respondents, the perceived fear significantly correlated with the real threat (Spearman correlation coefficient; Czechs: $r = 0.716$, $p < 0.0001$; Azerbaijanis: $r = 0.725$, $p < 0.0001$), but the perceived beauty did not (Spearman correlation, Czechs: $r = 0.227$, $p = 0.1767$; Azerbaijanis: $r = 0.160$, $p = 0.3430$).

DISCUSSION

Comparison of Fear and Beauty Evaluations of Snakes Between Czech and Azerbaijanis

In this paper, our main aim was to make cross-cultural comparisons of human fear responses to various venomous and non-venomous snake species common in Europe, Middle East, and North Africa. We hypothesized differences in fear perception of snakes in the Czech Republic compared to Azerbaijan, the two countries with considerably different risks of envenoming. While snakes in the Czech Republic do not present a significant threat, the risk of serious injuries or even deaths caused by snakebites in Azerbaijan is much higher. Contrary to our expectations, in the sample consisted largely of college students, we found a significant cross-cultural agreement in fear evaluation ($r^2 = 0.65$, $p < 0.0001$). This is in agreement with our previous study demonstrating that despite differences in snake abundance and risk of envenoming people from different countries self-report comparable snake fear (Polák et al., 2016).

To some extent, the Czechs and Azerbaijanis were able to categorize the snake species according to the real threat to humans. Most of the envenomings in Azerbaijan are caused by one particular species, the Levant viper, an aggressive snake that is responsible for many deaths. We predicted that it should be seen by Azerbaijanis as more fearful than other snakes. Despite that, the Levant viper did not figure at the top of fear ranking (14th most fearful out of 36 species). By contrast, only one slightly venomous snake that lives in the Czech Republic, the common European adder, was seen as quite dangerous by the Czech respondents (4th most fearful out of 36 species). Other deadly venomous species that are similar to the Levant viper (see Supplementary Figure 4), and thus present a serious threat, are evaluated by both the Azerbaijani and Czech respondents as highly fear eliciting. Compared to vipers, slender bodied elapids, including the Egyptian cobra in a resting position, were perceived as less fear eliciting. This could mean the fear module responds to a broader and more general category of dangerous, fear eliciting snakes rather than particular species. This is especially important from the ethnobiological and conservational perspective as due to the presence of one dangerous snake species people may incline to killing all other snakes that are similar though less dangerous. From the psychological point of view, it is interesting to find out how broad this "snake" category is (see below and in section Attitude Toward Snakes).

Moreover, when we analyzed the differences in fear evaluation between men and women from both countries in more details, the species causing slight discrepancies are not the most dangerous snakes of Azerbaijan, but other viperids (controls) that live neither in Azerbaijan nor the Czech Republic. Thus, co-habitation with the highly dangerous Levant viper in Azerbaijan did not lead to increased fear elicited by this species. The respondents rather generalized the fear evaluation of the local dangerous model snake to all vipers and pit vipers resembling it. Another possibility is that the characteristic viper-like body shape, i.e., a triangular head, narrow neck, and a thick body, is a prototypical stimulus that humans recognize ancestrally. This is because in Eastern Africa, the place of human origins, our ancestors have probably lived for last two million years together with highly venomous viperid species (Isbell, 2006). Nowadays, this region is inhabited by many deadly venomous species that still cause human deaths like the North-East carpet viper (*Echis pyramidum*), African puff adder (*B. arietans*), rhinoceros viper (*Bitis nasicornis*), rhombic night adder (*Causus rhombeatus*), or the African hairy bush viper (*Atheris hispida*) (Spawls et al., 1995). To tackle this question, research must be conducted on other ethnics where meeting a snake is still risky, but viperids do not pose the major threat.

The colubroid snakes evolved a highly efficient venom delivery system probably in the Late Cretaceous (around 60 Myr; Vidal and Hedges, 2002), with viperids evolving in Asia in the Early Miocene (around 20 Myr) or even later (Wüster et al., 2008). Molecular data show the diversification of some genera within viperids, e.g., *Vipera* and *Macrovipera*, around 10 Myr (Pook et al., 2009). Primates, including human ancestors, have also evolved predominantly in the Old World (switching between Africa and SE Asia), i.e., they continuously occurred in sympatry with the viperids and other venomous snakes. Subsequently, the mankind evolved in Africa from its common ancestor with chimpanzees around 7–13 million years ago (Langergraber et al., 2012). Thus, the last 10 million years our direct ancestors have spent in Africa, initially in tropical forests and later in open savannas (Dawkins, 2005). The repeated expansion of modern humans out of the African continent to Eurasia, where they could encounter the current genera of viperids, is estimated to about 90–100 Kyr to Levant, 60 Kyr to western Asia, and 40 Kyr to Europe (Deshpande et al., 2009; Stewart and Stringer, 2012). Thus, contemporary human populations have been exposed to various local snake faunas representing a different risk of envenoming. It can be expected that the number of deaths/injuries caused annually by snakebites in some countries is not a sufficient selective pressure to create an evolutionary adaptation to recognize and fear specific snake species in a given region (here the Levant viper in Azerbaijan) within such an evolutionary short time scale. A hypothetical innate adaptation of humans to the local snake species would need to evolve during a couple thousands of years following the African migration, which is unlikely. On the other hand, the co-evolution with viperids have been long enough to form a general mental representation of dangerous viperid snakes associated with a high fear response.

We have also tested human perception of snake beauty that, as we expected based on our previous findings and contrary to fear, should demonstrate intercultural similarity. We have already shown that in Papua New Guinea which is inhabited by highly venomous snakes from the Elapidae family (O'Shea, 1996), villagers evaluate the beauty of boid snakes similarly to Czech students (Marešová et al., 2009a); the cross-cultural agreement on beauty ranking was relatively high ($r^2 = 0.76$). This is despite an entirely different cross-cultural background of the Papuans who are exposed to a higher envenoming risk than people in Central Europe. Moreover, the viperids are missing in Papua New Guinea, so the morphotype of local dangerous snakes is different. A broader cross-cultural agreement (r^2 ranging from 0.56 up to 0.92) on beauty of these snakes was also found between the Papuans and villagers from Bolivia, Philippines, India (Rajasthan and Dehli), Malawi, and Morocco (Frynta et al., 2011). In this paper, we provide support for such findings showing a comparable or even higher cross-cultural agreement in the snake beauty evaluation ($r^2 = 0.83, p < 0.0001$).

Relationship Between Perceived Fear and Beauty of Snakes

We suppose that asthetic evaluation of snake beauty is closely connected with joy (Kühn and Gallinat, 2012; Frynta et al., 2014) and that during ranking according to fear this emotion is triggered as well. Previously, we have found only a loose correlation between perceived beauty and fear in king snakes when respondents evaluated photographs but not the same live specimens (Landová et al., 2012). King snakes include brightly colored species mimicking deadly venomous coral snakes and the perception of beauty and fear were rather two independent processes in these snakes. Interestingly, in this study, where respondents evaluate a more diverse sample containing snakes from 29 genera and 6 families, we also found that snake species eliciting higher fear tend to be at the same time perceived as more beautiful by all nationality/sex sub groups except Azerbaijani women. However, this correlation between fear and beauty evaluations is lower and varies cross-culturally (Czech men: $r^2 = 0.42$; Czech women: $r^2 = 0.30$; and Azerbaijan men: $r^2 = 0.17$), so people are able to subjectively distinct these two dimensions during ranking of the snake photographs. If we found, on the other hand, a high agreement between the fear and beauty rankings, it would mean that there is a need for simple explicit categorization rules that help respondents deal with both tasks promptly and are not dependent on a particular evaluation.

Features Predicting Evaluation of Snake Species as Fearful or Beautiful

The most fear evoking trait on snakes was a specific body form, a short snake with a wide but distinct neck and big eyes. On the contrary, worm-like snakes from the Typhlopidae family did not elicit fear in neither of the countries (see **Figure 2**). It has been shown that the typical curvilinear shape enhances quick detection of the snake (LoBue, 2014) even if it is introduced in scenes in gray scale (Hayakawa et al., 2011). Azerbaijani, as well as Czech respondents, perceive as the most fear evoking stimulus the Egyptian cobra in a threatening posture (with the extended neck and in an upright position, see Supplementary Figure 4D). However, the same species in a resting position (control) was according to fear only 22nd out of 36 species in Azerbaijani and 28th out of 36 species in Czech respondents. Thus, the snake's position seems crucial for its fear evaluation. Only this particular species was included in two different positions as the threatening cobras are very well known from the media, while threatening positions of other snakes are not so apparent. However, the snake's position before an attack (S-shaped neck) communicates a willingness to behave defensively (Johnson, 1975) and is worth of interest if people that are unfamiliar with snake behavior are able to recognize it as a signal of danger and perceive consequently more fear.

The high congruence in beauty perception may be partly explained not only by asthetic preferences for colors (Crozier, 1999), symmetry (Enquist and Arak, 1994), and contrast patterns on animals (Marešová et al., 2009b; Lišková et al., 2015), but also by more delicate features like animal body shapes (Lišková and Frynta, 2013; Janovcová, 2015). We have previously found in king snakes that perception of beauty depends on the body weight and presence of red and black colors (Landová et al., 2012). King snakes include a great variety of color forms, some possessing aposematic patterns (red-black-yellow/white stripes) that are highly preferred by respondents. However, in other studies, this color pattern contributes to perceiving the animal as dangerous (Prokop and Fančovičová, 2013). The set of snakes used in this paper does not comprise brightly colored species, thus the pattern complexity, high lightness, and presence of black color (inherently presented in contrast patterns) increase the relative beauty of presented species. Thus, the contrasting pattern on snake body is considered as beautiful similarly to our results in boid snakes (Marešová and Frynta, 2008) or interestingly in pitta birds (Lišková et al., 2015).

Attitude Toward Snakes

According to the contemporary theory in social psychology, learning can account for most of the attitudes we hold. We know that attitudes can be implicitly acquired via classical, operant, or evaluative conditioning. Formation of implicit attitudes employs the processes of both classical and operant conditioning, but social learning is probably of the same importance (Wegener Carlston and Carlston, 2005). Moreover, people can also form attitudes explicitly on the spot with just a little cognitive effort using several heuristics (Schwarz, 2000). It is generally accepted that attitudes form future behavior and results from a meta-analysis by Glasman and Albarracín (2006) indicate that this effect is stronger when attitudes are easy to recall and stable over time.

In our study, the respondents also filled out a questionnaire about their attitude toward snakes. Although most of our subjects were students and employees of biological sciences colleges, this relationship was different in both countries. In the Czech Republic, the proportion of people who like snakes (54%) is similar to those who hate them (46%). However, the majority of the Azerbaijani respondents have either a neutral relationship toward snakes (49%) or hate them (37%). This is an interesting finding regarding the association between biology education and more positive attitudes toward animals (see also section Study Limitations). Despite more biology students being represented in the Azerbaijani sample, their attitudes were more negative than those of Czechs. Thus, their education did not overcome the aversion to snakes. The number of unpleasant encounters should be theoretically an explanation for the different relationship to snakes, as only five species of snakes live in the Czech Republic, whilst about 32 snake species occur in Azerbaijan. Nevertheless, our results show that encounters with snakes are comparably common in both countries (87 and 99%). Different attitudes toward snakes are related to another question; if the respondent has ever killed a snake or has seen someone killing it.

It is known that dangerous animals, especially snakes, are killed for safety reasons in different geographical regions, e.g., in Brazil (Alves et al., 2009, 2012), India (Balakrishnan, 2010), or Nepal (Pandey et al., 2016). In Azerbaijan, a half of the respondents (49%) have seen killing a snake or killed one themselves (Supplementary Figure 5 shows a dead Levant viper killed by villagers in Katex, northern Azerbaijan, found during a zoological field expedition). By contrast, only a few Czechs have ever killed a snake (14%), either as a part of research or involuntarily (driving over a snake with a car). This proportion of reported cases of snake killing by adults is consistent with previously published data on children who intended to kill a snake if they would encounter one (Ballouard et al., 2013). This was surprisingly high among children from Morocco (45%), Portugal (60%), or even Slovakia (90%). However, in other countries this willingness to kill a snake was lower, ranging from 29% in Turkey to 7–13% in six European countries. Moreover, this was influenced by the sex of the respondents and their fear or likability of snakes (Ballouard et al., 2013). As Makashvili et al. (2014) reported, negative attitude to snakes can be overcome with knowledge.

Does Attitude Toward Snakes Explains Beauty or Fear Evaluation?

The attitude toward snakes explains perceived fear of snakes only marginally in the Czech respondents. Only 6% of women and 3% of men have purely negative attitudes to snakes, e.g., dislike and fear them. However, any cross-cultural differences in fear evaluation of snakes are mainly due to the different fear evaluation of snakes in Azerbaijan women. Higher fear response and more negative attitudes toward snakes in women have been reported several times (Arrindell et al., 2003; Prokop et al., 2009). Although we confirmed that Azerbaijani women in our sample had more negative attitudes toward snakes (26% highly dislike snakes) this does not explain their differences in relative fear evaluation. Moreover, ranking according to beauty was fully independent regardless of personal attitudes toward snakes.

Study Limitations

More than a half of our respondents from both countries were university biology students. One might argue that concerning their type of education and young age they did not constitute a proper representative sample. For example, Schlegel and Rupf (2010) found that natural resource sciences students showed higher levels of affinity to animals. Bjerke and Østdahl (2004) reported a positive correlation between the respondent's educational level in general and positive attitudes toward animals. In this study, this might be true for the attitude toward snakes, however, our results, and previous studies showed that the effect of individual characteristics on the ranking of animal species according to their beauty or perceived fear was usually only marginal (Frynta et al., 2010), even when comparing such different populations as Czech students and villagers in Papua New Guinea (Marešová et al., 2009a). Moreover, Collins (1976) pointed out that obvious differences between the first-year students (represented the most in our study) and biology majors could be found. The students we have recruited were mainly from the first or second year of university. At this stage of curriculum they have still not done any specialized course in herpetology. We also hypothesize that in the case of salient, emotionally charged, and evolutionary relevant stimuli, such as snakes, the stimulus' characteristics may be more important for its evaluation than sociodemographic traits of the respondent. This is consistent with results of Prokop and Tunnicliffe (2008), who found a moderate correlation between attitude toward and knowledge of bats, but not spiders. They suggested that this may be partly influenced by greater fear of spiders compared to fear of bats. To conclude, although we are aware of the limitations and want to avoid over-generalization of our results, we believe that our sample was adequate for the purpose of this study.

Throughout the study, we have found discrepancies between the Azerbaijani women and the rest of the subject groups (Azerbaijani men and Czech men and women) on almost all measures. Based on an evolutionary hypothesis, women have a higher reproductive value compared to men, because they give birth to the progeny. In the evolutionary history of mankind, women were staying around their homes gathering food while men went out hunting. Doing so, women had more chances of encountering snakes lurking in the environment. Having to protect not only themselves, but also their children or even unborn babies, there was a good evolutionary reason for women to develop higher fear of snakes compared to men (Öhman et al., 2012). Even today, women suffer considerably more often from specific animal phobias than men (Fredrikson et al., 1996). In light of the above, the results obtained from the Azerbaijani women make sense. Nevertheless, one has to explain then why no similar gender difference has been found in the Czech Republic. Perhaps, it may be argued that the traditional gender roles associated with differences in the expression of fear, among others, are more pronounced in Azerbaijan, where 98% of the population are Muslims. Contrary to that, the mostly atheist Czech population has gone through sociodemographic changes in the last few decades resulting in equalization of gender roles and stereotypes.

SUMMARY AND CONCLUSION

The major portion of variability in the data explains high similarity in fear 65% (as well as beauty 83%) perception of snakes in the Czech Republic compared to Azerbaijan, the two countries with considerably different risks of envenoming. The rest of the variability reflects the differences that should be accounted to some respondents' individual characteristics (especially the Azerbaijani women being different in fear evaluation of the snake species). Interestingly, biology education of the respondents influenced only the attitude to toward snakes, but not the fear evaluation itself. These results are further demonstrated by the canonical DFA showing the overlap between nationality/sex groups. The differences are caused by different evaluation of only three snake species specific for fear and beauty ranking.

Snake beauty evaluation was a valuable control task, to be sure that respondents rank the pictures according to elicited fear, not only due to applying more general esthetic and categorization rules. We found only a slight correlation between fear and beauty, indicating that only some species were evaluated as both fearful and beautiful at the same time. Further, we detected a different set of attributes behind the evaluation of fear (mainly the snake's morphology) and beauty (mainly colors and pattern) of snakes with only the lightness affecting both. In both countries, the respondents evaluated the Egyptian cobra in a threatening position or the "viper" morphotype as the most fear eliciting and dangerous. However, they did not evaluate the cobra in a resting position nor the particular species that locally represent the major risk of snakebite (the common European adder in Czech Republic and the Levant viper in Azerbaijan) as the most fear eliciting. The generalization concept of viperids as the most fearful snakes in our study may be due to their co-evolutionary history with humans and is responsible for a high cross-cultural agreement. We also found the role of experience (killing a snake or seeing someone killing a snake) on fear evaluation, but not on beauty evaluation of snakes. A general attitude (likability) of snakes was influenced by the family membership, but the influence of attitude or family factor on relative fear or beauty evaluations was not significant. Thus, it seems that the family context, environment where one grows up, may change the way we view snakes, whether we like them or not, but it will not affect the perceived fear or beauty of particular snake species which might be a universally shared pattern.

Despite the differences in the attitude toward snakes between the Azerbaijani and Czech respondents, agreement in the evaluation of snake beauty and fear is cross-culturally high. The "viper" type is generalized as the most fear evoking appearance of a snake in both countries. Thus, the fear response to snakes is not directly explainable by the observed current environmental and cultural differences.

AUTHOR CONTRIBUTIONS

EL, DF, and AG: conceived and designed the research; NB, MJ, EL, SP, MS, and JP: performed the research; DF and MJ: analyzed the data; EL, DF, MJ, and JP: wrote the paper; EL, DF, MJ, JP, NB, AG, MS, and SP: revised the paper and approved the final version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2018.00333/full#supplementary-material

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

5. Fyziologická odpověď při prožívání strachu a odporu z hadů

Třetí část se zabývá analýzou fyziologické odpovědi na obrázky dvou skupin hadů, z nichž jedna by měla v lidech vyvolávat pouze strach, ta druhá zase pouze odpor. Vhodné testové stimuly byly vybrány na základě výsledků studie popsané v předchozí kapitole (Rádlová, et al., 2019). Zatímco tedy první dva oddíly se zaměřily na subjektivní hodnocení emočního prožitku vyvolaného hady, tato a následující, závěrečná část se věnují objektivnímu měření autonomní tělesné a neurální odpovědi. Výsledky fyziologických měření jsou představeny v jediném článku, který byl nedávno publikován v časopise *PLoS ONE* (Landová et al., 2020).

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RESEARCH ARTICLE

Venomous snakes elicit stronger fear than nonvenomous ones: Psychophysiological response to snake images

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Abstract

Snakes have been important ambush predators of both primates and human hunter-gatherers throughout their co-evolutionary history. Viperid snakes in particular are responsible for most fatal venomous snakebites worldwide and thus represent a strong selective pressure. They elicit intense fear in humans and are easily recognizable thanks to their distinctive morphotype. In this study, we measured skin resistance (SR) and heart rate (HR) in human subjects exposed to snake pictures eliciting either high fear (10 venomous viperid species) or disgust (10 nonvenomous fossorial species). Venomous snakes subjectively evaluated as frightening trigger a stronger physiological response (higher SR amplitude) than repulsive non-venomous snakes. However, stimuli presented in a block (more intense stimulation) do not trigger a stronger emotional response compared to sequentially presented stimuli (less intense stimulation). There are significant interindividual differences as subjects with high fear of snakes confronted with images of viperid snakes show stronger, longer-lasting, and more frequent changes in SR and higher HR compared to low-fear subjects. Thus, we show that humans demonstrate a remarkable ability to discriminate between dangerous viperids and harmless fossorial snakes, which is also reflected in distinct autonomous body responses.

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1. Introduction

1.1. Snakes as evolutionary threat

Ever since their appearance, primates and early hunter-gatherers have been subject to life-threatening risks from snakes. As a consequence, primates including contemporary humans developed improved visual abilities and superior pre-attentive attention specifically for detecting snakes and other stimuli representing an evolutionary threat [1–4]. Although this predation pressure has left no trace in the fossil record, some circumstantial evidence is available. In

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an attempt to assess the hazards that snakes pose to primates, McGrew [5] observed a group of chimpanzees in Senegal. Within four years, as many as 142 encounters of snakes belonging to 14 species were recorded. Headland and Greene [6] showed that local populations in some parts of the world have been regularly exposed to predatory attacks by giant constrictor snakes in the recent past. Over the course of four decades, a quarter of Agta Negritos men, a tribe of hunter-gatherers from the Philippines, were attacked by the reticulated python (*Malayopython reticulatus*), resulting in six fatalities [6].

Even today, snakebite envenoming remains a significant health concern. In total, 3 709 snake species are currently being recognized and around 35% of them use venom to kill their prey [7]. In fact, the number of reptile species capable of producing toxins in their saliva may be up as high as 2 000 [8]. Out of these, 250 are listed by the World Health Organization as being medically important [9], especially members of the Elapidae and Viperidae families that possess a very potent venom delivery system [8]. Every year, 4.5–5.4 million people are bitten by snakes worldwide and the estimated death toll ranges from 81,000 to 138,000 [9]. Another 400,000 victims suffer major disabilities such as amputations [9]. Therefore, snakebites have been recently claimed the world's biggest and grossly underestimated hidden health crisis [10].

1.2. Risk of envenoming in different regions

The risk of snake envenomation is the highest in South and Southeast Asia and Sub-Saharan Africa [11, 12]. Southeast Asia is inhabited by several deadly venomous viperid and elapid snakes, e.g., the Russell's viper (*Daboia russelii*), saw-scaled viper (*Echis carinatus*), Indian cobra (*Naja naja*), monocled cobra (*Naja kaouthia*), and common krait (*Bungarus caeruleus*). Africa is home to some of the most dangerous snakes, e.g., the West African carpet viper (*Echis ocellatus*), Roman's saw-scaled viper (*E. leucogaster*), and puff adder (*Bitis arietans*) from Viperidae and the forest cobra (*Naja melanoleuca*), black-necked spitting cobra (*N. nigricollis*), and mambas (*Dendroaspis* spp.) from Elapidae. The majority of fatal snakebites in Europe and the Middle East is caused by the Levant viper (*Macrovipera lebetina*), coastal viper (*Montivipera xantina*), and Palestine viper (*Daboia palaestinae*). Rattle snakes (Crotalinae, Viperidae) are the most dangerous snakes in North America, mainly the western diamondback rattlesnake (*Crotalus atrox*) and eastern diamondback rattlesnake (*C. adamanteus*). Several viperid snakes pose a significant threat also in South America, e.g., the South American rattlesnake (*C. terrificus*), common lancehead (*Bothrops atrox*), jararaca (*B. jararaca*), jararacussu (*B. jararacussu*), and South American bushmaster (*Lachesis muta)*, as well as deadly venomous elapids, the coral snakes (*Micrurus* spp.) [12, 13]. Viperids are absent from Australia, while many elapids occur there, with the most venomous being the brown snakes (*Pseudonaja* spp.), tiger snake (*Notechis scutatus*), taipans (*Oxyuranus* spp.), and death adders (*Acanthophis* spp.) [13, 14].

To summarize, snakes of the Viperidae family in particular present a major health risk for humans over much of the world except Australia. Consequently, vipers elicit significant fear response and therefore can be used as a salient evolutionarily relevant stimulus in emotion research [15].

1.3. Fear module

It has been hypothesized that because of the risk presented by venomous snakes, human ancestors have evolved a complex adaptive system of interconnected fear responses manifested on the psychological, behavioral, physiological, and neural level [16]. This system, according to some authors, has been encapsulated in a specific brain structure, the so-called module of fear localized in the amygdala [16–18] (but see Rosen and Donely [19] who failed to observe amygdala activation in rodents experiencing unconditioned fear). Many years of extensive research have demonstrated that the fear module is particularly triggered by snakes. In contrast to other animals, snakes are associated with a fearful human voice already in infants as young as 9 months [20]. Snakes also capture pre-attentive attention, so they can be spotted much faster than, for example, flowers or mushrooms on a background of distractors [2]. And finally, the psychophysiological fear response elicited by snakes compared to other animate objects is stronger, longer-lasting [21, 22], and can be triggered even unconsciously [23–25, cf. 26].

1.4. Variable snake appearance may trigger distinct emotions of fear and disgust

So far, research has been treating snakes as a uniform stimulus category supposedly activating the evolved fear module [27], although different snake taxa are likely to elicit different levels of fear. Although venomous snakes show great pattern and morphological variation, only certain morphotypes are perceived as dangerous and highly fear-evoking, specifically snakes of the Viperidae family (*Crotalinae*, *Viperinae*, and *Azemiopinae*). It has been shown that large body size, conspicuous scales with contrasting patterns, and bright coloration contribute to fear perception [15]. This is congruent with results of a cross-cultural comparison of human fear responses to various venomous and nonvenomous snake species commonly occurring in Europe, Middle East, and North Africa. Both Czech and Azerbaijani respondents rated various species of vipers as the most fear-eliciting. These snakes have characteristic features such as a thick short body, wide distinct neck, and prominent eyes. Interestingly, the Egyptian cobra (*Naja haje*), which is a slender-bodied elapid, was evaluated by the respondents from both countries as the most fear-eliciting and dangerous only when presented in a threatening (in contrast to resting) position [28], highlighting the importance of context (and possibly movement) in fear perception.

Appearance and dangerousness to humans is even more variable across the whole suborder of snakes, including the non-venomous ones. Consequently, some snakes may be perceived as not frightening but highly disgusting [15, 29, 30]. Mainly harmless subterranean (fossorial) snakes from the group of blind snakes called Typhlopoidea (*Xenotyphlopidae*, *Typhlopidae*, *Leptotyphlopidae*, *Gerrhopilidae*, and *Anomalepididae*) are less fear-evoking, but highly repulsive [15]. These findings raise an intriguing question: do snake species advertise the danger they present to humans, for example, their toxicity, through their appearance?

From the functional perspective, fear and disgust are biologically adaptive and genetically fixed intense responses to potentially life-threatening situations [31]. Although both negative emotions should lead to avoidance/withdrawal [32], they can be clearly distinguished on the physiological, psychological, and behavioral level [33, 34]. While fear is elicited by the presence of a predator (e.g., a snake) or other imminent threat posing a direct risk of physical harm or even death [35–37], disgust has originally developed as a food-rejection emotion. Its main function is to prevent the transmission of illness or disease through ingestion of contaminated objects [38, 39]. Thus, it triggers disease-avoidance behavior [40, 41] as a part of the "behavioral immune system" [42]. However, understanding of the psychophysiological differences between emotions in general is still insufficient [43, 44], particularly between fear and disgust. The fear response involves activation of the sympathetic nervous system, which initiates the "fight or flight" reaction characterized by heart rate acceleration [45–47]. Disgusting stimuli, on the other hand, have highly variable physiological effects on heart and respiratory rates [44]. Skin conductance, which is determined by the activity of sympathetically innervated sweat glands, is reported to increase with both fear and disgust [44, 48].

However, some authors have challenged the view of basic emotions as biologically fixed, universally shared, discrete entities that serve a specific function in survival each having a distinct facial expression, physiological pattern and neural substrate. For example, Russell [49] conceptualized emotions as simple affective states called the core affects, which can be either good or bad and energized or enervated and were attributed to some internal or external cause. Similarly, Barrett [50] highlighted that despite people's belief of being able to recognize their own emotions, research has not yet identified clear criteria for the presence of a certain emotion. Therefore, according to her model, an emotional experience arises when affective feeling is cognitively categorized based on our knowledge.

1.5. Autonomic electrodermal and heart rate response to snakes

Since the 1970s, an extensive series of experiments has demonstrated that snakes, compared with other stimuli, selectively trigger a stronger and longer-lasting physiological fear response, particularly an increase in heart rate, blood pressure, and skin conductance, which is more resistant to extinction [22]. Its main purpose is to mobilize energy reserves and prepare the body for rapid action [cf. 51]. The majority of studies did not measure a spontaneous response to snakes but rather used a within-subject controlled differential conditioning paradigm in which some fear-relevant (snakes and spiders) and fear-irrelevant (flowers and mushrooms) stimuli were followed by an electric shock (CS+), while others were not paired with any shocks (CS-). Most often, the dependent variable was the skin conductance response (SCR), alternatively also heart rate (HR). It was argued that the difference in SCR to the CS+ vs CS- stimulus should be bigger for fear-relevant than for fear-irrelevant stimuli, which was then supported by several studies [23, 25, 52–55], for a review see [16, 21]. For example, Soares and Öhman [54] reported that both fearful and non-fearful control subjects had significantly larger differential electrodermal responses to pictures of snakes and spiders than to pictures of flowers and mushrooms. It was also shown that SCR triggered by fear-relevant compared with fear-irrelevant stimuli was more resistant to extinction, however, no effect of fear-relevance on HR was found [53]. Interestingly, a backwardly masked presentation (stimulus appears on the screen for only about 30 ms) or an instruction that no shock will follow may wipe out differential SCR to neutral stimuli, but has no effect on differential SCR to fear-relevant stimuli [23, 54, 55]. Öhman and Soares [25] demonstrated on SCR changes that subjects can be non-consciously conditioned by electric shocks to fear snakes and spiders but not flowers and mushrooms even when these are masked during acquisition.

Others have used a different approach and instead of conditioning normal subjects to fear snakes, they directly measured spontaneous physiological responses of respondents with low vs high (phobic) fear of snakes. It has been repeatedly shown that high-fear individuals display larger SCR and increased HR when exposed to snakes compared to control stimuli [56] and, moreover, their SCR in response to snakes is elevated compared to low-fear individuals under both conscious and unconscious (masked) presentation conditions [24].

In regards to autonomous fear responses to snakes in particular, there is an ongoing debate in the literature whether these are acquired through direct aversive experiences (or observation of others' behavior) during development [57], as the studies using classical Pavlovian fear conditioning might suggest, or snake fear is rather biologically prepared (genetically fixed), universal trait in humans and other animal species that can be manifested even without any prior negative experience (humans: [20], birds: [58], geckos: [59], primates: [60, 61]).

1.6. Study aims

Even though there is a substantial body of literature dealing with psychophysiological responses to snakes (live or on pictures), those studies fail to reflect the immense morphological and pattern variety of different snake taxa that can trigger various emotions. Often researchers use the snake as a uniform stimulus prototypically eliciting fear and no attention is being paid to characteristics of that particular species (in a majority of studies the species is not even specified) such as its body size, color pattern, posture, toxicity, etc. However, from our previous research, we know that this is crucial as it can significantly affect our responses [15, 28]. Moreover, as mentioned above, most of earlier studies measured physiological parameters using a differential conditioning paradigm, which is a qualitatively different phenomenon than spontaneous reactions of unconditioned individuals and therefore, such an approach is not ideal for studying traits that might be biologically prepared.

Viperid snakes are unique stimuli for humans in several aspects: 1) many species of viperid snakes currently pose a serious risk of venomous snakebite on all the continents except Australia and Antarctica [13] and thus exert an important selective pressure on the human ability to perceive, emotionally evaluate, and avoid these snakes; and 2) it was demonstrated cross-culturally that humans perceive the specific viperid morphotype (including the families *Crotalinae*, *Viperinae*, and *Azemiopinae)* as highly fear-eliciting [15, 28]. Thus, viperid snakes present an ideal model group for studying the effect of fear response when spotting a snake.

In this study, we focused on psychophysiological responses of human subjects elicited by 20 species of snakes belonging to two distinct groups differing in their morphology, ecology, behavior, toxicity (dangerousness), and fear/disgust-evoking properties. Although autonomous bodily responses (mostly skin conductance and heart rate) to snakes have been already well-explored in previous research, to our knowledge, no one has ever focused on interstimulus variability within the category of snakes. There is evidence that people distinguish between different snake species emotionally by experiencing either fear or disgust. It is thus reasonable to expect that the same distinction is reflected in physiological responses as well. For the first time, this would show that snakes are an emotionally ambivalent category, which might have significant implications for future research by highlighting the importance of careful stimulus selection. Moreover, it would also be beneficial to the clinical practice as it might tailor treatment of snake phobics to their specific needs of better emotional regulation. In our previous study, we demonstrated a difference in fear and disgust evaluation of various snake species between people with low and high fear of snakes and disgust propensity [62]. Thus, it would be interesting to see whether these interindividual differences also manifest in physiological parameters. Finally, comparing two distinct categories of snakes as stimuli might reveal an adaptive pattern of specific physiological response targeted to venomous viperid snakes.

First, we aimed to examine the autonomous physiological response to venomous viperid snakes eliciting high fear but low disgust compared to non-venomous fossorial snakes eliciting low fear but high disgust. This exploratory question has never been studied, although based on the research using other fear- and disgust-eliciting animal stimuli, one might assume that while fear-eliciting snakes should trigger the sympathetic (predatory defense) nervous system activating the body energy resources and leading to increased skin conductance and heart rate, disgust-eliciting worm-like snakes should activate the parasympathetic (behavioral immune) nervous system causing increased skin conductance but decreased heart rate. Second, we will study how physiological responses might be affected by different levels of snake fear and disgust propensity. Again, although a few studies have compared physiological responses of snake phobics versus healthy controls, no one has incorporated disgust into the model, which might shed more light on psychopathological dynamics of snake phobia development.

Previous psychophysiological research on snake fear has used various methodology which makes any comparisons difficult. Therefore, we have chosen to study the differences in physiological responses; first, between stimulus categories and then between subjects using two experimental designs, i.e., sequential (presentation of an individual picture stimulus followed by an interstimulus) and block presentation (presentation of 10 pictures one right after the other with no interstimulus in-between) that might provoke an emotional response of different intensity. Specifically, we assume that stimulation in a block design should trigger a more intense physiological response compared to stimulation in a sequential design. Finally, as the current literature is not consistent regarding correspondence between self-reported emotions and physiological parameters, we will investigate the link between evaluation of snake stimuli and physiological responses.

2. Materials and methods

2.1. Participants

We recruited respondents with different levels of fear of snakes and general disgust propensity as measured by commonly used psychometric questionnaires–the Snake Questionnaire (SNAQ [63], in a Czech translation [64]) and the Disgust Scale-Revised (DS-R [65, 66], in a Czech translation [67]). The respondents were selected so that the dataset would be balanced with comparable numbers of respondents with high and low scores from each of the above-mentioned questionnaires. The high-fear/disgust participants were defined as those scoring above the upper quartile on the SNAQ/DS-R scales (upper quartiles were computed for Czech population: SNAQ score ≥ 8 [64]; DS-R score ≥ 52 [67]). The respondents also completed the Emotion Reactivity Scale (ERS [68]) and provided information about their gender, age, and field of study. In total, 161 individuals were included in the study. Out of these, 143 respondents performed the sequential design experiment (139 of them completed all the questionnaires; 75 high-fear, 64 low-fear, 59 high-disgust, 80 low-disgust; 116 females, 27 males; 46 biological education, 97 non-biological education; mean age 28.12 ± 10.65) and 143 the block design experiment (all of them completed the questionnaires; 82 high-fear, 61 low-fear; 59 high-disgust, 86 low-disgust; 118 females, 25 males; 46 biological education, 97 non-biological education; mean age 28.0 ± 10.18). Both experimental designs were performed by 125 respondents with the second experiment being carried out after at least a month-long period, so that the effect of habituation would be minimized. The sample size was based on both, previous studies (for the comparison, see Table 4) and a statistical a priori power analysis computed in G*Power 3 [69]. This analysis was conducted to test the difference in physiological responses to three categories of stimuli (fear/disgust/control, see below) between two main categories of respondents (high/low fear of snakes) using an ANOVA, a medium effect size ($f = 0.25$) and an alpha of 0.05. The result showed that a total sample of 158 participants in one experimental design was required to achieve a power of 0.80. However, the prevalence of people with high fear of snakes who are willing to attend an experiment with snakes is rather low, thus, we compromised on having 143 respondents in each design. The sample is not perfectly balanced especially in terms of gender; however, our main aim was to keep the ratio of respondents with high and low fear of snakes balanced. As the prevalence of snake fear is higher in women [64, 70], our study included more women than men.

2.2. Stimuli

We selected 20 photographs of snake species evoking a strong and distinct emotional response based on their morphotype according to the self-reported evaluation (15)– 10 dangerous (highly venomous) viperid snakes evoking strong fear (for their venom characteristics, see Table 1) and 10 disgust-eliciting harmless (nonvenomous) fossorial snakes, evoking only a weak fear response (see also Fig). On a 7-point Likert scale of fear (1 = no fear, 7 = extreme fear), the fear-eliciting snakes scored high (mean score 5.15 ± 1.95), while the disgust-eliciting ones scored much lower (mean score 3.24 ± 2.00) [62]. As emotionally neutral controls, we used 20 photographs of tree leaves (see also Fig 1 for examples of the tested species in each

Table 1. List of fear-eliciting species included in the study and their venom and physiological parameters.

Latin name	English name	Subfamily	LD50 (IV)	Length (mm)	Venom (mg)	Danger	Venom ratio	Sources
Atheris squamigera	Variable bush viper	Viperinae	0.611	800	2.5	3.0	0.0031	[71–73]
Azemiops feae	Fea's viper	Azemiopinae	0.52	800	1.75	1.5	0.0022	[71, 74, 75]
Bitis gabonica	Gaboon viper	Viperinae	0.55	1800	750	5.5	0.4167	[71, 75, 76]
Bitis nasicornis	Rhinoceros viper	Viperinae	0.55	2000	848	5.5	0.4240	[71, 77, 78]
Cerastes vipera	Sahara sand viper	Viperinae	0.5	490	43	2.5	0.0878	[71, 79]
Crotalus adamanteus	Eastern diamondback rattlesnake	Crotalinae	1.33	2440	500	4.5	0.2049	[71, 75, 80]
Echis carinatus multisquamata	Multiscale saw-scaled viper	Viperinae	3.26	625	25	4.5	0.0400	[75, 81, 82]
Echis carinatus sochureki	Sochurek's saw-scaled viper	Viperinae	2.98	625	25	4.5	0.0400	[75, 81, 82]
Protobothrops jerdonii	Jerdon's pitviper	Crotalinae	1.5	990	300	3.0	0.3030	[71, 75, 83]
Vipera orlovi	Orlov's Viper	Viperinae	0.608	500	4	2.5	0.0080	[71, 77]

LD50 (IV) = 50% lethal dose (intravenous), the amount of venom injected intravenously, which kills 50% of mice, it is the measure of venom toxicity; Danger = the index of dangerousness to humans as retrieved from Clinical Toxinology Resources (toxinology.com: University of Adelaide, Australia) ranging from 0 = not at all dangerous till 6 = extremely dangerous; Venom ratio = the ratio of venom amount to body length.

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Fig 1. Illustrative examples of picture stimuli used in the study. Due to copyright restrictions, some of the pictures have been replaced by different photos/ illustrations that were not used in the study but are essentially very similar. The snake species are as follows, from left to right: A) fear-eliciting snakes: Sahara sand viper (*Cerastes vipera*), photo by Milan Kaftan, Sochurek's saw-scaled viper (*Echis carinatus sochureki*), photo by Tomáš Mazuch, and Gaboon viper (*Bitis gabonica*), photo by Milan Kaftan; (B) disgust-eliciting snakes: Eurasian blind snake (*Xerotyphlops vermicularis*), northern rubber boa (*Charina bottae*), and brahminy blindsnake (*Indotyphlops braminus*), all three illustrations have been painted by Pavel Procházka (please note that due to copyright restrictions, the photos used in the study had to be replaced by illustrations for the purpose of this illustrative figure only); (C) control stimuli (leaves): silver birch (*Betula pendula*), photo by Silvie Rádlová, Old World sycamore (*Platanus orientalis*), photo by Petra Frýdlová, and European beech (*Fagus sylvatica*), photo by Eva Landová.

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category depicting their morphological variety). According to a preliminary study with 135 respondents, leaves do not elicit any fear (mean score 1.09 ± 0.53), nor disgust (mean score 1.09 ± 0.54; 7-point scale, 1 = no fear/disgust). The photos used in the study were either taken by the authors themselves or downloaded from the Internet; in this case they were licensed under the Creative Commons and/or a written permission for scientific use was obtained from their authors. For the full list of included snake species, see S1 Table. The photos were standardized by placing the stimuli on a unified grey background and resized to assume a similar relative size in a 2:3 ratio of the picture.

To analyze the effect of morphologic characteristics of the examined snake species on the human responses, we included the following measures and color characteristics with considerable variability within the two snake categories (fear- and disgust-eliciting) as explanatory variables: body length, neck width, eye size, proportion of white, black, grey, red, brown, and blue colors, mean saturation and standard deviation of saturation (for more information on the measurement and extraction of these variables, see Rádlová et al. [15]. We also included three venom characteristics of the fear-eliciting snakes: LD50 (50% lethal dose, intravenous), index of dangerousness as retrieved from the Clinical Toxinology Resources [75], and a ratio of venom volume to body length (Table 1).

2.3. Procedure and apparatus

To fulfill the aims, we examined several skin resistance (SR) and heart rate (HR) parameters (see Table 2) in response to images of fear-eliciting venomous viperids, disgust-eliciting non-venomous fossorial snakes, and leaves as control stimuli. We also adopted two experimental designs to examine different intensities of visual stimulation. In the first one, further referred to as the sequential design, the pictures of snakes and leaves were presented individually in an alternating order starting with a control stimulus (i.e. leaf–venomous snake–leaf–disgusting snake and so on repeated through the entire presentation of 40 images), each presented for 5 seconds and separated with a black screen (interstimulus) presented for 5 seconds or until the participant calmed down, whichever lasted longer.

In the second experimental design, further referred to as the block design, the pictures were presented in blocks consisting of 10 pictures from a single category (fear/disgust/control). This design, commonly used in fMRI and EEG studies, is hypothesized to present stronger stimulation compared to individually presented stimuli (also called event-related design in fMRI/EEG studies). We applied it to physiological measurement to compare the effect of these

Table 2. Overview of the used variables. Unless otherwise stated, the values were computed separately for each stimulus category.

Abbreviation	Variable	Definition
Skin resistance (SR)		
NR	Number of reactions	Total number of reactions
MAS	Mean amplitude per stimulus	The sum of all the amplitudes divided by the number of stimuli
MDS	Mean duration of reaction per stimulus	The sum of all the reaction durations divided by the number of stimuli
MAR	Mean amplitude per reaction	The sum of all the amplitudes divided by the number of reactions
MDR	Mean duration per reaction	The sum of all the reaction durations divided by the number of reactions
Heart rate (HR)		
HR slope	Heart rate slope	Slope of linear regression of heart rate in time

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two designs of visual stimulation on the physiological response and we plan to compare the results of the block design with a subsequent fMRI experiment. The pictures in the block design were presented one right after the other (with no black screen in-between) and each picture from the specific category appeared on the screen for 2.5 seconds only, i.e. the entire block was shown for 25 seconds. This was followed by a black screen presented for at least 5 seconds or more if necessary, for the respondent to calm down (see Fig 2).

Snake illustrations in this preview have been made by Pavel Procházka, photos of leaves taken by Petra Frýdlová and Eva Landová. Please note that during the experiment, photos of real snakes were used.

High-fear participants were presented with the fear-evoking block at the end of the presentation, and similarly, high-disgust participants viewed the disgust-evoking block as the last one. This was mainly due to methodological reasons to ensure that the physiological response we were most interested in would not be compromised by object novelty. Additionally, this design was also more suitable for the high-fear/disgust subjects as they were exposed to the strongest stimuli at the end of the trial. Low-fear and low-disgust participants viewed these two presentations in a random order (in total, 70 respondents started with the fear-evoking snakes and 73 with the disgust-evoking ones). Respondents, who attended both experiments (n = 125) did so in a random, counter-balanced order.

Moreover, 111 respondents from the main sample (59 high-fear, 52 low-fear, 49 high-disgust, 62 low-disgust, 93 females, 18 males, 40 with biological education, mean age 27.89 ± 8.41) rated all depicted snake species for fear and disgust. We adopted a well-established method used in a number of previous studies [84–86]. The photographs of snakes (360 x 540 pixels) were presented one by one on a computer screen in a random order. The respondent was asked to score fear or disgust elicited by each species on a 7-point Likert scale (1 –not disgusting/fear-evoking at all, 7 –the most disgusting/fear-evoking) in two separate tasks, the first scored emotion was chosen randomly. The rating was performed after the main experiment to minimize the effect of habituation.

For measuring physiological responses, we used Multifunction Biotelemetry Support System for Psychophysiology Monitoring VLV3 [87], which enables measuring and evaluating multiple physiological variables in real time during the stimuli presentation. Skin resistance (SR) was measured using dry sensors attached to the second phalanx of the index and middle fingers of the non-dominant hand. Heart rate (HR) was measured with a pair of standard Ag/AgCl electrodes attached by adhesive collars to the skin under the right collarbone and the center fifth intercostals. To analyze the reactions, we measured length (from the beginning of the SR change curve to the peak of the curve) and amplitude of the SR change curve, which corresponds to the intensity of the emotional reaction. The heart activity was recorded as mean HR (in beats per minute) in the given time period. The pictures (1772 x 1181 pixels, 300 DPI resolution) were presented on a computer screen (26", 2560 x 1440 resolution, full screen presentation) placed 55 cm from the edge of the table. The respondents were asked to leave their hands with attached sensors on the table and to watch the screen during the whole presentation without unnecessary movements.

This study was carried out in accordance with the approval of the Ethical Committee of the National Institute of Mental Health no. 55/16, with the written informed consent from all subjects in accordance with the Declaration of Helsinki.

2.4. Statistical analysis

For the variables used to characterize physiological responses, see Table 1. They were used as raw data when possible and were transformed for use of linear models, using either


A) Sequential design
Control (5s) → IS (5+s) → Fear (5s) → IS (5+s) → Control (5s) → IS (5+s) → Disgust (5s) → IS (5+s)
(repeats 10 times with different stimuli in each category)
B) Block design (high DS-R score respondents)
Control block (25s)
(10 images, 2.5s each) → IS (5+s) → Fear block (25s)
(10 images, 2.5s each) → IS (5+s) → Control block (25s)
(10 images, 2.5s each) → IS (5+s) → Disgust block (25s)
(10 images, 2.5s each) → IS (5+s)
(presentation ends)
C) Block design (high SNAQ score respondents)
Control block (25s)
(10 images, 2.5s each) → IS (5+s) → Disgust block (25s)
(10 images, 2.5s each) → IS (5+s) → Control block (25s)
(10 images, 2.5s each) → IS (5+s) → Fear block (25s)
(10 images, 2.5s each) → IS (5+s)
(presentation ends)

Fig 2. Visual diagram of the experimental design. The presentation always started with the control stimuli. A) Sequential design–the pictures of fear-eliciting snakes (fear), disgust eliciting snakes (disgust), and leaves (control) were presented on a computer screen individually in an alternating order, each presented for five seconds and separated with a black screen (interstimulus, IS). The interstimuli were presented for five seconds or until the participant calmed down, whichever took more time. The presented scheme was repeated ten times, each time with a different picture from the same category. B, C) Block design–similar to the sequential design, but the stimuli were presented in blocks of ten pictures not interlaced with the IS, which only followed after the presentation of all 10 pictures of the block. Each block consisted of ten different pictures from the same category, i.e. the same stimuli as used in the sequential design. The two block designs differed in the order in which the fear and disgust stimuli were presented: participants with high disgust propensity scores were presented the (B) order, while participants with high snake fear were presented the (C) order.

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logarithmic or square root transformations to approximate to the normal distribution. The distribution of model residuals was visually inspected for both deviations from normality and variance heterogeneity. The Spearman's correlation coefficient was computed to compare the self-reported evaluation and physiological responses. To test the differences in physiological responses to individual snake species and to different stimulus categories, we performed a Friedman test and post hoc Nemenyi test as implemented in the R package PMCMR [88]. A Mann-Whitney U test was used to compare the physiological reactions of high- and low- fear/disgust respondents. The above-mentioned tests were used as a non-parametric alternative for raw data deviating from normality, as we aimed to maintain extreme values of highly fearful participants. Two analyses were used to examine the contribution of respondent's characteristics (gender, age, education, SNAQ, DS-R, and ERS scores) to the physiological responses; these were used as explanatory variables in linear mixed effects models (LME; implemented in R package nlme), which allowed for inclusion of the effects of respondent's characteristics accounted for the individual identity using it as a random factor. An ANOVA was applied to test the effect of explanatory variables. We also performed an exploratory redundancy analysis (RDA; implemented in the R package vegan [89]), which is a multivariate direct gradient method. It extracts and summarizes the variation in a set of response variables (parameters of physiological reactions) that can be explained by a set of explanatory variables. This analysis permits to plot both response and explanatory variables to a space defined by the extracted gradients and enables detection of redundancy (i.e., shared variability) between sets of response and explanatory variables. Statistical significance of the gradients was confirmed by permutation tests. Repeatability was computed as another exploratory analysis to test the intra-individual consistency between respondents performing both tasks using the R package rptR [90]. Repeatability allowed us to establish the relative contribution of between-individual variation to the overall variation [91, 92]. Calculations were performed in R [93] and Statistica [94].

3. Results

3.1. Sequential design of individual stimuli presentation

3.1.1. Differences in the physiological response to fear- and disgust-eliciting snakes. We pooled the data for individual stimuli and performed further analyses with the mean SR parameters for each stimulus category (fear-eliciting snakes, disgust-eliciting snakes, and leaves as control stimuli). To fully compare the physiological responses to a given category, we computed the number of reactions (NR), mean amplitude/duration of reaction per stimulus (MAS and MDS, respectively; i.e. the sum of the amplitudes/durations divided by the number of stimuli in each category), and mean amplitude/duration per actual reaction (MAR and MDR, respectively; i.e., the sum of the amplitudes/durations divided by the number of reactions in each category). NR describes the frequency of any SR reaction regardless its intensity or overall respondent's responsiveness, MAR and MDR describe the quality of the response (e.g. intensity) and MAS and MDS combine both quantity and quality in one parameter. We included the respondents with no skin resistance reaction (n = 9), too, because this represents a relevant result for people with no fear of snakes. Mean number of reactions was 14.04 ± 9.37. We also computed the mean HR slope for each stimulus category (fear/disgust/control), i.e., the slope of the linear regression line through the data points, which describes the change in heart activity in time. It was computed for the five-second interval of each stimulus presentation and subsequently as a mean for all stimuli in a given category. Positive slope values indicate an increase in HR in time, while negative values indicate a decrease, and zero slope indicates no change (for overview of the variables, see Table 1).The Friedman test revealed that the effect of category on all tested SR parameters was highly significant (Friedman NR χ^2 = 74.711, MAS χ^2 = 58.682, MDS χ^2 = 74.652, MAR χ^2 = 27.106, MDR χ^2 = 25.879, all df = 2, all $p < 0.0001$; for the visualization, see Fig 3). Furthermore, we performed a pairwise comparison of the stimulus categories using the post-hoc Nemenyi test. All of the comparisons were significant (p values from 0.0210 to < 0.0001) except for MAR and MDR, where the disgust vs

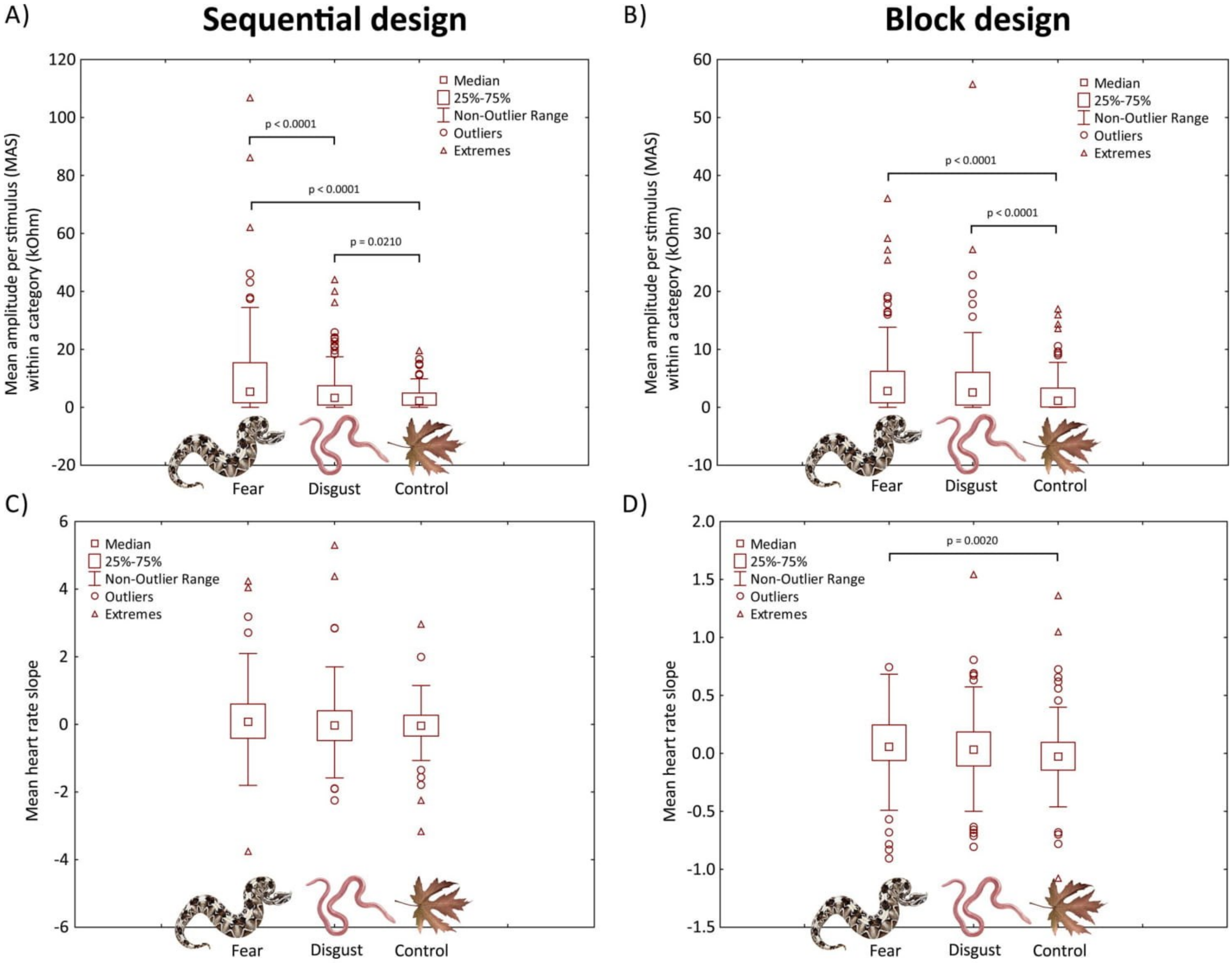

Fig 3. Boxplots of differences between fear, disgust, and control conditions in measurements of (a, b) galvanic skin resistance (SR) and (c, d) heart rate (HR). Significance of the difference was measured using the Friedman and post-hoc Nemenyi tests. Depicted species: rhinoceros viper (*Bitis nasicornis*) as a fear-eliciting snake, Eurasian blind snake (*Xerotyphlops vermicularis*) as a disgust-eliciting snake (both illustrations by Pavel Procházka), and Old World sycamore (*Platanus orientalis*) as a control stimulus, photo by Petra Frýdlová.

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control comparison was not significant ($p > 0.05$). Therefore, the SR responses to fear-eliciting snakes are significantly differentiated from those to the control stimuli in all examined parameters. However, when responses to disgust-eliciting snakes are compared to controls, the differences lie rather in the response frequency rather than in their amplitude or length.

For the HR slope, the result of the Friedman test was not significant, however, the visualization shows there is a slight tendency for higher HR in response to fear-eliciting snakes and lower HR in response to disgust-eliciting snakes compared to controls (Fig 3). When we performed the analysis separately for high-fear respondents, the result was marginally significant (Friedman $\chi^2 = 5.5254$, df = 2, p-value = 0.0631). The subsequent post-hoc Nemenyi test was also marginally significant for the comparison of fear-evoking snakes and controls ($p = 0.056$) and not significant in other cases (for more analyses of high-fear respondents, see below).

3.1.2. Effect of respondents' fear of snakes and disgust propensity. Next, we analyzed the effect of respondents' scores on the Snake Questionnaire (SNAQ, a measure of snake fear), Disgust Scale-Revised (DS-R, a disgust propensity measure), and Emotion Reactivity Scale (ERS, a measure of emotional sensitivity, intensity, and persistence) and other characteristics, e.g., the gender, age, biological or non-biological education, stimulus category, and interactions of the respondent's characteristics with the stimulus category on the SR response. We used an LME model that allows to include the effects of respondent's characteristics accounted for individual identity.

Regarding the amplitude (MAS), five explanatory variables remained in the final reduced model: category, DS-R, age, ERS and ERS*category interaction. The ANOVA revealed that only the effects of stimulus category ($F_{2,274} = 42.7670$, $p < 0.0001$) and ERS*category interaction ($F_{2,274} = 8.4200$, $p = 0.0003$) were significant. In the case of duration (MDS), seven explanatory variables remained in the final reduced model: stimulus category, SNAQ, DS-R, ERS, gender, SNAQ*category and ERS*category interactions. The ANOVA revealed that the effects of category ($F_{2,272} = 58.5345$, $p < 0.0001$), SNAQ ($F_{1,134} = 7.6997$, $p = 0.0063$), SNAQ*category interaction ($F_{2,272} = 9.9585$, $p = 0.0001$) and ERS*category interaction ($F_{2,272} = 5.4564$, $p = 0.0047$) were significant.

Furthermore, we employed an RDA with the same explanatory variables except the stimulus category. The analysis generated three constrained axes that explained 9.3% of the full variability. The sequential "Type I" ANOVA (n permutations = 20 000) revealed that the effect of SNAQ scores ($F_{1,135} = 5.2362$, $p = 0.0097$), ERS ($F_{1,135} = 3.7564$, $p = 0.0344$), and age ($F_{1,135} = 4.8459$, $p = 0.0191$) on the mean physiological parameters (MAS, MDS, and NR) were significant. Thus, the examined individual characteristics have a significant effect on the SR response, however, they explain only a small portion of the full variability. On the other hand, the effect of stimulus category on the HR slope was not significant. Five explanatory variables remained in the final reduced model: stimulus category, SNAQ, gender, age and SNAQ*category interaction. The ANOVA revealed that only the effects of SNAQ ($F_{1,111} = 17.4560$, $p = 0.0001$), age ($F_{1,111} = 7.2836$, $p = 0.0080$) and SNAQ*category interaction ($F_{2,226} = 6.6595$, $p = 0.0015$) remained significant.

We then analyzed differences in the examined SR parameters between high- and low-fear and high- and low-disgust respondents using the Mann-Whitney U tests. As for high- and low-fear respondents, the comparisons were significant in the case of number and duration of reactions to fear-eliciting snakes (NR $p = 0.0187$, MDS $p = 0.0129$ and MDR $p = 0.0103$; Fig 4), but nonsignificant in the case of amplitude and reactions to other categories of stimuli. As for high- and low-disgust respondents, the comparisons were significant for all the examined parameters in responses to both the fear- and disgust-eliciting snakes (for fear-eliciting snakes all $p < 0.05$, for disgust-eliciting snakes all $p < 0.01$; Fig 4), except for MDR, which was significant only for disgust-eliciting snakes ($p < 0.01$). Thus, respondents differing in the disgust propensity level demonstrate not only different reactions to disgust- but also fear-eliciting

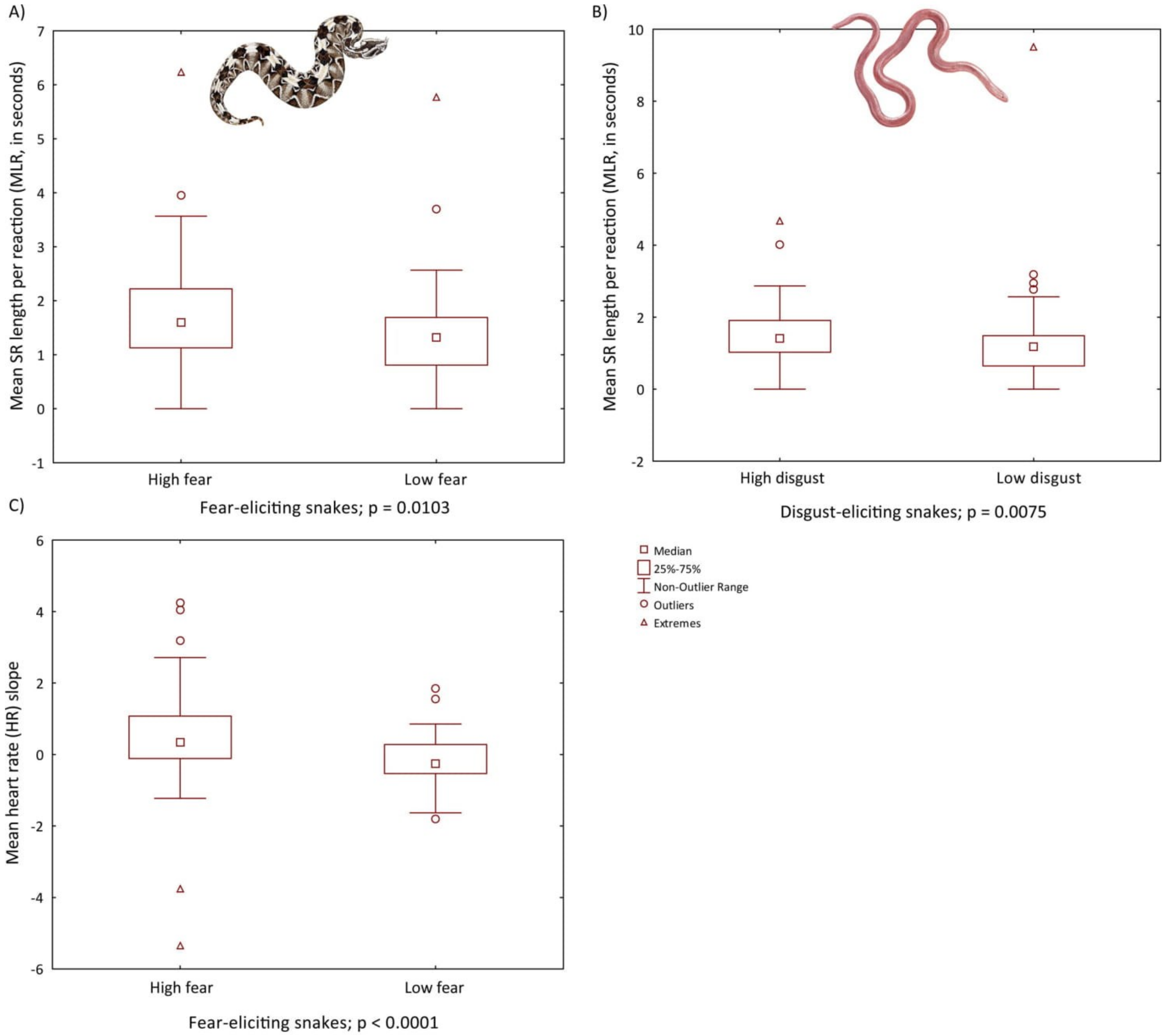

Fig 4. Boxplots of differences in (a, b) skin resistance (SR) and (c) heart rate (HR) between respondents with high snake fear or disgust propensity and controls in the sequential design. Significance of the differences was measured using the Mann-Whitney U test. Depicted species: rhinoceros viper (*Bitis nasicornis*) as a fear-eliciting snake and Eurasian blind snake (*Xerotyphlops vermicularis*) as a disgust-eliciting snake. Illustrations by Pavel Procházka.

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snakes. Furthermore, the Mann-Whitney U test revealed a significant difference in the HR slope for fear-evoking snakes when comparing low- vs high-fear respondents ($p < 0.0001$), but no significant difference when comparing high- vs low-disgust respondents.

3.2. Block design of stimuli presentation

3.2.1. Differences in the physiological response to fear- and disgust-eliciting snakes.

To compare the physiological response not only between the blocks of stimuli of discrete categories (fear/disgust/control), but also between both designs (intra-individual consistency, see below in section 3.3.), we computed the same mean variables for both designs: NR, MAS, MDS, MAR, MDR, and HR slope for the whole block of each stimulus category (see Table 1). The mean number of reactions was 12.29 ± 7.77 and respondents with no skin resistance reaction were included (n = 7). Similarly to the sequential design, the Friedman test revealed a highly significant effect of stimulus category on all the measured SR parameters (Friedman NR $\chi^2 = 24.852$, MAS $\chi^2 = 43.758$, MDS $\chi^2 = 40.950$, MAR $\chi^2 = 22.535$, MDR $\chi^2 = 17.112$, all df = 2, all $p < 0.0001$, except for MDR: p = 0.0002; for the visualization, see Fig 3). However, based on the post-hoc Nemenyi test, both snake categories significantly differed from controls (p values ranged from 0.0030 to < 0.0001), but the difference in the SR response to fear- and disgust-eliciting snakes in the block design was not significant in any of the comparisons. Thus, compared to the sequential design, there is always a significant difference between disgust and control stimuli, but not between fear and disgust stimuli. The result of the Friedman test was also significant for the HR slope (Friedman chi-squared = 11.529, df = 2, p-value = 0.0031). However, unlike for SR, the only significant difference in the HR slope was between the fear-eliciting snakes and controls as revealed by the post-hoc Nemenyi test (p = 0.002).

3.2.2. Effect of respondent's fear of snakes and disgust propensity. Subsequently, we analyzed the effect of respondent's individual characteristics (SNAQ, DS-R, and ERS score, gender, age, and biological vs non-biological education), the stimulus category, and their interactions on the SR response using the LME models. The results (see below) supported the crucial effect of stimulus category on the SR changes. In the case of amplitude (MAS), five explanatory variables remained in the final reduced model: category, SNAQ, gender, age, and SNAQ*category interaction. The ANOVA subsequently revealed that only the effect of stimulus category ($F_{2,282} = 22.3322$, $p < 0.0001$), SNAQ ($F_{1,139} = 8.6516$, p = 0.0038), and SNAQ*category interaction ($F_{2,282} = 5.7753$, p = 0.0035) were significant. In case of duration (MDS), five explanatory variables remained in the final reduced model, four of them were significant: category (ANOVA, $F_{2,280} = 23.2492$, $p < 0.0001$), SNAQ ($F_{1,140} = 12.1516$, p = 0.0007), SNAQ*category ($F_{2,280} = 5.1285$, p = 0.0065), and DS-R*category interaction ($F_{2,280} = 4.6166$, p = 0.0107), while the effect of DS-R was not significant.

We also performed an RDA, which generated 3 constrained axes that explained 12.6% of the full variability. The sequential "Type I" ANOVA (n permutations = 20 000) revealed a significant effect of SNAQ scores ($F_{1,103} = 6.7917$, p = 0.0013), age ($F_{1,103} = 3.1672$, p = 0.0407), and gender ($F_{1,103} = 4.8827$, p = 0.0115) on the mean SR parameters (NR, MAS, and MDS). However, we did not find a significant effect of stimulus category on the HR slope. Seven explanatory variables remained in the final reduced model: category, DS-R, education, age, ERS, age*category interaction, and ERS*category interaction. The ANOVA revealed that only the effect of age*category interaction was significant ($F_{2,266} = 5.6566$, p = 0.0039). Thus, in both experimental designs, the effect of stimulus category on the HR change was not significant. We also performed Mann-Whitney U tests to analyze the differences in SR responses between pre-defined groups of respondents with high and low fear of snakes and disgust propensity. As for high- and low-fear respondents, the comparisons were significant for MDS (p = 0.0322) and MAR (p = 0.0386) in response to fear-eliciting snakes, as well as for all the parameters in response to disgust-eliciting snakes (p values from 0.0419 to 0.0022; Fig 5).

Thus, in the block design, different levels of fear of snakes affected more the reactions to disgust- but not fear-eliciting snakes. Unlike in the sequential design, there were no significant differences between respondents with high and low disgust propensity in the block design. Furthermore, the Mann-Whitney U test revealed no significant difference in the HR slope when comparing low- and high-fear respondents. For the comparison of high- vs low-disgust

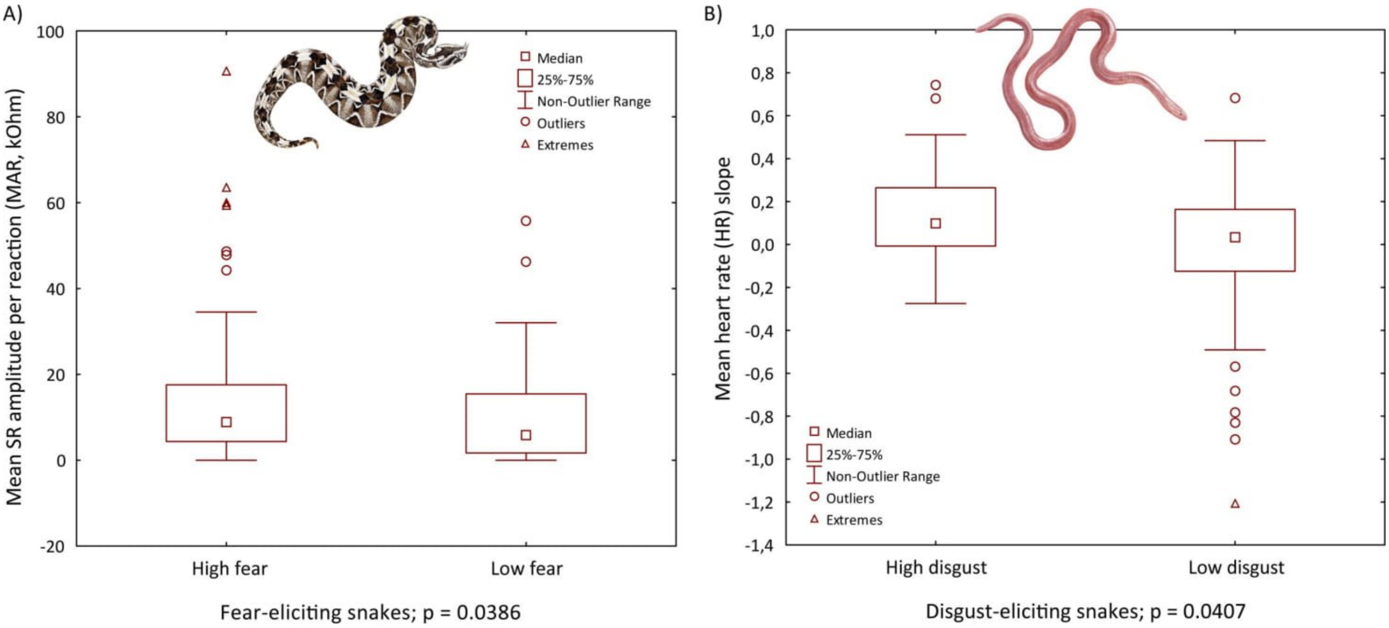

Fig 5. Boxplots of differences in (a) skin resistance (SR) and (b) heart rate (HR) between sensitive respondents and controls in the block design. Significance of the differences was measured using the Mann-Whitney U test. Depicted species: rhinoceros viper (*Bitis nasicornis*) as a fear-eliciting snake and Eurasian blind snake (*Xerotyphlops vermicularis*) as a disgust-eliciting snake. Illustrations by Pavel Procházka.

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respondents, the only significant difference was in the reactions to fear-evoking snakes (p = 0.0407).

3.3. Comparison of the two designs

3.3.1. Effect of experimental design. From the above-presented results, we concluded that the effect of experimental design was not negligible and examined it further employing LME models. The experimental design and respondent's characteristics (SNAQ, DS-R, and ERS scores, gender, age, and biological or non-biological education) were used as explanatory variables. The ANOVA revealed that in the case of MAS for all stimuli, the effects of design ($F_{1,124} =$ 9.0677, p = 0.0032), SNAQ ($F_{1,118}$ = 5.7467, p = 0.0181), and age ($F_{1,118}$ = 4.2450, p = 0.0416) were significant. For MDS, the effects of design ($F_{1,124}$ = 7.1368, p = 0.0086) and SNAQ ($F_{1,118}$ = 10.9151, p = 0.0013) were significant. And for MDR, only the effect of SNAQ ($F_{1,118}$ = 8.3484, p = 0.0046) was significant. The results were comparable when computed for mean reactions to all stimuli and to fear- and disgust-eliciting snakes separately. However, in the case of MAR, the results were different when computed for all stimuli and both snake categories separately. For all stimuli, the effects of gender ($F_{1,118}$ = 6.7606, p = 0.0105) and age ($F_{1,118}$ = 5.7223, p = 0.0183) were significant, in the case of fear-eliciting snakes the effects of design ($F_{1,124}$ = 12.2090, p = 0.0007), gender ($F_{1,118}$ = 4.5649, p = 0.0347), and age ($F_{1,118}$ = 5.3629, p = 0.0223) were significant. Conversely, there was no significant effect on the reactions to disgust-eliciting snakes. Thus, the experimental design affects especially the mean reactions per stimulus, which corresponds to the reaction frequency rather than its amplitude or duration and is higher in the sequential design. The amplitude of the SR reaction (MAR) is higher in the sequential design only in response to fear-eliciting snakes.

3.3.2. Intra-individual consistency. We moreover examined intra-individual consistency of SR responses in respondents who performed both experimental designs (n = 125) by computing repeatability. The results were highly significant for NR (R values from 0.392 for control stimuli to 0.563 for all stimuli, all $p < 0.0001$), MAS (R values from 0.384 for disgust-eliciting stimuli to 0.454 for all stimuli), and MDS (R values from 0.351 for disgust-eliciting stimuli to 0.491 for all stimuli), except for MAS in response to fear-eliciting stimuli, which was significant at $p = 0.0003$ ($R = 0.301$). As for MAR and MDR, the results were highly significant in the case of MDR in response to control stimuli ($R = 0.337$, $p < 0.0001$) and significant at the p level from 0.0067 to 0.0004 in all other cases (MAR: R values from 0.222 for disgust-eliciting to 0.3 for control stimuli; MDR: R values from 0.224 for disgust-eliciting to 0.241 for fear-eliciting stimuli). We then computed repeatability for high-fear respondents ($n = 70$). Overall, the results were significant except for MDR in response to disgust-eliciting and control stimuli. For the control stimuli, the repeatability R level was lower in all parameters and higher in the case of amplitude in response to snake stimuli and all stimuli. Thus, despite a significant effect of the design, the SR responses were relatively highly intra-individually consistent across both designs in most examined cases. For the complete repeatability results, see Table 3.

3.4. Correlation of self-reported emotions and physiological response

In the current study, we measured the physiological response to 10 venomous fear-eliciting snakes and 10 harmless disgust-eliciting snakes (see S1 Table for more details on the snake species in both categories). To examine the relationship between the self-reported evaluation and physiological response, we computed Spearman's correlations. Mean fear or disgust score of each snake species reported by the respondents was highly correlated with the mean SR

Table 3. Results of repeatability of physiological responses.

		All respondents (incl. HF)			**HF respondents only**		
		R	**CI**	**p**	**R**	**CI**	**p**
mean amplitude per stimulus	**all**	0.454	0.299, 0.585	< 0.0001	0.516	0.334, 0.667	< 0.0001
	fear	0.301	0.128, 0.450	0.0003	0.313	0.099, 0.502	0.0043
	disgust	0.384	0.216, 0.518	< 0.0001	0.481	0.283, 0.637	< 0.0001
	control	0.401	0.251, 0.545	< 0.0001	0.29	0.072, 0.496	0.0077
mean duration of reaction per stimulus	**all**	0.491	0.349, 0.607	< 0.0001	0.465	0.263, 0.631	< 0.0001
	fear	0.360	0.197, 0.500	< 0.0001	0.306	0.074, 0.509	0.0051
	Disgust	0.351	0.194, 0.493	< 0.0001	0.365	0.152, 0.550	0.0009
	control	0.443	0.301, 0.574	< 0.0001	0.336	0.109, 0.516	0.0023
mean amplitude per reaction	**all**	0.249	0.082, 0.403	0.0026	0.342	0.118, 0.530	0.0019
	fear	0.260	0.088, 0.418	0.0018	0.368	0.146, 0.581	0.0009
	disgust	0.222	0.043, 0.394	0.0068	0.325	0.101, 0.517	0.0031
	control	0.300	0.129, 0.452	0.0004	0.25	0.029, 0.464	0.0194
mean duration per reaction	**all**	0.226	0.061, 0.385	0.0060	0.232	0.010, 0.432	0.0279
	fear	0.241	0.083, 0.401	0.0036	0.242	0.016, 0.440	0.0231
	disgust	0.224	0.054, 0.388	0.0063	0.178	0.000, 0.388	*0.0752*
	control	0.337	0.167, 0.480	0.0001	0.176	0.000, 0.395	*0.0767*
number of reactions	**all**	0.563	0.425, 0.686	< 0.0001	0.539	0.313, 0.689	< 0.0001
	fear	0.471	0.291, 0.599	< 0.0001	0.422	0.179, 0.598	0.0007
	disgust	0.508	0.325, 0.629	< 0.0001	0.507	0.270, 0.671	< 0.0001
	control	0.392	0.196, 0.521	0.0001	0.296	0.019, 0.487	0.0145

HF = high fear, R = repeatability, CI = confidence interval; all p values were significant except for two (MDR disgust and control in HF respondents), which are highlighted in italics.

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amplitude of the response to the respective snake (fear: Spearman's r = 0.7729, p = 0.0001; disgust: Spearman's r = - 0.6827, p = 0.0009; Fig 6).

3.5. Testing homogeneity of physiological responses within categories of fear- and disgust-eliciting snakes—exploratory analysis

As most analyses were based on a comparison of means of distinct stimulus categories, we furthermore explored the homogeneity within the categories of snake stimuli defined by Rádlová et al. [15], whether the SR responses correspond to the same distinct categories of two types of snakes. The Friedman test showed that the differences in the SR amplitude between snakes within the pre-defined categories were significant (fear: Friedman $\chi2 = 73.02$, df = 9, $p < 0.0001$; disgust: Friedman $\chi2 = 45.435$, df = 9, $p < 0.0001$). However, the post-hoc Nemenyi test revealed that only one species from each snake category significantly differed from the others in the mean SR amplitudes: in the case of fear-eliciting snakes, the Sochurek's saw-scaled viper differed from all the other snake species except the Sahara sand viper (*Cerastes vipera*), thus, only 8 out of 45 comparisons were significant ($p < 0.05$). In the case of disgust-eliciting snakes, the brahminy blind snake (*Indotyphlops braminus*) differed from the other snake species except the northern blind snake (*Anilios diversus*), Eurasian blind snake (*Xerotyphlops vermicularis*), rotund blind snake (*Anilios pinguis*), and the northern rubber boa (*Charina botae*), thus, only 5 out of 45 comparisons were significant ($p < 0.05$). The results calculated for SR duration were in this case almost identical to those for the amplitude and therefore will not be further mentioned in the text.

The Friedman test comparing the responses to individual species was significant. Therefore, we used a redundancy analysis (RDA) to further examine the contribution of nine morphological and three venom characteristics (Table 2) of relatively more diverse fear-eliciting snakes (treated as explanatory variables—constraints) to the SR amplitude. However, the model showed no constrained component. Thus, these analyses supported the hypothesis that the selected snake species present a homogenous category based on both the self-reported evaluation and physiological measures, regardless of their morphological or venom variability.

4. Discussion

In the current research using two experimental designs, we directly compared autonomous physiological responses of human subjects exposed to snake pictures of two distinct emotional and zoological categories. One composed of viperid snakes that are all venomous, dangerous to humans and evoke intense fear, the other one including fossorial snakes that are non-venomous, harmless, and evoke mainly disgust and repulsion. We have demonstrated that the fear-eliciting venomous snakes trigger a significantly more pronounced physiological response as evidenced by higher SR amplitude compared with the disgust-eliciting snakes, while no significant difference could be found in HR. Furthermore, we provide evidence that the individual level of snake fear greatly effects bodily responses as high-fear subjects show more increased response in both SR and HR parameters compared with low-fear subjects.

Although people demonstrate a measurable emotional response in both the SR and HR channels upon seeing a snake picture, measuring SR was a much more sensitive and robust method in the current study. By analyzing the curve of SR changes, we can reliably discriminate between reactions to fear-eliciting viperids and disgust-eliciting fossorial snakes. In other studies, the measurement of electrodermal activity was sensitive enough to detect differences in reactions to phobia-triggering animal stimuli (snakes and spiders) compared to controls even in a masked condition, when the stimuli were presented only for 30 ms [23, 24]. Fredrikson and Öhman [53] in their detailed study of fear conditioning likewise measured both

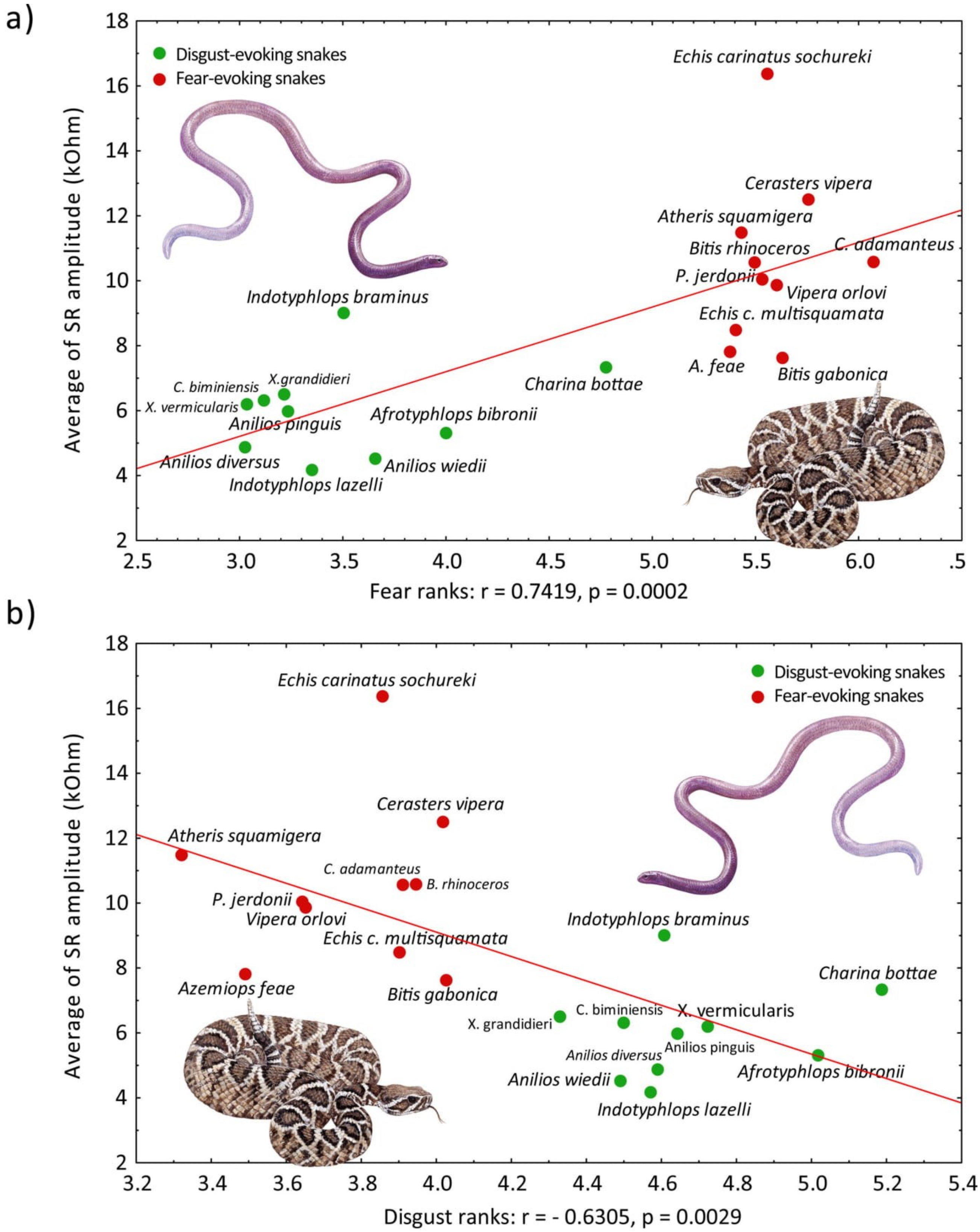
a)
Disgust-evoking snakes
Fear-evoking snakes
Average of SR amplitude (kOhm)
18
16
14
12
10
8
6
4
2
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
.5
Fear ranks: r = 0.7419, p = 0.0002
Echis carinatus sochureki
Cerasters vipera
Atheris squamigera
Bitis rhinoceros
C. adamanteus
P. jerdonii
Vipera orlovi
Echis c. multisquamata
A. feae
Bitis gabonica
Indotyphlops braminus
Charina bottae
C. biminiensis
X.grandidieri
X. vermicularis
Anilios pinguis
Afrotyphlops bibronii
Anilios diversus
Anilios wiedii
Indotyphlops lazelli
b)
Disgust-evoking snakes
Fear-evoking snakes
Average of SR amplitude (kOhm)
18
16
14
12
10
8
6
4
2
3.2
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
Disgust ranks: r = - 0.6305, p = 0.0029
Echis carinatus sochureki
Cerasters vipera
Atheris squamigera
C. adamanteus
B. rhinoceros
P. jerdonii
Vipera orlovi
Echis c. multisquamata
Azemiops feae
Bitis gabonica
Indotyphlops braminus
Charina bottae
X. grandidieri
C. biminiensis
X. vermicularis
Anilios diversus
Anilios pinguis
Anilios wiedii
Afrotyphlops bibronii
Indotyphlops lazelli

Fig 6. Spearman's correlation between physiological responses and scores of the snake stimuli (sequential design). Both (A) fear scores and (B) disgust scores of fear- and disgust-eliciting snake stimuli closely correlated with the average of skin resistance amplitude. The venomous Viperid snakes (the variable bush viper *Atheris squamigera*, Fea's viper *Azemiops feae*, Gaboon viper *Bitis gabonica*, rhinoceros viper *Bitis nasicornis*, Sahara sand viper *Cerastes vipera*, eastern diamondback rattlesnake *Crotalus adamanteus*, multiscale saw-scaled viper *Echis carinatus mutlisquamata*, Sochurek's saw-scaled viper *Echis carinatus sochureki*, Jerdon's pitviper *Protobothrops jerdonii*, and the Orlov's viper *Vipera orlovi*) were scored as more fear-eliciting (and less disgust-eliciting) and also elicited stronger physiological reactions than harmless fossorial snakes (the Bibron's blind snake *Afrotyphlops bibronii*, northern blind snake *Anilios diversus*, rotund blind snake *Austrotyphlops pinguis*, brown-snouted blind snake *Anilios wiedii*, Bahamian slender blind snake *Cubatyphlops biminiensis*, northern rubber boa *Charina bottae*, brahminy blind snake *Indotyphlops braminus*, Hong Kong blind snake *Indotyphlops lazelli*, Madagascar blind snake *Xenotyphlops grandidieri*, and the Eurasian blind snake *Xerotyphlops vermicularis*). Depicted species: eastern diamondback rattlesnake as a fear-eliciting snake and Madagascar blind snake as a disgust-eliciting snake. Illustrations by Pavel Procházka.

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parameters, i.e., the SR as well as HR response to snakes and spiders (fear-relevant stimuli). They found that electrodermal responses conditioned to fear-relevant stimuli, once learned, showed a resistance to extinction compared to neutral stimuli. However, this was not the case for HR, nor did they find differences in HR during acquisition or habituation phases, in contrast to SR. Similarly, Bradley, Cuthbert, & Lang [95] showed that HR after the stimulus onset first increased (1 s), then decreased (2–3 s), and then increased again (4–5 s), but no such pattern was detected for SR. This phasic HR response is also typical for anticipated threat situations [96]. For all these reasons, HR as a psychophysiological response parameter may be highly dependent not only on intensity of the stimulus, but also the details of a particular experimental design, e.g., the time for which the stimulus is presented to the subject or whether the subject has a chance to somehow predict when the stimulus is going to appear.

It is noteworthy that the way of visual emotional stimulation plays a significant role [95, 97–99]. It can be demonstrated that stimuli presented sequentially elicit a different level of emotional response compared to a stronger visual stimulation by 10 consecutive stimuli in a block design. When using a single stimulus presentation (sequential design), we can better differentiate responses to fear- and disgust-eliciting snakes and at the same time, the reactions to fear-eliciting are stronger in a sequential than in a block design. The question remains as to why the psychophysiological responses measured in the block design are lower. It can be argued that the block design facilitates habituation and this effect is even more pronounced in the category of fear-eliciting snakes. However, it has been shown that repeated presentation of pictures of similar affective valence does not lead to habituation and the emotional response measured by corrugator electromyographic (EMG) activity is maintained across more than twenty trials [91]. Surprisingly, in our experiment a stronger visual stimulation in the block design did not necessarily lead to a stronger emotional response, particularly if fear-eliciting snakes are shown. This may have considerable implications for fMRI or PET studies where similar picture block designs are commonly used to study the emotional response [100–102].

There have already been numerous psychophysiological studies using snakes as emotionally relevant stimuli. However, not all of them could be easily compared with the present work due to substantial methodological differences (e.g., conditioned electrodermal responses to masked stimuli [23, 25, 52–55], which is not the same as unconditioned spontaneous responses examined here). For a more detailed comparison, we have selected 11 studies meeting at least one of the following criteria: 1) measurement of electrodermal activity or heart rate in response to snakes compared to fear-irrelevant control stimuli or 2) comparison of responses to snakes in respondents with high and low fear of snakes (see Table 4, which compares mean changes in the physiological response between given categories of stimuli or respondents). Most of the studies found higher or more frequent changes in electrodermal activity in response to snake stimuli compared to neutral controls and stronger reactions in snake fearful participants, which is consistent with our results. The results of HR changes were not as robust, however, there was a trend for HR acceleration in reaction to fear-eliciting snakes compared to controls

Table 4. An overview of results from 11 previous studies compared to ours.

Study	Measured parameters	Participants N	Type of stimuli	HR snakes	EDA snakes	HR snakes HF vs LF	EDA snakes HF vs LF
Courtney et al. 2009 [103]	EDA	32	Pictures, CG pictures, CG videos		↑ HF		
Courtney et al. 2010 [104]	HR, EDA	38	Pictures, CG pictures, CG videos	↑ HF	↑ HF		
Craske & Sipsas 1992 [105]	HR	65	Live			↑	
Dimberg et al. 1998 [56]	HR, EDA	56	Pictures	↑	↑	↑	↑
Flykt & Caldara 2006 [106]	HR	27	Pictures	=		=	
Flykt et al. 2017 [107]	HR, EDA	12	Pictures (un-/masked)	↑/ =	↑/ =		
May 1977 [108]	HR, EDA	24	Pictures, words	↑	↑/ =	↑	↑
Öhman & Soares 1994 [24]	EDA	48	Pictures (un-/masked)		↑		↑
Sánchez-Navarro et al. 2018 [99]	HR, EDA	54	Pictures	↑ HF	↑		
Schaefer et al. 2014 [109]	EDA	42	Videos		↑		=
Wikström et al. 2004 [110]	EDA	51	Words (un-/masked)		↑		=
Present study	HR, EDA	161	Pictures	↑/ =	↑	↑/ =	↑

Only comparable parameters were included in the table: mean heart rate (HR) or electrodermal activity (EDA) change in response to fear-eliciting snakes compared to control stimuli (for all respondents, unless otherwise stated) and a comparison of these two parameters in response to snakes in respondents with high (HF) and low (LF) fear of snakes (↑ higher reaction, = no significant difference, ↑/ = significant in some cases, blank cells indicate that no such analysis was performed in the study). CG = computer generated stimuli.

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(significant in the block design) and higher HR acceleration in fearful respondents (significant in the sequential design), which is also in agreement with results of the previous studies.

4.1. Effect of individual characteristics on the emotional response to fear- and disgust-evoking snakes

Further intensification of the emotional reaction can be attributed to variable sensitivity of subjects to emotions in general (ERS), their physiological reactivity (repeatability in different parameters of physiological response), and specifically increased snake fear (corresponding to the SNAQ score). Even when filtering out the individual variability in LME models, the intensity and duration of emotional response (SR) is still affected by the subject's emotional reactivity as measured by the ERS, especially in response towards fear-eliciting snakes. Duration of the SR response is also specifically influenced by the subject's preexisting snake fear. Individuals experiencing higher levels of snake fear tend to demonstrate longer reactions and increased HR in response to fear-eliciting viperid snake images. These effects apply when we measure reactions to a single stimulus, however, when presented in the block design, there is no measurable effect of emotional reactivity (ERS) either on SR, or on HR. In either case, snake fear still significantly influences the intensity (amplitude) and duration of SR response. As snake fear seems to be a crucial variable affecting a range of measured psychophysiological parameters which is also supported by the literature [56, 63, 102, 111, 112], it is necessary to examine the differences between individuals with low and high snake fear in more detail.

Subjects with high fear of snakes experience more frequent and longer SR reactions (NR, MDS, MDR; see Table 2 for the abbreviations' explanation) to individually presented viperid snakes, but there is no difference in intensity (amplitude). Snake fearful respondents also show increased HR. In the block design, individuals with high snake fear demonstrated longer SR reactions (MDS) and a higher mean amplitude per reaction (MAR). In the block design, differences in the measured emotional reaction between individuals with low and high snake fear were smaller, but the latter ones demonstrated longer SR reactions (MDS) and a higher mean amplitude per reaction (MAR). In responses to the disgust-evoking fossorial snakes, we only found differences in the block design, where high-fear respondents reacted more strongly in all the parameters of SR (the number of reactions, their amplitude and duration). A similar effect has been observed in snake phobics or participants with a high level of snake fear, where snake pictures provoked an increased number of SR reactions [99] or a larger skin conductance response [56]. These subjects also showed HR acceleration during exposure to snake pictures [56, 99].

When analyzing differences in reactions of individuals with low and high disgust propensity, it seems that the latter ones tend to react more intensely to snakes in general. They show increased SR (the number of reactions, their amplitude and duration) in response not only to the fear-eliciting viperids, but also the repulsive fossorial snakes. It can be argued that people with higher disgust propensity react more strongly to any snake picture irrespective of its morphotype. Individuals with high disgust propensity also show increased HR, but only in response to viperid snakes presented in a block design. However, it is noteworthy that the association between disgust (presumably activating mainly the parasympathetic nervous system) and HR is a complex one often with opposite effects (for example disgust-associated decrease in HR in blood-injection phobia [113]). However, even if these individual characteristics, i.e., snake fear or emotional reactivity, are associated with the measured psychophysiological parameters, the overall explained variability remains as little as 9–12% (based on the RDA). The largest effect is attributable to the stimulus category, i.e., whether the subject is looking at a fear-eliciting viperid or a disgust-eliciting fossorial snake (or alternatively a leaf as a control stimulus).

As the variability of physiological parameters might be caused not only by external factors (in this case the experimental design), but also intrinsic inter-individual differences, we calculated repeatability of the SR parameters to establish the relative contribution of respondent's individuality to the overall variation (see Table 3). In our results, repeatability was the highest for responses to all the stimuli pooled together irrespective of specific variables, while NR, MAS, and MDS were the most individually repeatable variables. It has been previously shown that HR has an exceptionally good repeatability when measured twice in the same design [114]. In our study, we found relatively high repeatability of SR parameters as well, even across different experimental designs of stimuli presentation (single stimulus vs. block of stimuli). This is fairly surprising given the fact that the mean repeatability of behavioral traits in animals is $r = 0.37$ [115]; no meta-analysis for humans was found. The fact that there is significant repeatability even across very different experimental designs shows that there are consistent inter-individual differences in SR, which account for 30–50% of the overall variability.

For people with high fear of snakes, the intensive reactions to both snake groups (amplitudes) were more repeatable as opposed to reactions to control stimuli. In general, fear-eliciting stimuli (viperids) evoke more repeatable individual reactions (SR) in many parameters reflecting the intensity of emotional response (MDR, MAR) than fossorial snakes, despite the fact that fear-eliciting snakes often evoke more extreme fear responses.

4.2. Psychophysiological response to viperid snakes and how it might affect venom activity

Based on our previous study, all viperids clearly belong to the fear-eliciting group of snakes [15]. Here, we demonstrate that they evoke a fear response of similar intensity on the physiological level too, irrespective of their toxicity or relative threat presented to humans. Here we hypothesize that the observed higher psychophysiological response to viperid snakes is a result of ancestral prioritization in terms of early recognition as well as associated emotion of fear. Furthermore, this autonomous bodily response might be adaptive in a specific interaction with the main components of snake venom. Conversely, it might be argued that the distinct physiological response to viperids is not driven by higher fear, but is merely based on specific low-level visual features that differ between the two studied groups of snakes (i.e., size of scales, head shape, tail shape, body posture, etc.). However, people still report significantly higher fear of vipers. Moreover, some of our subjects demonstrated an increased physiological response to fossorial snakes that do not possess those visual cues. Therefore, it seems that both attention and emotion play a key role. To separate their influence, another experimental design using artificially created rather than natural stimuli would have to be employed.

Besides venom characteristics, there are additional factors contributing to the level of dangerousness of a particular snake species to humans, mainly its body size (which also corresponds to the venom expenditure [116]), level of defensiveness (aggression), as well as the species' abundance and distribution that influences the probability of encounter (see Table 2). Toxicity of the fear-eliciting snakes from the Viperidae family that we tested is highly variable. The most dangerous snakes for humans are vipers of the genus *Bitis* (*B. gabonica a B. rhinoceros*) and *Echis* (*E. carinatus multisquamata* and *E. carinatus sochureki*) with cardiotoxins directly affecting heart activity. Specifically, they cause a decrease in myocardial contractility, as well as disturbances in atrio-ventricular conduction and reduction in amplitude and duration of the action potential [117]. Their venom has a systemic effect on the body, is more toxic and, consequently, causes significantly more fatalities (about 10–20% of envenomings may be fatal). Another very dangerous snake from this subfamily is the eastern diamondback rattlesnake that alongside to the above-mentioned possesses also myotoxins, which can directly affect heart activity (via non-enzymatic destruction of the cardiac muscle [118, 119]). On the other hand, even though the venom of the Sahara sand viper (*Cerastes vipera*) has similar effects (procoagulants, hemorrhagins), its bite does not pose such a high risk of lethality [120]. The Sahara sand viper is a small-sized snake that releases a low amount of venom, which only has a local impact of low efficacy and can resolve even without medical intervention. Similarly, the remaining species (i.e. the Orlov's viper *Vipera orlovi*, Fea's viper *Azemiops feae*, and variable bush viper *Atheris squamigera*) are rather smaller snakes producing less venom that predominantly specialize in feeding on amphibians, reptiles, and small-sized mammals [71, 73].

It can be argued that alteration of heart rate activity is a parameter common to both snake venom action and the corresponding psychophysiological emotional response. Fear in general (not only of snakes) operates through activation of the sympathetic nervous system and hypothalamic–pituitary–adrenal (HPA) axis, which leads to a significant increase in heart rate [121]. In the case of disgust evoked by other types of snakes, which is probably mediated by the parasympathetic nervous system, we might expect considerably smaller or even opposite effects [122, 123]. The interaction between venom of viperid snakes and psychophysiological changes might therefore vary depending on the underlying emotion, i.e., fear or disgust.

It has long been known that some snake venoms dramatically lower the blood pressure in human victims and experimental animals [124–126]. This effect could either be caused directly by specific hypotensive agents present in the venom or indirectly through pulmonary vascular obstruction and coronary ischemia [127]. As venom of viperid snakes may affect HR [128], which is also affected by intense fear of snakes, we propose a hypothetical interaction between elicited fear and venom spreading and action following a snakebite. However, it is necessary to distinguish between different timeframes when emotional state of the patient and efficacy of venom may interact.

Immobilization is used as first aid immediately after a snakebite to reduce spreading of venom of viperids [129] and elapids [130]. In this early stage, high fear that increases HR might lead to snake venom spreading faster in the body with negative consequences for the victim's survival. Experiencing disgust, on the other hand, might have an opposite effect by decreasing HR through parasympathetic activation. However, in later stages, the interaction between fear or disgust, their associated physiological changes, and the venom might depend more specifically on the particular composition of toxins. Interestingly, there are various hypotensive agents in toxins contained in venom of viperid snakes which have been extracted to develop drugs for treating hypertension [128]. When these hypotensive compounds take effect, the blood pressure drastically drops. Therefore, we may hypothesize that the counter-effect of fear increasing the blood pressure might potentially improve the physiological response to envenoming by these snakes. However, no clear-cut prediction for the interaction with disgust can be made, due to its highly variable effect on heart rate. This phenomenon is worth studying.

Alternatively, the stronger physiological response to venomous snakes found in our study might as well be explained by the need of activating energetic resources in dangerous situations, which is necessary for a fast and effective defense (fight-or-flight) response before a snakebite can be delivered, i.e., eliminate the source of threat or rather withdraw oneself from the snake's presence. However, in their latest review on presumed preparedness of fear of snakes, Coelho et al. [51] argue, that most snakebites happen at very close vicinity and are extremely fast, so the victim usually has no chance to effectively respond.

5. Conclusions

The psychophysiological response to images of fear-eliciting venomous snakes from the family Viperidae is higher than the response evoked by images of fossorial, disgust-eliciting snakes. Interestingly, more intensive visual stimulation (i.e., presented longer in a block of ten subsequent images) does not lead to a stronger emotional response than less intensive stimulation (presentation of single images). It would be interesting to explore the effect of different modes of visual stimulation (e.g., comparing the effect of pictures, videos, and live snakes) on the emotional response of human subjects to fear-eliciting snakes.

Our study showed that various parameters of skin resistance reflect changes in the emotional response evoked by snake pictures while heart rate activity increases only when watching pictures of venomous snakes. Various analyses revealed that the respondents' increased general emotional reactivity, disgust propensity, and specific sensitivity to snake fear measured by psychological questionnaires (ERS, DS-R, and SNAQ) predict the psychophysiological response. High-fear respondents (as compared to low-fear respondents) show a stronger, longer, and more frequent skin resistance response and higher heart rate when watching images of venomous, fear-eliciting snakes. As physiological mechanisms underlying this response may modify the effects of snakebite envenoming, we suggest paying attention not only to the venom itself, but also to the particular species delivering the bite and the victim's individual sensitivity. It should become an integral part of studies quantifying the effects of envenomation, including studies on animal models.

Supporting information

S1 Table. List of species and picture sources used in the study as visual stimuli. The columns D and E show mean ratings of fear and disgust based on self-reported answers by 112 respondents.
(XLSX)

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6. Neurální koreláty strachu a odporu z hadů

Závěrečná část dizertační práce se zabývá neurální odpovědí na obrázky hadů vyvolávajících strach nebo odpor. Vzhledem k náročnosti sběru dat i jejich následné analýzy nebyla jako jediná dosud zpracována do podoby manuskriptu, proto v následujícím textu představuji dosažené výsledky klasickou formu.

Úvod

V kapitole 7 teoretické části jsou detailně popsány dosavadní poznatky o neurální aktivaci vyvolané hady u zdravých dobrovolníků i fobických pacientů. Hlavním centrem zpracování strachu v mozku je amygdala, ACC a OFC. Jak je však rovněž popsáno v cílech dizertačního projektu, v současnosti existuje více než 3 700 druhů hadů, mezi kterými existuje relativně vysoká morfologická i barevná variabilita. Je tedy možné, že na různé druhy hadů existuje rozdílná neurální odpověď. Pokud by se to skutečně potvrdilo, mohl by mít takový výsledek, vedle prohloubení teoretického poznání, i praktické dopady pro terapii ofidiofobie, která je jednou z vůbec nejrozšířenějších specifických fobií v obecné populaci.

Na základě dříve popsaných výzkumů se potvrdilo, že vedle strachu je další základní emocí, kterou hadi u člověka vzbuzují, odpor. Ten má však zcela odlišnou psychologickou dynamiku, fyziologickou odezvu i neurální substrát, kdy hlavním centrem v mozku pro zpracování odporu je insulární kůra. Aktivace insuly při prožívání odporu se již prokázala v řadě experimentálních studií a je např. vyvolána pohledem na pavouky. Role insuly a amygdaly při prožívání strachu či odporu z hadů však zatím nebyla plně vyjasněna, a proto hlavním cílem této části dizertačního projektu je odhalení příslušných funkčních okruhů asociovaných s vnímáním hadích stimulů, a to u zdravých dobrovolníků i jedinců s fobickým strachem z hadů či zvýšenou tendencí k prožívání odporu.

Metodika

Popis výzkumného souboru

Pro účely této studie byla využita databáze celkem 3 186 respondentů, kteří v rámci předchozích výzkumných projektů popsaných výše (první a druhá experimentální část) vyplnili dotazníky SNAQ a DS-R (899 mužů a 2 287 žen, průměrný věk 30,7 let, 173 respondentů se základním vzděláním či vyučení, 1 612 osob dokončilo středoškolské nebo vysokoškolské vzdělání). Průměrný SNAQ skór byl v tomto souboru 4,66 ± 0,17 u mužů a 6,85 ± 0,14 u žen, průměrný DS-R skór 35,05 ± 0,44 u mužů a 44,60 ± 0,30 u žen. Na základě SNAQ a DS-R skórů pak bylo z tohoto souboru do následujícího fMRI experimentu cíleně vybráno 81 osob (19 mužů a 62 žen, věkové rozpětí 19-87 let, průměrný věk 28,5 let) tak, aby v něm bylo rovnoměrné zastoupení respondentů s nízkým a vysokým skóre SNAQ a DS-R, zároveň však, aby strach z hadů nepřesáhl v této skupině klinickou hranici typickou pro fobické pacienty (SNAQ 24: Fredrikson, 1983). Průměrný SNAQ skór byl v tomto výběru 9,69 ± 0,97 (9,74 ± 2,03 u mužů a 9,67 ± 1,11 u žen), průměrný DS-R skór pak 42,54 ± 1,77 (39,00 ± 3,11 u mužů a 43,64 ± 2,10 u žen). Většinu tvořili studenti Univerzity Karlovy v Praze a Jihočeské Univerzity v Českých Budějovicích a zaměstnanci Národního ústavu duševního zdraví v Klecanech. Z 81 subjektů mělo 23 biologické vzdělání, ovšem bez detailní znalosti hadů, zbylí respondenti měli humanitní, ekonomický, technický, či jiný typ vzdělání.

Vedle těchto zdravých dobrovolníků bylo do studie zařazeno i 37 žen s diagnostikovanou specifickou fobií z hadů[66] (průměrný věk 31,7 let, SNAQ skór 23,45 ± 0,60 a DS-R skór 54,11 ± 2,56, 7 žen mělo biologické vzdělání) a jako kontrolní skupina s odlišnou specifickou fobií i 22 pacientů s diagnostikovanou arachnofobií (1 muž a 21 žen, průměrný věk 27,9 let, SNAQ skór 7,82 ± 1,62, SPQ skór 22,36 ± 0,68 a DS-R skór 52,50 ± 2,99). Pro více detailů o zařazených subjektech viz Příloha 4. Diagnóza ofidiofobie či arachnofobie byla potvrzena na základě strukturovaného klinické rozhovoru, který jsem pro tyto účely vyvinul na základě diferenciálních diagnostických kritérii popsaných v pátém vydání Diagnostického a statistického manuálu duševních poruch (DSM-5: Raboch, Hrdlička, Mohr, Pavlovský, & Ptáček, 2015; viz Příloha 5 a 6).

Stimuly

V předchozí studii (Rádlová et al., 2019) nejprve 342 respondentů seřadilo 45 standardizovaných fotografií hadů ze všech podčeledí podle strachu nebo odporu, který v nich vzbuzují. Na základě výsledků pak byl vytvořen nový set fotografií, který obsahoval 40 hadů vyvolávajících převážně vysoký strach (různé druhy zmijovitých hadů z čeledi Viperidae, tedy zmije, chřestýši apod., dále v textu označování jako "děsiví hadi") a 40 hadů vyvolávajících převážně vysoký odpor (slepákovití podzemní hady z čeledi Typhlopidae apod., dále označovaní jako "odporní hadi"), viz Obr. 12. V navazující studii (Rádlová, et al., 2020) pak tuto

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[66] Bohužel se nepodařilo nalézt ani jednoho muže s ofidiofobií, který by byl ochotný se experimentu zúčastnit.

sadu 80 fotografií hadů ohodnotil nový vzorek 330 respondentů na 7-bodové Likertově škále opět podle pociťovaného strachu a odporu. Průměrné hodnocení strachu bylo 5,16 ± 1,94 u děsivých a 3,22 ± 1,99 u odporných hadů, průměrné hodnocení odporu pak 3,28 ± 2,17 u děsivých a 4.37 ± 2,00 u odporných hadů, viz Příloha 7 pro seznam druhů a jejich průměrné skóry strachu a odporu.

Obrázek 12. Ukázka testovaných stimulů ze tří kategorií: hadi působící strach (a), hadi působící odpor (b) a listy (c) jako kontrolní stimuly. Zobrazené druhy hadů zleva doprava, v horní a prostřední řadě: zmije růžkatá (*Vipera ammodytes*), ateris ježatý (*Ateris squamigera*), azemiops (*Azemiops feae*), *Letheobia episcopus*, hroznýšek červený (*Charina bottae*), *Afrotyphlops lineolatus*.

Stejné fotografie byly použity i v této studii. Každý obrázek zobrazoval jeden druh hada umístěného na 18% šedém pozadí, v klidné, neútočící pozici a ve standardizované velikosti. Celý set byl poté zkopírován a horizontálně překlopen, takže nakonec obsahoval 160 fotografií hadů (80 vyvolávajících strach a 80 odpor). Nakonec byl ještě doplněn o 40 standardizovaných fotografií listů různých druhů stromů, znovu zkopírovaných a horizontálně překlopených (celkem tedy 80 obrázků), které sloužily jako kontrolní podněty. Předchozí nepublikovaná studie totiž potvrdila, že tyto fotografie listů nevyvolávají v respondentech žádný strach (průměrné hodnocení na 7-bodové Likertově škále: strach 1,09 ± 0,53; odpor 1,09 ± 0,54, n = 135). Listy byly upraveny tak, aby velikostně i barevně odpovídali testovaným hadům.

Design experimentu

Účastníci experimentu byli předem rozděleni do tří skupin: zdravé kontroly (n = 81), ofidiofobici (n = 37) a arachnofobici (n = 22). Každý participant byl na začátku studie informován o charakteru studie i možných rizicích souvisejících s vyšetřením pomocí fMRI. Poté byl uložen do skeneru Siemens MAGNETOM Prisma s výkonem 3 Tesla, který se nachází v Národním ústavu duševního zdraví. Pro dané měření byla použita standardní 64-kanálová hlavová cívka. Během vyšetření se přes zrcátko v hlavové cívce (projektor byl umístěn za skenerem) výzkumné osobě postupně promítaly v sérii obrázky ze tří kategorií stimulů: hadi působící strach, odpor a listy jako kontroly.

Pro tento experiment byl zvolen blokový design, kdy se během každé stimulace vyšetřované osobě prezentuje série několika po sobě jdoucích podnětů ze stejné kategorie. Každý blok obsahoval 10 obrázků z dané kategorie zobrazených v náhodném pořadí. Pořadí prezentace jednotlivých bloků bylo vyvážené tak, aby každá kategorie podnětů následovala zbylé dvě kategorie se stejnou frekvencí (LSOSOLOSLSLOLOSOLSLSOSOL, L = list, S = had vyvolávající strach, O = had vyvolávající odpor). Každý obrázek v jednom bloku byl zobrazen po dobu 3 sekund a každá kategorie podnětu byla prezentována v 8 blocích, celkem tedy 24 bloků. Experiment tak trval celkem 12 minut (10 obrázků x 3s x 3 kategorie podnětů x 8 bloků). Po ukončení měření ve fMRI každý subjekt ještě ohodnotil přes webovou aplikaci každý z prezentovaných obrázků hadů na 7-bodové Likertově škále podle strachu a odporu.

Statistická analýza

Pro zobrazení mozkové aktivity během sledování vizuálních podnětů byly použity T2* vážené gradienty pokrývající celý mozek i vybrané mozkové oblasti: 1) emoční okruh: amygdala, hipokampus, parahipokampální gyrus, insula, PFC a ACC; 2) okruh zpracování vizuálních podnětů v temenním laloku: tři okcipitální a tři temporální gyry - vždy spodní, střední a horní, dále fusiformní gyrus, linguální gyrus a rýha calcarine; 3) podkorové oblasti pro přepojování senzorických signálů a koordinaci pohybů: thalamus a putamen. Pro tyto oblasti je totiž známo, že jsou zodpovědné za zpracování a regulaci strachu a odporu. Výsledná funkční data byla před samotnou analýzou očištěna o případné artefakty vzniklé např. pohybem hlavy.

Data byla analyzována zvlášť pro každou skupinu experimentálních osob (zdravé kontroly, ofidiofobici, arachnofobici), a to na dvou úrovních, individuální (analýza aktivace pro každý subjekt) a skupinové. Pro analýzu aktivace jednotlivých voxelů[67] (velikost voxelu stanovena na 2 x 2 x 2 mm) na individuální úrovni byly použity obecné lineární modely (GLM), kdy sada regresorů obsahovala bloky hadů působících strach a odpor, bloky listů a pohybové parametry (zaznamenané pohyby hlavou) spočítané během prvního zpracování dat (preprocessing). Poté byla pro každý voxel testována hypotéza signifikance regresního koeficientu odpovídající dané kategorii prezentovaného podnětu. Kvůli problému mnohonásobného testování dané hypotézy jsme použili FWE korekci na hladině významnosti 0,05.

Na individuální úrovni byl nejprve spočítán nárůst aktivace při prezentaci hadů vyvolávajících strach i odpor a poté porovnána aktivace mezi následujícími kategoriemi: hadi působící strach vs. listy, hadi působící odpor vs. listy a obě kategorie hadů mezi sebou. Tyto analýzy ukázaly, které specifické mozkové oblasti jsou aktivované při neurální odpovědi na setkání se dvěma typy hadů. Následně byla data analyzována na skupinové úrovni, kdy se využila sada kontrastních obrázků definovaných pro každý subjekt, statisticky vyhodnocených pomocí GLM a párového t-testu. Ten určil, ve kterých mozkových oblastech došlo na skupinové úrovni k nárůstu aktivace. Párovým t-testem byl také spočítán rozdíl v kontrastech nalezených mezi oběma kategoriemi hadů a listy. V GLM modelu byl nakonec analyzován vliv skórů SNAQ a DS-R (přidány jako kovariáty) a hodnocení sady obrázků hadů vyvolávajících strach a odpor na 7-bodové Likertově škále. Zpracování obrázků a statistické analýzy byly provedeny v programu SPM, verze 12 (Statistical Parametric Mapping software, SPM; http://www.fil.ion.ucl.ac.uk), implementovaném v prostředí MATLAB, verze R2016b (MathWorks).

Výsledky

Ze 140 subjektů zařazených do experimentu nakonec měřením ve fMRI prošlo 139 osob, jedna dobrovolnice z kategorie zdravých kontrol před samotným měřením odmítla účast kvůli klaustrofobii.

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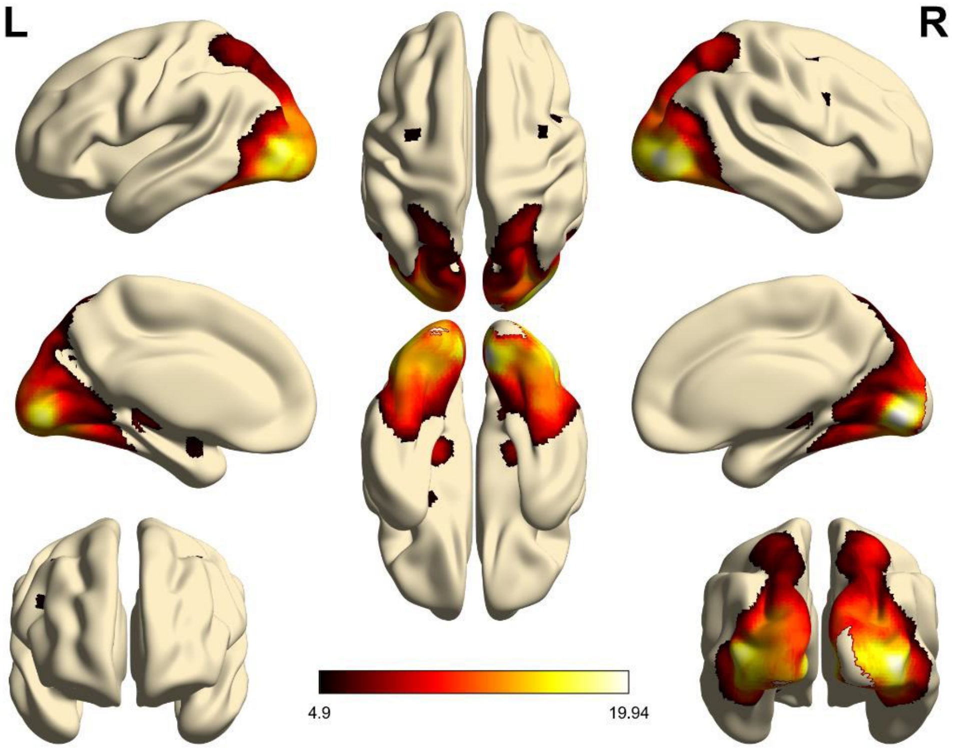
[67] Voxel (zkratka z anglických slov *volumetric element*) označuje v MR analýze jednotku objemu zobrazovaného mozku, která má určitou polohu v pravidelné mřížce 3D prostoru. Umístění každého voxelu je tedy popsáno souřadnicemi x, y, z v trojrozměrném poli. Voxel je analogií pixelu ve 2D zobrazení, tedy čím menší velikost voxelu zvolíme, tím větší získáme výsledné rozlišení obrazu. Ve fMRI platí, že více zaznamenaných voxelů značí intenzivnější mozkovou aktivaci.

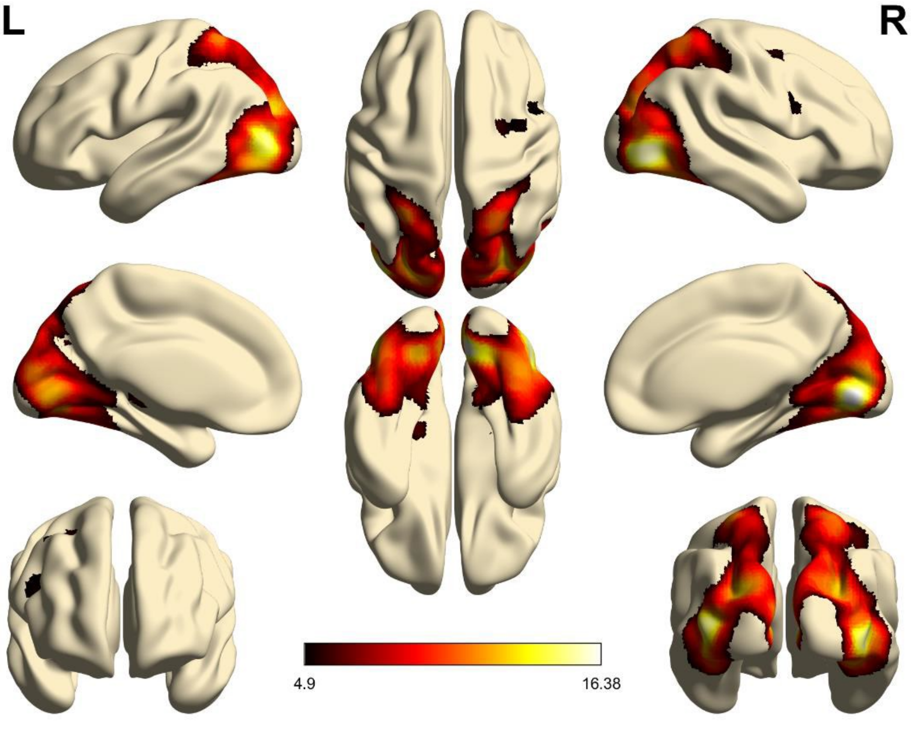
Neurální odpověď u zdravých dobrovolníků

V prvním kroku jsem se zaměřil na analýzu aktivace v rámci celého mozku u kontrolních subjektů. Při porovnání neurální odpovědi na děsivé hady vs. listy byla patrná silná bilaterální aktivace ve zrakové kůře a přilehlých oblastech (spodní, střední a horní okcipitální gyrus, rýha calcarine, linguální, fusiformní, angulární, supramarginální a precentrální gyrus), levém thalamu a pravé i levé amygdale. Statisticky významný byl rozdíl u celkem 8 clusterů, z nichž největší se skládal z 25 300 voxelů (z celkem 188 402 voxelů; p < 0,001; Obr. 13 a Příloha 8). Velmi podobný výsledek přineslo i srovnání aktivace při sledování odporných hadů vs. listů (7 clusterů, největší z nich 24 448 voxelů, p < 0,001; aktivní oblasti: okcipitální gyry, rýha calcarine, linguální, angulární, supramarginální a precentrální gyrus a pravý i levý thalamus; Obr. 14 a Příloha 9). Nakonec jsem mezi sebou porovnal mozkovou aktivaci při sledování hadů z obou skupin. Děsiví hadi vyvolali oproti odporným hadům výrazně vyšší aktivaci v oblasti primární zrakové kůry (5 627 voxelů, p < 0,001; spodní a prostřední okcipitální gyrus; Obr. 15 a Příloha 10), zatímco opačné srovnání (odpor > strach) odhalilo vyšší aktivaci v omezené oblasti pravého linguálního gyru (80 voxelů; p = 0,001; Příloha 11).

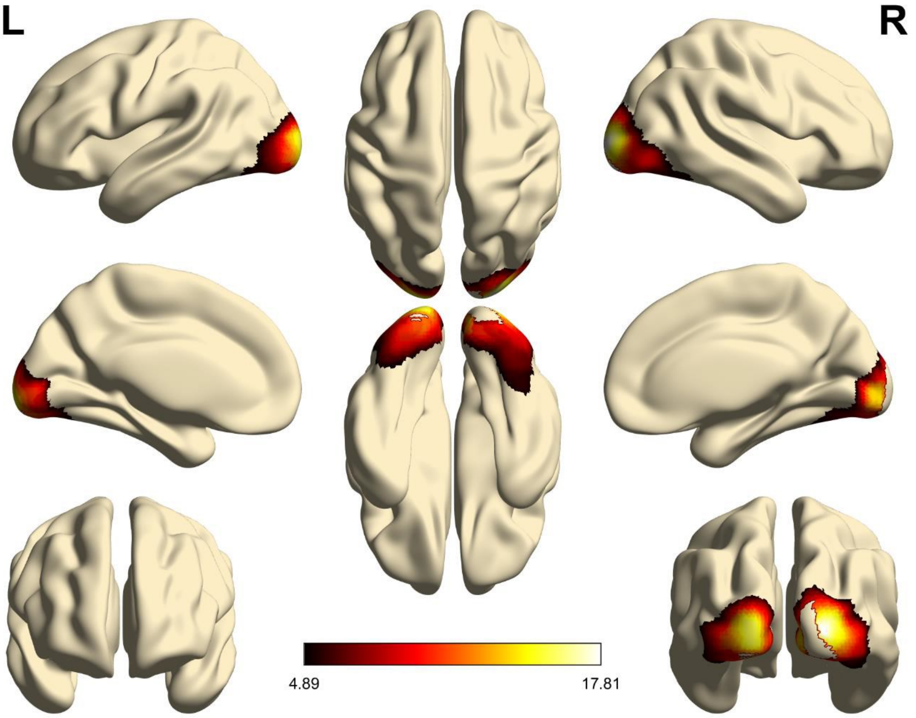
Obrázek 13. Zobrazení signifikantních rozdílů v aktivaci mozku při sledování děsivých hadů a kontrolních podnětů (strach > listy).



Obrázek 14. Zobrazení signifikantních rozdílů v aktivaci při sledování odporných hadů a kontrolních podnětů (odpor > listy).



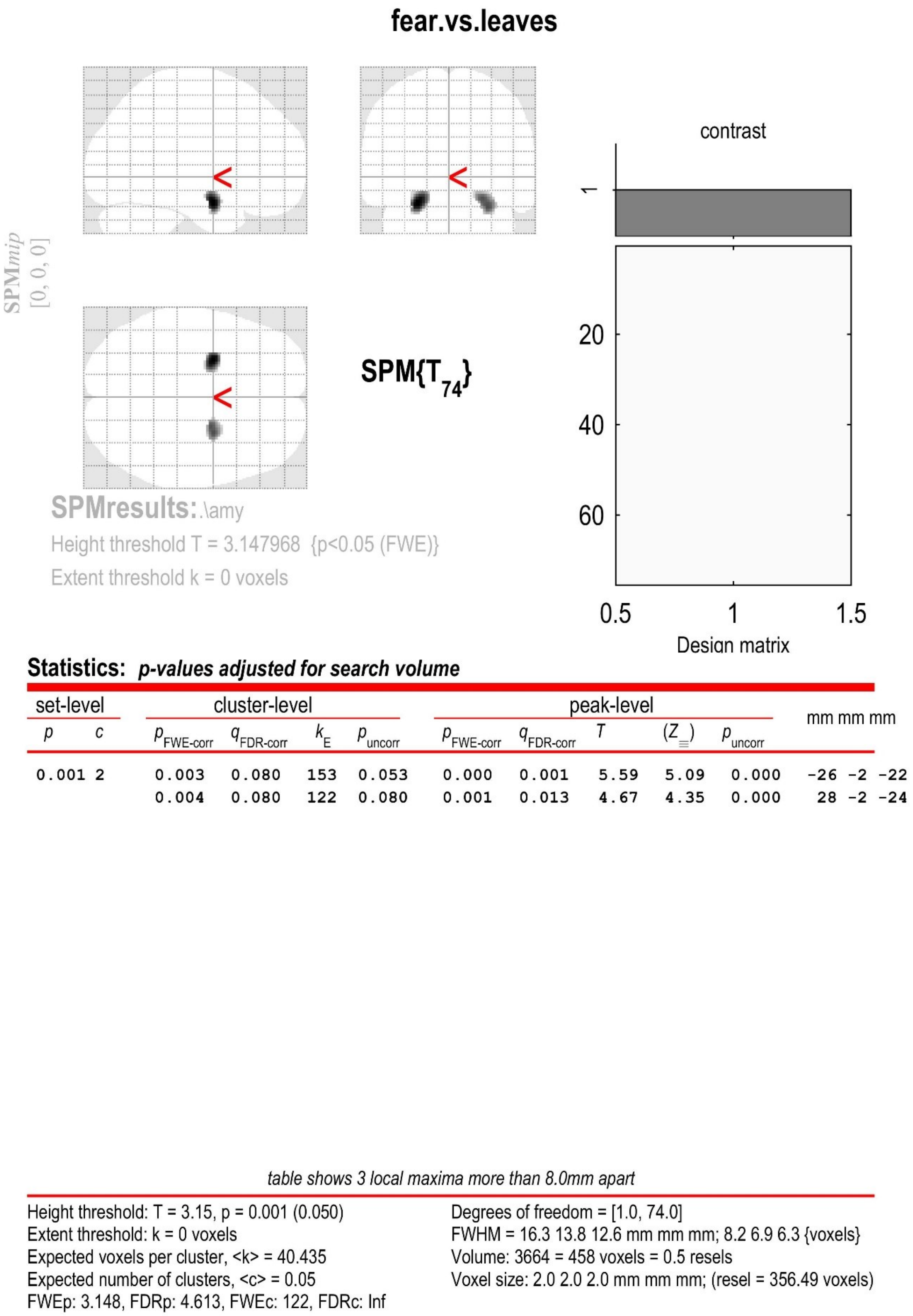
Obrázek 15. Zobrazení signifikantních rozdílů v aktivaci při sledování děsivých a odporných (strach > odpor).



V další analýze jsem porovnal aktivace ve vybraných mozkových strukturách (region of interest, ROI) u zdravých dobrovolníků. Při srovnání neurální odpovědi na děsivé hady vs. listy byla patrná vyšší oboustranná aktivace v amygdale (153 a 122 voxelů; p = 0,003 a 0,004; Obr. 16) a hipokampu (147 a 110 voxelů; p = 0,001; Příloha 12), dále v nepatrné oblasti levého parahipokampálního gyru (11 voxelů, p = 0,027; Příloha 13) a levé insuly (5 voxelů; p = 0,037; Příloha 14), 4 omezených clusterech PFC (největší z nich 22 voxelů, p = 0,013; Příloha 15) a bilaterální aktivace v okcipitálních gyrech (2 732 a 3 756 voxelů; p < 0,001; Příloha 16), temporálním gyru (1 370 a 749 voxelů, p < 0,001; Příloha 17), fusiformním gyru (1 302 a 1 225 voxelů; p < 0,001; Příloha 18), rýze calcarine (2 801 voxelů; p < 0,001; Příloha 19), linguálním gyru (3 315 voxelů; p < 0,001; Příloha 20) a thalamu (79 a 76 voxelů; p = 0,006 a 0,007; Příloha 21).

Odporní hadi v porovnání s listy vyvolali signifikantně vyšší aktivaci v levé i pravé amygdale (55 a 14 voxelů; p = 0,015 a 0,031; Příloha 22), levém hipokampu (62 voxelů; p = 0,005; Příloha 23), nepatrné oblasti levého parahipokampálního gyru (9 voxelů; p = 0,029; Příloha 24), 3 clusterech PFC (největší z nich 90 voxelů; p = 0,001; Příloha 25) a bilaterálně v okcipitálních gyrech (2 530 a 3 554 voxelů; p < 0,001; Příloha 26), temporálním (1 358 a 827 voxelů; p < 0,001; Příloha 27), fusiformním (1 154 a 1 221 voxelů; p < 0,001; Příloha 28) a linguálním gyru (3 276 voxelů; p < 0,001; Příloha 29), rýze calcarine (2 781 voxelů; p < 0,001; Příloha 30) a thalamu (29 a 20 voxelů; p = 0,019 a 0,023; Příloha 31), ne však v insule (p = 0,175; Příloha 32). Děsiví hadi vyvolali v porovnání s odpornými hady signifikantně vyšší aktivaci v okcipitálních gyrech oboustranně (1 234 a 1 490 voxelů; p < 0,001; Příloha 33), pravém temporálním gyru (108 voxelů; p = 0,002; Příloha 34), fusiformním gyru oboustranně (665 a 362 voxelů; p < 0,001; Příloha 35), rýze calcarine (838 voxelů; p < 0,001; Příloha 36), linguálním gyru oboustranně (501 a 389 voxelů; p < 0,001; Příloha 37) a části levého thalamu (14 voxelů; p < 0,025; Příloha 38), ne však v amygdale. Naproti tomu odporní hadi oproti těm děsivým vyvolali vyšší aktivaci jen v levé insule (16 voxelů; p = 0,023; Obr. 17), rýze calcarine (48 voxelů; p = 0,013; Příloha 39) a linguálním gyru (216 voxelů; p = 0,001; Příloha 40).

Obrázek 16. Analýza rozdílu v aktivaci amygdaly u zdravých dobrovolníků při sledování hadů vyvolávajících strach vs. listů (strach > listy).



fear.vs.leaves

$SPM\{T_{74}\}$

SPMresults: .\amy
Height threshold T = 3.147968 {p<0.05 (FWE)}
Extent threshold k = 0 voxels

Statistics: *p-values adjusted for search volume*

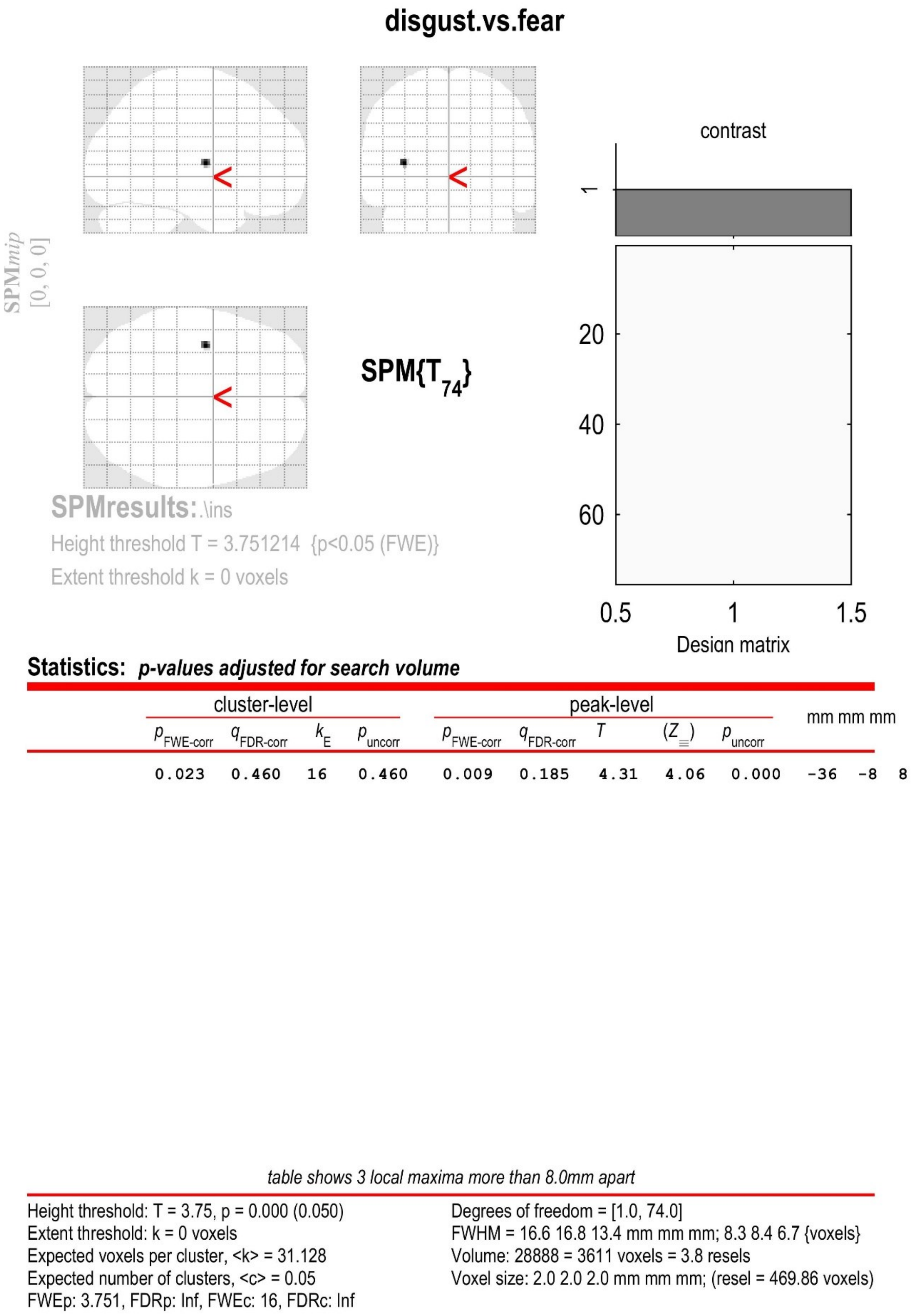
set-level		cluster-level				peak-level					mm mm mm
p	c	$p_{FWE\text{-}corr}$	$q_{FDR\text{-}corr}$	k_E	p_{uncorr}	$p_{FWE\text{-}corr}$	$q_{FDR\text{-}corr}$	T	$(Z_{\equiv})$	p_{uncorr}	
0.001	2	0.003	0.080	153	0.053	0.000	0.001	5.59	5.09	0.000	-26 -2 -22
		0.004	0.080	122	0.080	0.001	0.013	4.67	4.35	0.000	28 -2 -24

table shows 3 local maxima more than 8.0mm apart

Height threshold: T = 3.15, p = 0.001 (0.050)
Extent threshold: k = 0 voxels
Expected voxels per cluster, <k> = 40.435
Expected number of clusters, <c> = 0.05
FWEp: 3.148, FDRp: 4.613, FWEc: 122, FDRc: Inf

Degrees of freedom = [1.0, 74.0]
FWHM = 16.3 13.8 12.6 mm mm mm; 8.2 6.9 6.3 {voxels}
Volume: 3664 = 458 voxels = 0.5 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 356.49 voxels)

Obrázek 17. Analýza rozdílu v aktivaci insuly u zdravých dobrovolníků při sledování hadů vyvolávajících odpor vs. strach (odpor > strach).



```
SPMresults: .\ins
Height threshold T = 3.751214  {p<0.05 (FWE)}
Extent threshold k = 0 voxels

Statistics:  p-values adjusted for search volume
            cluster-level                          peak-level
  pFWE-corr  qFDR-corr  kE  puncorr    pFWE-corr  qFDR-corr  T     (Z≡)   puncorr    mm mm mm
  0.023      0.460      16  0.460      0.009      0.185      4.31  4.06   0.000      -36  -8   8

                      table shows 3 local maxima more than 8.0mm apart

Height threshold: T = 3.75, p = 0.000 (0.050)        Degrees of freedom = [1.0, 74.0]
Extent threshold: k = 0 voxels                       FWHM = 16.6 16.8 13.4 mm mm mm; 8.3 8.4 6.7 {voxels}
Expected voxels per cluster, <k> = 31.128            Volume: 28888 = 3611 voxels = 3.8 resels
Expected number of clusters, <c> = 0.05              Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 469.86 voxels)
FWEp: 3.751, FDRp: Inf, FWEc: 16, FDRc: Inf
```

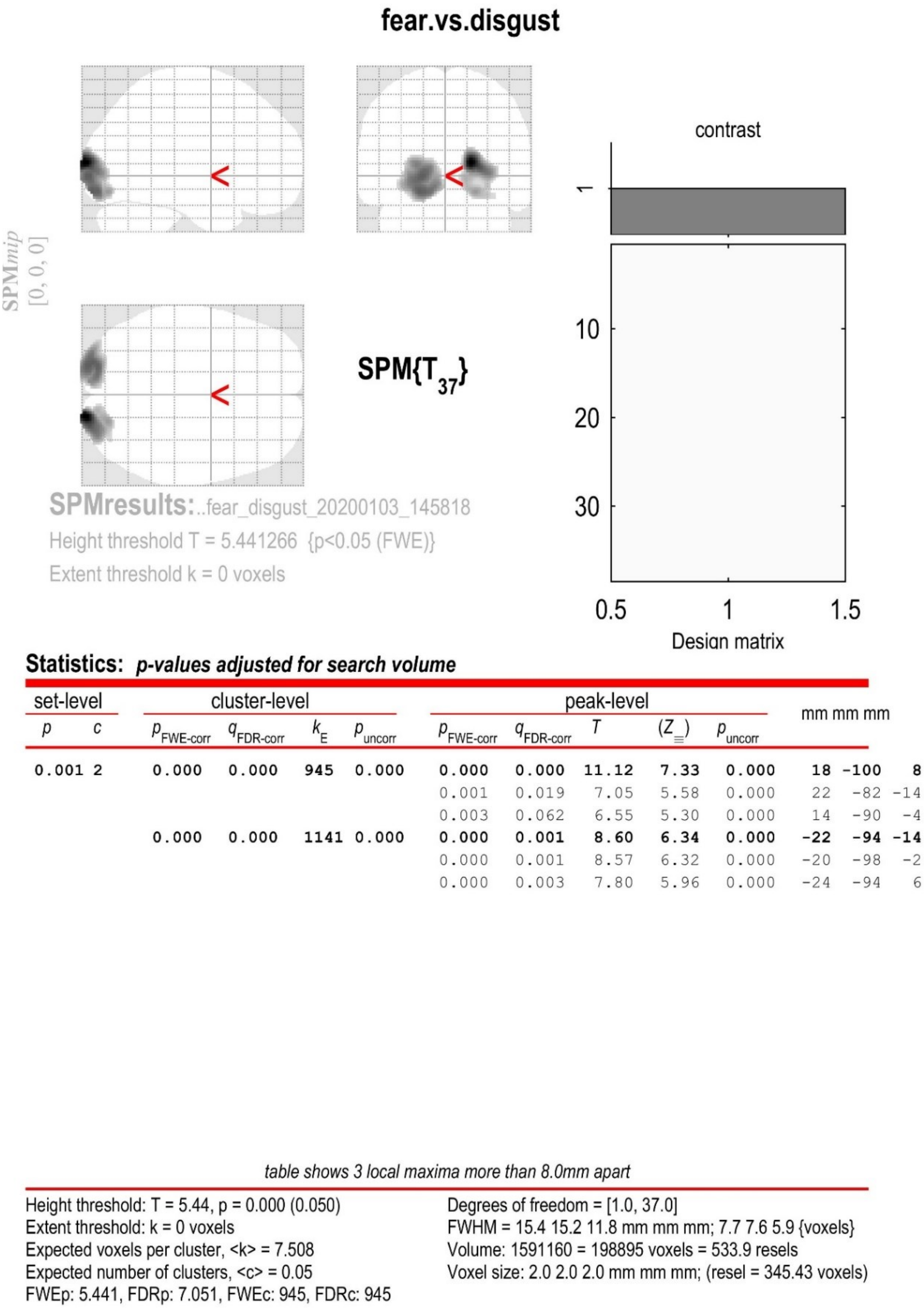
Neurální odpověď u ofidiofobiků

V analýze na úrovni celého mozku vyvolali děsiví hadi v porovnání s listy zvýšenou aktivaci v okcipitálním a částečně i temporálním a parietálním laloku, tedy ve zrakové a somatosenzorické kůře (15 clusterů, největší z nich 13 300 voxelů; p < 0,001; aktivní oblasti: okcipitální gyry, rýha calcarine, linguální, fusiformní, angulární a horní parietální gyrus; Příloha 41). Srovnání aktivace vyvolané odpornými hady vs. listy vedlo k velmi podobnému výsledku (16 clusterů, největší z nich 10 694 voxelů, p < 0,001; Příloha 42). Sledování děsivých hadů vedlo v porovnání s odpornými hady k vyšší oboustranné aktivaci v oblasti primární zrakové kůry (1141 a 945 voxelů; p < 0,001; aktivní oblasti: spodní a střední okcipitální gyrus, fusiformní gyrus; Obr. 18). Naopak kontrast neurální odpovědi na odporné vs. děsivé hady žádnou zvýšenou aktivaci v rámci celého mozku neodhalil.

Děsiví hadi v porovnání s listy vyvolali vyšší aktivaci v levé amygdale (42 voxelů; p = 0,022; Příloha 43), nepatrné části levého parahipokampálního gyru (4 voxely; p = 0,033; Příloha 44) a pravé insuly (5 voxelů; p = 0,034; Příloha 45), PFC (8 clusterů, největší z nich 87 voxelů; p = 0,001; Příloha 46), ACC (3 clustery, největší z nich 33 voxelů; p = 0,017; Příloha 47) a bilaterálně v okcipitálních gyrech (3 080 a 2 923 voxelů; p < 0,001; Příloha 48), temporálních gyrech (137 a 1 364 voxelů a 2 923 voxelů; p < 0,001; Příloha 49), fusiformním gyru (1 258 a 1 188 voxelů; p < 0,001; Příloha 50), rýze calcarine (2 008 voxelů; p < 0,001; Příloha 51), linguálním gyru (2 043 voxelů; p < 0,001; Příloha 52) a levém i pravém thalamu (36 a 11 voxelů; p = 0,011 a 0,026; Příloha 53) a putamen (130 a 74 voxelů; p = 0,005 a 0,011; Příloha 54).

Při prezentaci odporných hadů byla v porovnání s listy signifikantně vyšší aktivace v malé oblasti levé amygdaly (11 voxelů; p = 0,031; Příloha 55) a levého hipokampu (4 voxely; p < 0,036; Příloha 56), jediném voxelu parahipokampálního gyru (p = 0,042; Příloha 57), insule oboustranně (6 clusterů, největší z nich 21 voxelů; p = 0,018; Příloha 58), PFC (9 clusterů, největší z nich 60 voxelů; p = 0,001; Příloha 59), okcipitálních gyrech oboustranně (2 282 a 1 947 voxelů; p < 0,001; Příloha 60), temporálních gyrech vpravo (1 437 voxelů; p < 0,001; Příloha 61), fusiformním gyru oboustranně (1 067 a 1 230 voxelů; p < 0,001; Příloha 62), rýze calcarine (1 945 voxelů; p < 0,001; Příloha 63), linguálním gyru (2 221 voxelů; p < 0,001; Příloha 64), pravém thalamu (18 voxelů; p < 0,001; Příloha 65) a putamen oboustranně (87 a 68 voxelů; p = 0,005 a 0,007; Příloha 66).

Obrázek 18. Analýza rozdílu v aktivaci celého mozku u ofidiofobiků při sledování hadů vyvolávajících strach vs. odpor (strach > odpor). Zobrazená oblast odpovídá primární zrakové kůře.



SPMresults:..fear_disgust_20200103_145818
Height threshold T = 5.441266 {p<0.05 (FWE)}
Extent threshold k = 0 voxels

Statistics: ***p-values adjusted for search volume***

set-level		cluster-level				peak-level					mm mm mm
p	c	$p_{FWE-corr}$	$q_{FDR-corr}$	k_E	p_{uncorr}	$p_{FWE-corr}$	$q_{FDR-corr}$	T	$(Z_{\equiv})$	p_{uncorr}	
0.001	2	0.000	0.000	945	0.000	0.000	0.000	11.12	7.33	0.000	18 -100 8
						0.001	0.019	7.05	5.58	0.000	22 -82 -14
						0.003	0.062	6.55	5.30	0.000	14 -90 -4
		0.000	0.000	1141	0.000	0.000	0.001	8.60	6.34	0.000	-22 -94 -14
						0.000	0.001	8.57	6.32	0.000	-20 -98 -2
						0.000	0.003	7.80	5.96	0.000	-24 -94 6

table shows 3 local maxima more than 8.0mm apart

Height threshold: T = 5.44, p = 0.000 (0.050)
Extent threshold: k = 0 voxels
Expected voxels per cluster, <k> = 7.508
Expected number of clusters, <c> = 0.05
FWEp: 5.441, FDRp: 7.051, FWEc: 945, FDRc: 945

Degrees of freedom = [1.0, 37.0]
FWHM = 15.4 15.2 11.8 mm mm mm; 7.7 7.6 5.9 {voxels}
Volume: 1591160 = 198895 voxels = 533.9 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 345.43 voxels)

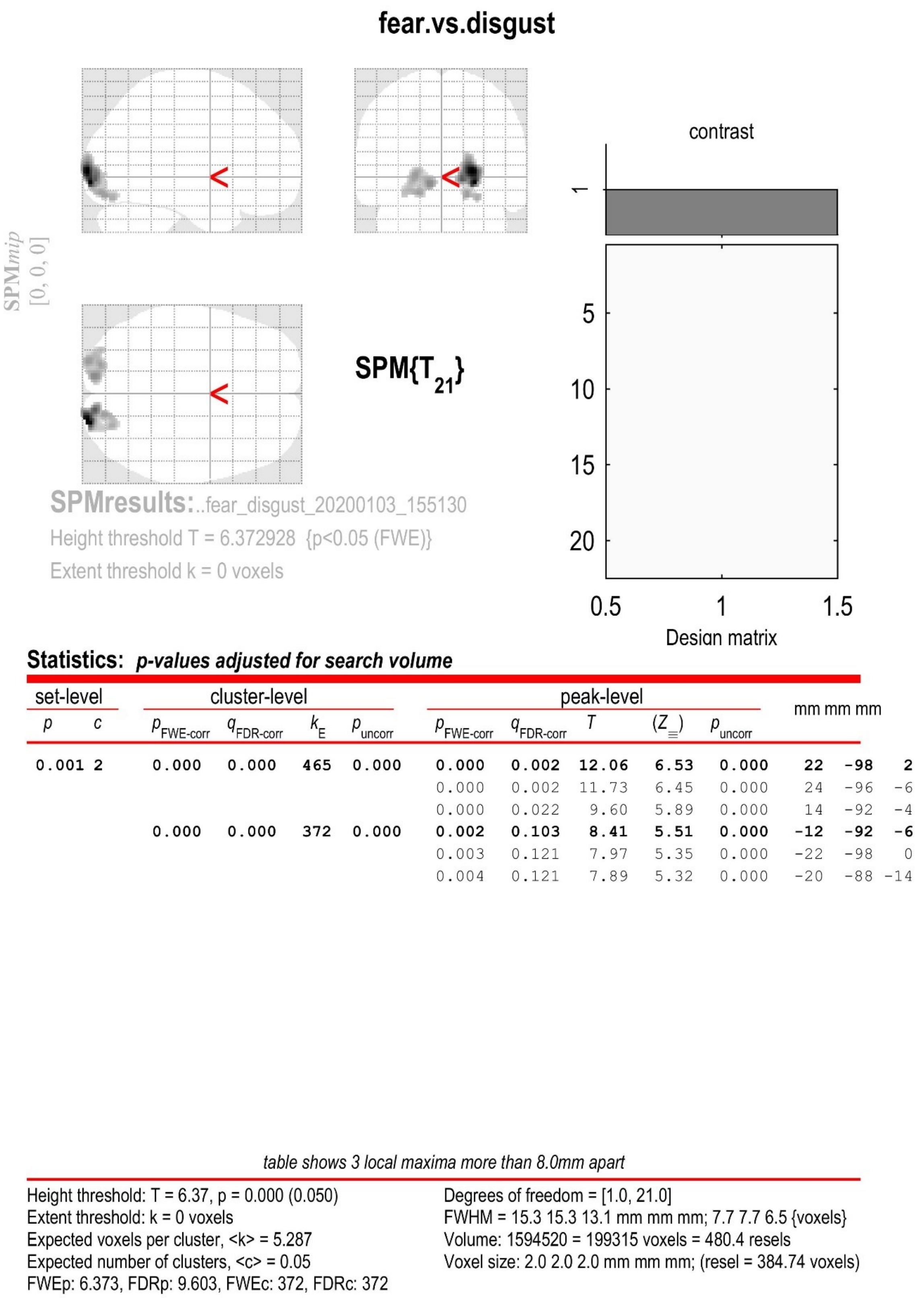
Děsiví hadi v porovnání s odpornými vedli k vyšší bilaterální aktivaci pouze v okcipitálních gyrech (657 a 1 112 voxelů; p < 0,001; Příloha 67), fusiformním gyru (134 a 219 voxelů; p = 0,001; Příloha 68), rýze calcarine (587 voxelů; p < 0,001; Příloha 69) a linguálním gyru (320 a 398 voxelů; p < 0,001; Příloha 70). Naproti tomu prezentace odporných hadů nevyvolala ve srovnání s děsivými hady signifikantně vyšší aktivaci v žádné ze sledovaných oblastí.

Neurální odpověď u arachnofobiků

U skupiny arachnofobiků byla na úrovni celého mozku výrazně vyšší aktivace v okcipitální oblasti při prezentaci děsivých hadů v porovnání s listy (5 704 clusterů; p < 0,001; aktivní oblasti: spodní, střední a horní okcipitální gyrus, fusiformní fyrus, horní parietální gyrus; Příloha 71), naopak odporní hadi ve srovnání s listy tak výraznou neurální odpověď nevyvolali (celkem 11 menších clusterů, z nichž největší měl 335 voxelů; p < 0,001; aktivní oblasti: spodní a střední okcipitální gyrus, fusiformní gyrus, linguální gyrus, cuneus, horní parietální gyrus, Příloha 72). Při srovnání reakce na děsivé vs. odporné hady byla nalezena zvýšená aktivace v oblasti primární zrakové kůry (465 a 372 voxelů; p < 0,001; aktivní oblasti: spodní a střední okcipitální gyrus, fusiformní gyrus a linguální gyrus; Obr. 19), zatímco opačný kontrast (odporní vs. děsiví hadi) neodhalil v rámci celého mozku žádný výrazný rozdíl v aktivaci.

Na úrovni jednotlivých mozkových oblastí byla při srovnání reakce na děsivé hady vs. listy vyšší aktivace v levém hipokampu (22 voxelů; p < 0,001; Příloha 73), bilaterálně v okcipitálních (3 107 a 1 766 voxelů; p < 0,001; Příloha 74) a temporálních gyrech (534 a 63 voxelů; p < 0,001 a p = 0,002; Příloha 75), fusiformním (632 a 785 voxelů; p < 0,001; Příloha 76) a linguálním gyru (1 428 voxelů; p < 0,001; Příloha 77) a také v rýze calcarine (1 668 voxelů; p < 0,001; Příloha 78) a malé části levého thalamu (6 voxelů; p = 0,032; Příloha 79).

Obrázek 19. Analýza rozdílu v aktivaci celého mozku u arachnofobiků při sledování hadů vyvolávajících strach vs. odpor (strach > odpor).



SPMresults:..fear_disgust_20200103_155130
Height threshold T = 6.372928 {p<0.05 (FWE)}
Extent threshold k = 0 voxels

Statistics: *p-values adjusted for search volume*

set-level		cluster-level				peak-level					mm mm mm		
p	c	$p_{FWE-corr}$	$q_{FDR-corr}$	k_E	p_{uncorr}	$p_{FWE-corr}$	$q_{FDR-corr}$	T	$(Z_{\equiv})$	p_{uncorr}			
0.001	2	0.000	0.000	465	0.000	0.000	0.002	12.06	6.53	0.000	22	-98	2
						0.000	0.002	11.73	6.45	0.000	24	-96	-6
						0.000	0.022	9.60	5.89	0.000	14	-92	-4
		0.000	0.000	372	0.000	0.002	0.103	8.41	5.51	0.000	-12	-92	-6
						0.003	0.121	7.97	5.35	0.000	-22	-98	0
						0.004	0.121	7.89	5.32	0.000	-20	-88	-14

table shows 3 local maxima more than 8.0mm apart

Height threshold: T = 6.37, p = 0.000 (0.050)
Extent threshold: k = 0 voxels
Expected voxels per cluster, <k> = 5.287
Expected number of clusters, <c> = 0.05
FWEp: 6.373, FDRp: 9.603, FWEc: 372, FDRc: 372

Degrees of freedom = [1.0, 21.0]
FWHM = 15.3 15.3 13.1 mm mm mm; 7.7 7.7 6.5 {voxels}
Volume: 1594520 = 199315 voxels = 480.4 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 384.74 voxels)

Odporní hadi oproti listům vyvolali vyšší bilaterální aktivaci v okcipitálních (969 a 1 754 voxelů; p < 0,001; Příloha 80) a temporálních gyrech (117 a 34 voxelů; p < 0,001 a p = 0,003; Příloha 81), fusiformním gyru (345 a 210 voxelů; p < 0,001; Příloha 82), linguálním gyru (827 voxelů; p < 0,001; Příloha 83) a rýze calcarine (1 075 voxelů; p < 0,001; Příloha 84). Děsiví hadi ve srovnání s odpornými vyvolali vyšší bilaterální aktivaci v oblasti okcipitálních gyrů (395 a 711 voxelů; p < 0,001; Příloha 85), fusiformním (465 a 372 voxelů; p < 0,001; Příloha 86) a linguálním gyru (321 a 276 voxelů; p < 0,001; Příloha 87), rýze calcarine (525 voxelů; p < 0,001; Příloha 88) a jediném voxelu pravého putamen (p = 0,043; Příloha 89). Opačný kontrast (odporní vs. děsiví hadi) neodhalil vyšší aktivaci v žádné ze sledovaných oblastí.

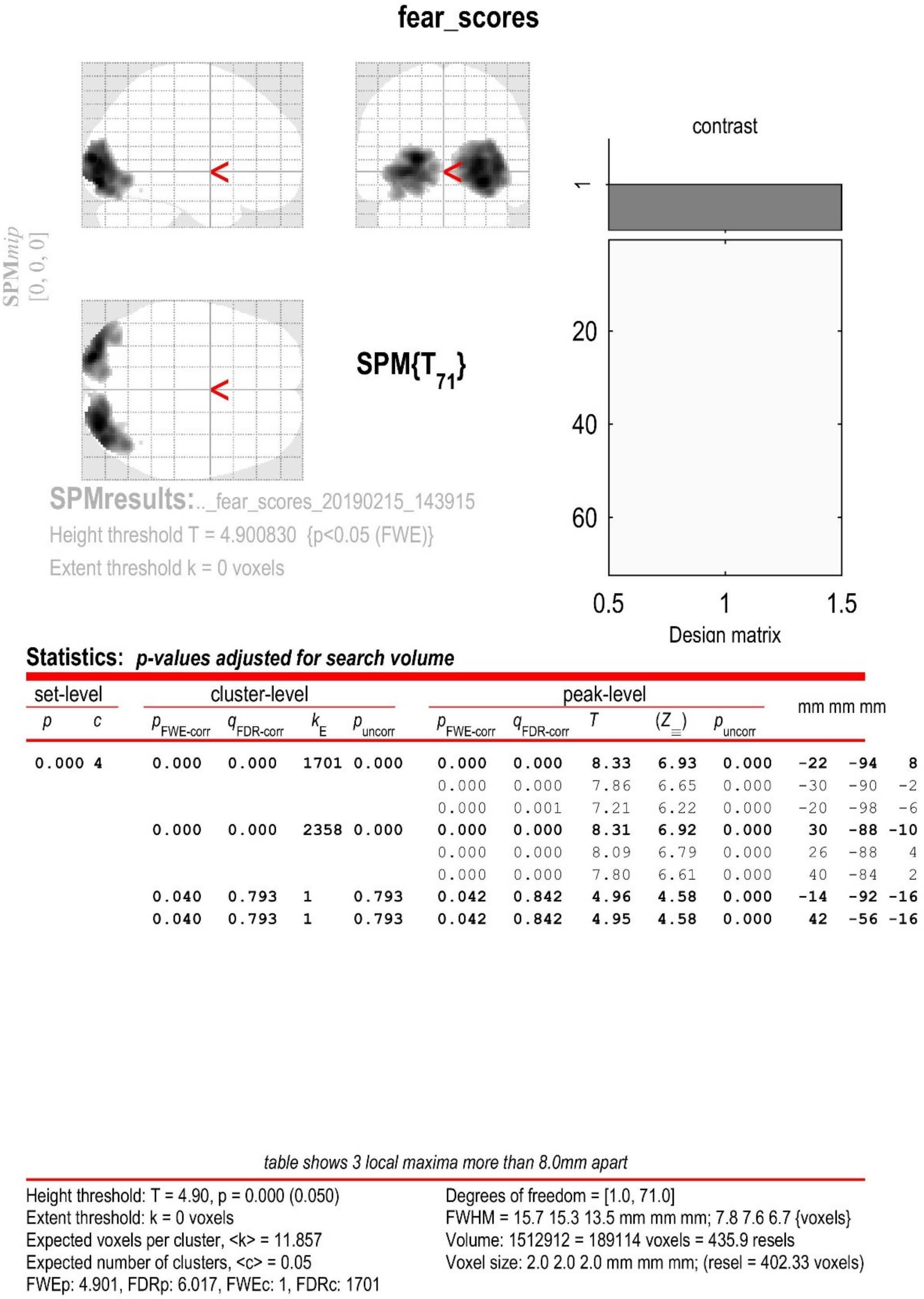
Vztah mezi mozkovou aktivací a skóry SNAQ a DS-R

U zdravých dobrovolníků byla na úrovni celého mozku nalezena pozitivní korelace pouze mezi skórem SNAQ a aktivací v jednom clusteru (5 voxelů; p = 0,025; Příloha 90) v levé posteriorní thalamokortikální dráze při sledování děsivých hadů v porovnání s listy a ve třech clusterech (58, 40 a 9 voxelů; p = 0,001 - 0,017; Příloha 91) v superiorním parietálním a prostředním okcipitálním gyru při sledování odporných hadů v porovnání s listy. U skupiny ofidiofobiků ani arachnofobiků nebyla žádná z korelací mezi skóry v obou dotaznících a mozkovou aktivací statisticky signifikantní.

Vztah mezi mozkovou aktivací a hodnocením obrázků hadů podle strachu a odporu

V rámci poslední analýzy vyšla u zdravých dobrovolníků jako statisticky signifikantní pouze korelace mezi subjektivním hodnocením obrázků hadů na základě strachu a aktivací v oblasti primární zrakové kůry bilaterálně (1 701 a 2 358 voxelů; p < 0,001; aktivované oblasti: spodní a střední okcipitální gyrus, rýha calcarine; Obr. 20). U skupiny ofidiofobiků ani arachnofobiků nebyla opět žádná z korelací mezi skóry v obou dotaznících a mozkovou aktivací statisticky signifikantní.

Obrázek 20. Korelace mezi mozkovou aktivací u zdravých dobrovolníků a subjektivním hodnocením obrázků hadů prezentovaných během měření ve fMRI na 7-bodové Likertově škále podle strachu (od 1 - žádný strach do 7 - velmi vysoký strach). Respondenti, kteří hodnotí obrázky hadů výše na škále strachu, zároveň vykazují vyšší aktivaci v primární zrakové kůře a přilehlých oblastech.



SPMresults:.._fear_scores_20190215_143915
Height threshold T = 4.900830 {p<0.05 (FWE)}
Extent threshold k = 0 voxels

Statistics: *p-values adjusted for search volume*

set-level		cluster-level				peak-level					mm mm mm		
p	c	$p_{FWE-corr}$	$q_{FDR-corr}$	k_E	p_{uncorr}	$p_{FWE-corr}$	$q_{FDR-corr}$	T	$(Z_{\equiv})$	p_{uncorr}			
0.000	4	0.000	0.000	1701	0.000	0.000	0.000	8.33	6.93	0.000	-22	-94	8
						0.000	0.000	7.86	6.65	0.000	-30	-90	-2
						0.000	0.001	7.21	6.22	0.000	-20	-98	-6
		0.000	0.000	2358	0.000	0.000	0.000	8.31	6.92	0.000	30	-88	-10
						0.000	0.000	8.09	6.79	0.000	26	-88	4
						0.000	0.000	7.80	6.61	0.000	40	-84	2
		0.040	0.793	1	0.793	0.042	0.842	4.96	4.58	0.000	-14	-92	-16
		0.040	0.793	1	0.793	0.042	0.842	4.95	4.58	0.000	42	-56	-16

table shows 3 local maxima more than 8.0mm apart

Height threshold: T = 4.90, p = 0.000 (0.050)
Extent threshold: k = 0 voxels
Expected voxels per cluster, <k> = 11.857
Expected number of clusters, <c> = 0.05
FWEp: 4.901, FDRp: 6.017, FWEc: 1, FDRc: 1701

Degrees of freedom = [1.0, 71.0]
FWHM = 15.7 15.3 13.5 mm mm mm; 7.8 7.6 6.7 {voxels}
Volume: 1512912 = 189114 voxels = 435.9 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 402.33 voxels)

Diskuze

Hadi představují výrazný evoluční podnět s intenzivním emočním nábojem, který v průběhu lidského vývoje tvaroval mozkové okruhy zodpovědné za vizuální, pozornostní a emoční zpracování (Öhman & Mineka, 2001). Jediným cílem této modulace neurálního substrátu u primátů a posléze i přímých předků člověka měla být adaptivní behaviorální a emoční odpověď na možné ohrožení. Zatímco existují výzkumy zabývající se mozkovou aktivací při sledování hadů (e.g., Carlsson et al., 2004; Åhs et al., 2009; Lueken et al., 2011; Schaefer et al., 2014), žádná studie dosud nepopsala potenciální variabilitu v neurální odpovědi na různé druhy, které se mezi sebou liší morfologií, zbarvením, nebezpečností pro člověka, ekologií i chováním. Proto jsem se v tomto fMRI experimentu detailně zabýval rozdíly v neurální odpovědi na dvě skupiny hadů, z nichž jedni vyvolávají v lidech převážně strach a druzí odpor.

Hadi, bez ohledu na skutečnost, zda patří do skupiny vzbuzující strach nebo odpor, vyvolávají ve srovnání s kontrolními podněty (listy) vyšší aktivaci v okcipitálním laloku, která částečně zasahuje i do temporální a parietální oblasti. Tak je tomu u zdravých dobrovolníků, kteří netrpí fobickým strachem z hadů a v menší míře i u lidí s arachnofobií. Je však zajímavé, že stejně lokalizovanou, avšak mnohem intenzivnější aktivaci šířící se do více mozkových oblastí, kraniálním směrem až k precentrálnímu gyru v parietálním laloku a laterálně pokrývající celý temporální lalok, je možné sledovat u ofidiofobiků, tedy lidí trpících panickým, iracionálním strachem z hadů. Setkání s hadem, byť jen ve formě statického obrázku, tak u nich vede k silné elektrofyziologické reakci mající ohnisko především ve zrakové kůře, ale zasahující značnou část zadní poloviny obou hemisfér až ke středové mozkové rýze (sulcus centralis). Zapojení oblastí v okcipitálním a temporálním laloku tak svědčí o rozsáhlém vizuálním zpracování a ostražitosti, která je s fobickým strachem často spojována (Öhman et al., 2001). Aktivace v parietálním laloku, kde se nachází mimojiné i motorický kortex, může být zase důkazem přípravy útěkové reakce. Vzhledem k tomu, že neurální odpověď arachnofobiků na hady je daleko slabší, jedná se v případě lidí s ofidiofobií skutečně o specifickou reakci na fobický podnět, nikoliv pouze o obecný vzorec aktivace subjektů zvýšeně úzkostných.

Při detailnější analýze jednotlivých struktur se potvrdilo, že mozek reaguje na spatření jakéhokoliv hada, bez ohledu na vyvolanou emoci, vyšší aktivací ve všech sledovaných oblastech zapojených do emočního a vizuálního okruhu, tedy amygdale, thalamu, hipokampálním gyru, okcipitálních a temporálních gyrech, rýze calcarine, fusiformním a linguálním gyru a částečně i PFC, a to většinou v obou mozkových hemisférách. Všechny zmíněné mozkové struktury a jejich aktivace během prožívání strachu, nejenom při pohledu na hady (Schaefer et al., 2014), se zmiňují napříč vědeckou literaturou (např. Silva, Gross, & Gräff, 2016). Výsledky této dizertační práce jsou proto v souladu s předchozími studiemi, především s ohledem na bilaterální aktivaci v amygdale, která hraje klíčovou roli při rychlém zpracování senzorické informace představující ohrožení (Öhman, 2005; Almeida et al., 2015), a thalamu, který má zase úlohu při prvotním hrubém vyhodnocení vizuálních signálů souvisejících s evoluční hrozbou a jejich rychlém přepojení přímo do amygdaly pomocí subkortikální zrakové dráhy obcházející primární zrakovou kůru (Tamietto & de Gelder, 2010). Aktivace v amygdale je při zpracování emočně salientních podnětů také často korelována s aktivací ve fusiformním a linguálním gyru, což se potvrdilo i v mém experimentu. Fusiformní gyrus, známý také jako laterální okcipitotemporální gyrus, je jeden z největších mozkových závitů ležící pod povrchem mezi okcipitálním a temporálním lalokem (Ward, 2015). Jeho funkce je často dávána do souvislosti s vyšším zpracováním vizuálních informací, především rozpoznáváním lidských tváří, přičemž obličeje vyjadřující strach nebo překvapení vyvolají ve srovnání se znechucenými obličeji vyšší aktivaci ve fusiformním gyru (Haxby, Hoffman, & Gobbini, 2000). Vedle toho se potvrdila jeho aktivace i při rozpoznávání a kategorizaci zvířat (Chao, Martin, & Haxby, 1999). Linguální gyrus (mediální okcipitotemporální gyrus), ležící v okcipitálním laloku v blízkosti rýhy calcarine kraniálně od fusiformního gyru, je rovněž spojen se zpracováním zrakových informací, především písmen, ale i s analýzou logického pořadí událostí a vizuální pamětí. Ve studii provedené Taylorem a kol. (1998) se navíc prokázalo, že rozpoznávání negativních obrázků ve srovnání s neutrálními vyvolalo vyšší aktivaci v linguálním gyru.

V rozporu s původní hypotézou se v mé studii nepodařilo jasně prokázat aktivaci insuly, u které bylo naměřeno pouze pět aktivních voxelů v případě děsivých hadů a ani jediný při prezentaci odporných hadů. Takový výsledek je velmi překvapivý především z toho důvodu, že insula byla řadou neurozobrazovacích studií označena jako hlavní struktura v mozku pro zpracování pocitů odporu (např. Wright, He, Shapira, Goodman, & Liu, 2004). Dokonce k aktivaci insulárního kortexu není potřeba přímého prožitku, ale stačí i jen pohled na jiného člověka právě pociťujícího odpor (Wicker et al., 2003). Na druhou stranu někteří autoři zase argumentují, že insula ve skutečnosti není specifickou strukturou pro zpracování odporu, protože podněty vyvolávající odpor aktivují vedle insuly i amygdalu, OFC a okcipito-temporální kortex (Schienle et al., 2002). To se ostatně potvrdilo i v této studii, i přesto je negativní nález v insule při sledování odporných hadů překvapivý. Ačkoliv byly pro tuto skupinu vybrány druhy hodnocené v rámci všech hadů jako nejvíce odporní, výsledky fMRI mohou napovídat, že ani v takovém případě se co do schopnosti vyvolávat v lidech odpor nevyrovnají běžně užívaným, vysoce odporným stimulům, jakými jsou zkažené jídlo, červy, otevřené rány, krev, výkaly apod. Větší aktivace v insule při prezentaci jakéhokoliv hada v porovnání s kontrolními podněty však byla zjištěna u skupiny ofidiofobiků, u kterých bylo také výrazně více aktivované i putamen, ACC a PFC. Putamen je jedno z velkých jader v bazální části koncového mozku a jako součást bazálních ganglií je zapojeno do senzorimotorické dráhy kontrolující pohyby. Pomocí tzv. nepřímé dráhy dokáže zvýšeně aktivní putamen potlačit nechtěné pohyby (DeLong et al., 1984). Každý experimentální subjekt byl před samotným měřením ve fMRI požádán, aby se po celou dobu vyšetření maximálně snažil ležet nehybně, protože jakýkoliv pohyb podstatně sníží kvalitu naměřených dat. Můžeme se proto domnívat, že sledování hadů vede u ofidiofobiků k mnohem intenzivnějšímu vnitřnímu napětí a tendenci k nekontrolovaným pohybů. Vědomá snaha na základě předchozí instrukce tyto pohyby potlačit, pak vede k vyšší aktivaci putamen. Oblasti ACC a PFC zase mají spolu s hipokampem významnou úlohu při podmiňování reakce strachu, proto jejich zvýšená aktivace u ofidiofobiků během prezentace fobických podnětů opět není překvapující.

Zaprvé, tyto oblasti se totiž mohou podílet na udržování fobie tím, že vyvolávají vzpomínky na předchozí epizody strachu a asociují příslušnou reakci organismu v takové chvíli s hady. Neustálá snaha vyhýbat se fobickému podnětu a tím i předejít dalšímu intenzivnímu prožitku strachu je navíc pomocí klasického podmiňování neustále posilována, ačkoliv možná paradoxně naopak vystavení se podnětu by postupně vedlo ke snížení fobické reakce. Na tomto principu graduované (hierarchické) expozice v kontrolovaných podmínkách je ostatně založena jedna z nejúspěšnějších terapií specifických fobií, tedy KBT (Doctor et al., 2008). Za druhé, ACC i PFC jsou známé svojí úlohou při zpětné kognitivní regulaci negativních emocí. Fobičtí pacienti si velmi dobře uvědomují, že jejich reakce jsou zcela přehnané a neadekvátní dané situaci. Přestože nedokážou zabránit rozvoji fobické reakce, jsou schopni kognitivního náhledu a za své chování se často stydí a snaží se je alespoň dodatečně potlačit. Proto aktivace ACC a PFC v tomto experimentu mohla být známkou takové snahy subjektu o kontrolu silně prožívaného strachu během měření. Navíc se znovu nejedná pouze o rozdíl v porovnání se zdravými kontrolami, ale i s arachnofobiky, tedy lidmi trpícími jinou specifickou fobií. Tyto závěry ostatně potvrzuje i další nedávná fMRI studie, která nalezla vyšší aktivaci v ACC u lidí se strachem z hadů v situaci, kdy se snažili svému strachu čelit a přiblížit se k živému hadovi (Nili, Goldberg, Weizman, & Dudai, 2010). Oblast ACC je proto autory zmíněné studie označována za mozkové centrum odvahy.

K velmi podobným výsledkům jako v mojí práci dospěli i Schaefer a kol. (2014), kteří s využitím fMRI porovnávali odpověď mozku u zdravých kontrol a lidí s ofidiofobií na videa útočících hadů, plazících se hadů a ryb. Mozek zdravých dobrovolníků s normativním strachem reagoval na útočící hady aktivací bilaterálně v amygdale a insule, thalamu, ACC, pravém spodním frontálním gyru, suplementární motorické oblasti, pravém precentrálním gyru, bilaterálně ve fusiformním gyru a primární vizuálním kortexu. Zdravé kontroly také reagovaly celkově vyšší mírou mozkové aktivace na videa útočících hadů v porovnání s plazícíme se hady a rybami. Porovnáním neurální odpovědi kontrol a ofidiofobiků tito autoři také dospěli k závěru, že mozkové aktivace během sledování hadů se u obou skupin částečně překrývají, a zahrnují tedy podobné oblasti, ty jsou nicméně u fobiků aktivnější. A zatímco nefobické kontroly reagují aktivací v daných oblastech pouze na videa útočících hadů, u fobiků byla nalezena podobná intenzita aktivace i při sledování plazících se hadů. Vedle toho ale fobická reakce navíc zasahuje aktivací i do dalších částí mozku nepozorovaných u zdravých kontrol, kam patří řada korových (levý orbitální gyrus, bilaterální ACC, precentrální, postcentrální, temporální a okcipitální gyry a bilaterálně parietální lobuli) i podkorových oblastí (bilaterálně hipokampus, ocasaté jádro a putamen).

Vedle potvrzení závěrů předchozích výzkumů však výsledky mého experimentu také poprvé prokázaly, že není had jako had, neboli že existuje jasný rozdíl v neurální odpovědi na hady působící strach nebo odpor, a to jak na úrovni celého mozku, tak i při analýze vybraných oblastí. Zmijovití hadi vzbuzující v lidech intenzivnější strach vyvolali ve srovnání s podzemními slepákovitými hady budícími spíše odpor vyšší bilaterální aktivaci v primární zrakové kůře a přilehlých oblastech jako je fusiformní a linguální gyrus, a to u všech tří skupin subjektů velmi podobně. Naproti tomu prezentace odporných hadů ve srovnání s děsivými vyvolala vyšší aktivaci především v pravém linguálním gyru a levé insule. Další součásti emočního okruhu (amygdala, hipokampus, parahipokampální gyrus, atd.), ani korové regulační oblasti (PFC, ACC) se však významně nelišily v aktivaci při porovnání obou skupin hadů mezi sebou.

Překvapivě nebyl nalezen žádný vztah mezi skórem DS-R a mozkovou aktivací a pouze marginální efekt skóru SNAQ, který je kvantifikací subjektivně prožívaného strachu z hadů. Mnohem robustnějšího efektu bylo dosaženo při analýze vlivu subjektivního hodnocení obrázků hadů, kdy zdraví dobrovolníci hodnotící prezentované stimuly výše na škále strachu měli zároveň signifikantně vyšší bilaterální aktivaci v oblasti primární zrakové kůry. Je zajímavé zjištění, že mozkovou aktivitu konkrétně v okcipitálním kortexu je u každého jedince možno predikovat na základě subjektivního hodnocení strachu z prezentovaných stimulů mnohem lépe než pomocí skóru ve standardizovaném psychologickém dotazníku. Podobný efekt nebyl nalezen pro obě skupiny fobiků, a to pravděpodobně vzhledem k menší velikosti vzorku.

Všechny tyto výsledky tedy společně naznačují, že vědomá percepce emočně salientních stimulů, jakými jsou i hadi, vede k přímému zapojení zrakové kůry a přilehlých oblastí. Rozdíl v aktivaci během sledování dvou zkoumaných skupin hadů může souviset s nepřetržitou pozorností věnovanou právě děsivým hadům, což vysvětluje kontinuální aktivaci primární zrakové kůry i poté, co je prvotní zpracování vizuálního podnětu již ukončeno. To je také v souladu s dřívějšími nálezy, že zvýšená aktivace zrakových oblastí umožňuje zpracování podnětů ohrožujících přežití jedince. Bradley a kol. (2003) zjistili pomocí měření fMRI, že obrázky vyvolávající intenzivní emoce a současně navozující primární motivační stavy, ať už pozitivní (erotické scény), nebo negativní (fyzické zranění nebo přímé ohrožení – obrázek útočícího hada), vedou k signifikantně vyšší aktivaci v primární zrakové kůře (spodní okcipitální gyrus a rýha calcarine) a fusiformním gyru ve srovnání s méně emočně intenzivními nebo neutrálními podněty. Autoři studie se domnívají, že to jsou především basolaterální jádra amygdaly primátů a člověka, která přednostně reagují právě na podněty aktivující jeden ze dvou motivačních systémů (apetenční nebo defenzivní). Amygdala navíc dokáže díky přímým i nepřímým spojením na senzorické dráhy modulovat vyšší zpracování senzorických signálů na úrovni mozkové kůry. Aktivace amygdaly tak může změnit reprezentaci emočně nabitých událostí ve vizuálním kortexu a zároveň i nasměrovat selektivní pozornost ke zdroji potenciálního ohrožení, což umožní maximální přísun dalších senzorických informací o daném podnětu. Taková schopnost je velmi užitečná především ve světě, který náš mozek neustále zahlcuje velkým množstvím signálů, z nichž pouze malá část je skutečně relevantní a má pro jedince biologickou hodnotu (Vuilleumier, 2005).

Klíčovou úlohu amygdaly při nasměrování pozornosti k možnému zdroji nebezpečí však částečně zpochybnily nejnovější neurobiologické výzkumy japonských primatologů. Prokázaly totiž, že k prvotnímu vyhodnocení signálu při setkání s hadem nedochází až v amygdale, ale ještě dříve v pulvinárních jádrech thalamu, odkud je teprve signál veden do amygdaly (Van Le et al., 2013, 2014, 2016). Řada neuronů tvořících pulvinar je přitom citlivá na kontrastní vzory hadů (barevné proužky korálovců, klikaté tmavé čáry a kostkovaný vzor zmijovitých hadů) nebo jejich typickou výhružnou pozici těla. To může být vysvětlením i pro má zjištění rozdílné aktivace v okcipitální oblasti vyvolané děsivými a odpornými hady. Mezi hady vzbuzující strach totiž patří druhy barevně kontrastní, kteří tak skrze vyšší aktivaci pulvinaru vyvolají i vyšší neuronální odezvu v primární zrakové kůře. Naopak odporní hadi mají nevýrazné jednobarevné zbarvení, na které pravděpodobně neurony pulvinaru nereagují excitací. Jedná však pouze o domněnka, protože aktivace pulvinárních jader nebyla v této studii měřena.

Pozorovaný rozdíl v aktivaci primární zrakové kůry svědčící o zvýšené motivované pozornosti má nakonec i funkční (ultimátní) vysvětlení. Mezi děsivé hady vzbuzující v lidech největší strach totiž patří především zmijovité druhy s vysoce efektivním jedovým aparátem, zřetelnou hlavou a robustním tělem, žijící na povrchu a lovící větší kořist, kteří mohou být člověku velmi nebezpeční. Naproti tomu ve skupině odporných hadů je většina druhů nejedovatá nebo jenom velmi mírně, s malou hlavou a úzkým tělem, žijící skrytě pod povrchem a živící se drobnými bezobratlými, pro člověka tak představují jen zanedbatelné nebezpečí. Proto moje výsledky částečně potvrzují evoluční hypotézu, že náš mozek (konkrétně vzájemně propojený emoční a senzorický okruh) přednostně reaguje na typický barevný vzor a tvar těla zmijovitých hadů, se kterými sdílíme minimálně 60 miliónů let společného vývoje ve Východní Africe (Isbell, 2006, 2009), zatímco nejedovatí hadi s jednotvárným zbarvením a odlišnou morfologií těla takovou neurální odpověď vyvolat nedokážou.

7. Další publikované práce

Během svého postgraduálního studia jsem se podílel i na dalších publikacích o emocích vyvolaných zvířaty, jež jsou součástí Příloh:

1. Landová E., Musilová V., **Polák J.**, Sedláčková K., Frynta D. (2016): Antipredatory reaction of the leopard gecko (*Eublepharis macularius*) to snake predators. *Current Zoology*, 62: 439-450. **IF = 1.76** (Příloha 92)
2. Landová L., Rádlová S., **Polák J.**, Frynta D. (2016). Evoluční původ fobií ze zvířat. In J. Horáček, L. Kesner, C. Höschl, F. Španiel (eds.), *Mozek a jeho člověk, mysl a její nemoc* (pp. 235-245). Praha: Galén. (Příloha 93)
3. Rádlová S., Janovcová M., **Polák J.**, Landová E., Frynta D. (2018). Emoce vyvolané zvířaty I: krása a estetické preference. *E-psychologie*, 12(3): 35-50. (Příloha 94)
4. Rádlová S., Peléšková Š., **Polák J.**, Landová E., Frynta D. (2019). Emoce vyvolané zvířaty II: strach a odpor. *E-psychologie*, 12(4): 61-77. (Příloha 95)
5. Vobrubová B., Sedláčková K., Janovcová M., Rádlová S., **Polák J.**, Peléšková Š., Frynta D., Landová E. (2021). Eye movement patterns in response to fear- and disgust-eliciting reptiles. *Evolution and Human Behavior*, under review. (Příloha 96)
6. Coelho C. M., **Polák J.**, Suttiwan P., Zsido A. N. (2021). Fear inoculation among snake experts. *BMC Psychiatry*, under review. (Příloha 97)
7. Zsido A. N., Coelho C. C., **Polák J.** (2021). Nature relatedness: a protective factor for snake and spider fears and phobias. *Journal of Environmental Psychology*, under review. (Příloha 97)

8. Závěr

Tato dizertační práce se zabývá některými vybranými aspekty lidské emocionální reakce na hady, k čemuž využívá řady psychologických nástrojů, ať už klasických, vycházejících ze subjektivního hodnocení jedince (standardní psychologické škály a hodnocení vizuálních stimulů), či více pokročilých metod objektivního měření fyziologických a neurálních emočních korelátů. Had byl záměrně zvolen jako prototypický podnět představující evoluční hrozbu. V celé práci totiž vycházím z hypotézy, že díky milióny let trvající společné koevoluci s jedovatými hady ve Východní Africe došlo ještě u společných předků primátů a člověka k vývoji komplexního neuro-fyzio-psychologického systému adaptivní odpovědi na spatření hada. Současně s tím došlo i ke zdokonalení zrakového systému a předvědomých pozornostních procesů, takže mozek byl schopen rychlé detekce hada i v nepřehledném terénu. Tento propojený systém kognitivní, afektivní a behaviorální reakce byl následně díky působení přírodního výběru zafixován do genetické výbavy primátů. Zároveň jsem však svou rozšířil i o výzkum další základní emoce, která nebyla v souvislosti s hady dosud studována, a to odpor.

Negativní emoce vyvolané hady jsem se snažil empiricky studovat na několika úrovních. Výchozím bodem bylo vytvoření standardního překladu škály strachu z hadů (SNAQ), která se stala důležitým nástrojem v navazujících experimentech. Hlavním výsledkem této psychometrické analýzy bylo stanovení distribuce strachu z hadů v české populaci, a tedy i vytvoření norem. Strach z hadů měřený pomocí škály SNAQ nemá normální rozdělení, jako některé psychologické charakteristiky, ale spíše negativně binomické, tzn. že naprostá většina lidí skóruje nízko a pouze nepatrná část dosahuje nadprůměrných hodnot. Jen 2,6% respondentů dosáhlo v mé studii skóru, který může být signálem přítomnosti specifické fobie. Několik studií subjektivního hodnocení vizuálních stimulů pak prokázalo, že had jako jedno z mála fobických zvířat (spolu s pavoukem) vyvolává poměrně intenzivní strach i ve zdravé populaci, a to i ve srovnání s ostatními plazy. Navíc se mi podařilo dokázat existenci dvou odlišných skupin, z nichž jedna vzbuzuje v lidech převážně strach, zatímco druhá zahrnuje druhy vyvolávající spíše pocity odporu. Do první skupiny patří zmijovití hadi s robustním tělem, ´výraznou hlavou, účinným jedovým aparátem a výstražným kontrastním zbarvením, druhou skupinu tvoří spíše drobnější skrytě žijící hadi s malou hlavou, slabým jedem a nevýrazným zbarvením. Srovnáním hodnocení Čechů a Azerbajdžánců se prokázala i mezikulturní shoda na větším strachu ze zmijovitých hadů.

Dvě závěrečné studie pak ukazují, že obě skupiny hadů vyvolávajících strach nebo odpor lze jasně odlišit i na úrovni autonomní odpovědi organismu, a to jednak fyziologické, která se projeví především různou kožně galvanickou reakcí a srdečním tepem, ale i neurální aktivací různých částí mozku. Hadi vyvolávající subjektivně vyšší strach způsobí i intenzivnější tělesnou reakci v podobě vyšší kožní vodivosti a rychlejší srdečního tepu, zároveň také více aktivují především amygdalu, thalamus a oblasti zrakové kůry svědčící o vyšší míře motivované pozornosti.

Výsledky této dizertační práce tedy dokazují, že lidé nereagují na všechny druhy hadů stejně, ale mají pravděpodobně vrozenou tendenci přednostně prožívat intenzivní strach v přítomnosti smrtelně jedovatých druhů zmijí, které se vyvíjeli se po dlouhou dobu ve stejné oblasti jako předci člověka. Taková schopnost rozpoznávat nebezpečné druhy hadů od těch neškodných a adekvátně na ně reagovat je přitom zcela nezávislá na znalostech či zkušenostech jedince s hady, protože se vyskytuje i u lidí, kteří mají o hadech pouze minimální vědomosti. Můžeme se domnívat, že hlavními rozlišovacími znaky nesoucími pro člověka informaci o možné nebezpečnosti konkrétního druhu hada je jeho zbarvení, tvar hlavy a velikost těla. Právě klikatá tmavá čára na zádech, trojúhelníkovitá hlava a podsadité tělo typické pro zmije se ukázaly jako nejefektivnější spouštěče strachu.

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10. Seznam zkratek

ACC: anteriorní cingulární kůra

AMG: amygdala

DS-R: Disgust Scale - Revised

KBT: kognitivně-behaviorální terapie

LC: locus coeruleus

LGN: laterální genikulátní jádro

NA: nucleus accumbens

PAG: periakvaduktální šedá hmota

PFC: prefrontální kůra

PULV: pulvinar

SC: horními párové hrbolky (colliculi superiores)

SNAQ: Snake Questionnaire

TH: thalamus