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DIPLOMOVÁ PRÁCE

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Kognitivní mechanismy spjaté s náchylností k halucinacím

Cognitive Mechanisms Associated with Proneness to Hallucinations

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Abstrakt

Halucinace jsou často považovány za závažný symptom psychické poruchy. V posledních dekádách se nashromáždily důkazy o výskytu halucinací i u neklinických populací. Zkoumání neklinických vzorků by mohlo zlepšit pochopení procesů, které způsobují auditorní halucinace. Tato práce zkoumá kognitivní mechanismy, u kterých bylo prokázáno, že ovlivňují náchylnost k auditorním halucinacím. Byla použita baterie experimentálních metod ke změření mechanismů, které jsou spjaté s etiologií halucinací. Baterie zahrnovala metody měřící zdrojovou paměť, kognitivní inhibici, bottom-up kognitivní procesy, pracovní paměť a rané traumatické zkušenosti. Studie byla provedena v laboratoři na 52 participantech. Výsledky práce napovídají, že náchylnost k halucinacím je spjata se zhoršenou funkcí top-down kognitivních procesů a s traumatickými zkušenostmi. Nebyla objevena žádná asociace mezi ostatními kognitivními mechanismy a náchylností k halucinacím, a to navzdory předchozím vědeckým zjištěním. Výsledek této práce může naznačovat, že zhoršená zdrojová paměť, pracovní paměť a atypické bottom-up kognitivní procesy mohou rozlišovat osoby s halucinacemi v klinické a neklinické populaci. Další interpretace výsledků může poukazovat na zhoršenou reprodukovatelnost vědeckých zjištění z oblasti výzkumu halucinací.

Klíčová slova: auditorní verbální halucinace, náchylnost k halucinacím, kognitivní mechanismy, reprodukovatelnost

Abstract

Hallucinations are often seen as a serious symptom of mental illness. Nonetheless, recent decades have produced a body of evidence that documented the presence of hallucinations even in non-clinical samples. Therefore, focusing on these samples is critical for improving understanding of processes underlying auditory hallucinations. The present study examines cognitive mechanisms that have been proposed to influence proneness to auditory hallucinations. A battery of experimental measures is implemented to assess some of the mechanisms implicated in the aetiology of hallucinations. Source monitoring, cognitive inhibition, bottom-up processes, working memory and traumatic experiences were measured in a laboratory study of 52 participants. Findings suggest that proneness to hallucinations is associated with impaired top-down processing and early traumatic experiences. No association between other cognitive mechanisms and hallucination proneness, contrary to previous evidence, has been found. This indicates that impaired source memory, working memory and bottom-up processing impairments might distinguish clinical and non-clinical hallucinators. An alternative implication of these findings points at issues with reproducibility in the hallucination research.

Keywords:

Auditory verbal hallucinations, Hallucination proneness, Cognitive mechanisms, Non-clinical Voice-hearers, Reproducibility

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List of abbreviations:

ACES – Adverse Childhood Experiences Scale

AH – Auditory hallucinations

AVHS – Auditory verbal hallucinations

CAPS – Cardiff Anomalous Perceptions Scale

CPA – Childhood physical abuse

CSA – Childhood sexual abuse

DASS – Depression Anxiety and Stress Scale

DL – Dichotic listening

FL – Forced-left condition

FR – Forced-right condition

ICHR – International Consortium on Hallucination Research

KR20 – Kuder-Richardson formula 20

LSHS - E – Launa-Slade Hallucination Scale Extended

NF – Non-forced condition

NHST – Null hypothesis significance testing

NÚDZ – Národní ústav duševního zdraví (National Institute of Mental Health)

REA – Right ear advantage

SDT – Signal detection task

SMT – Source memory task

SMF – Source Monitoring Framework

SPQ – Schizotypal Personality Questionnaire

SZ – Schizophrenia

TOST – Two One-Sided Tests

VSM – Verbal source monitoring

WM – Working memory

Introduction

When our *minds hear* voices, *we* hallucinate. Hallucinations are experiences resembling veridical perception; however, these perceptions are without any external stimuli. Hearing 'voices' represents a form of auditory hallucination, particularly auditory verbal hallucinations that have been long seen as a sign of the divine and the mystical. Over centuries the mystical was replaced with the development of medical science and cryptic messages from spirits, angels and Gods transformed into a prototypical sign of insanity. Yet, hallucinatory experiences are not beyond mystery as their aetiology remains elusive and hallucinations remain one of the most researched and least understood phenomena in modern psychopathology.

Although auditory verbal hallucinations are a significant symptom of severe mental illness, an increasing number of studies observed auditory and other hallucinatory experiences in the general population. Besides, many phenomenological similarities have been observed between hallucinations in clinical samples and non-clinical individuals, prompting interest in whether the same cognitive processes underlie hallucinations in healthy individuals and patients with psychiatric disorders. Additionally, discovering the presence of hallucinations in healthy populations spurred debate about the evidence base for discrete models of psychoses and other classification systems for psychiatric disorders. As a result, new models have been proposed and studied. Particularly, continual models of psychoses have been explored which claim that hallucinatory experiences are variously distributed in the population. This continuum likely ranges from healthy individuals to individuals who experience hallucinations but do not require any care and, finally, to patients with different disorders. Therefore, a better understanding of mechanisms associated with proneness to hallucinations in the general population might provide an important insight into auditory hallucination literature.

The present thesis is a part of the research project by International Consortium on Hallucination Research which opted to study mechanisms associated with proneness to auditory verbal hallucinations in the general public. Decades of research identified cognitive mechanisms that might contribute to the auditory verbal hallucinations. Historically, research has mostly focused on schizophrenic patients, however, the same mechanisms have been with some variability documented in a non-clinical population of voice-hearers. Studying healthy groups might lead to a better understanding of the nature of mechanisms underlying hallucinatory experiences as well as provide novel evidence for the models used in the clinical practice.

The theoretical section follows historical development and current literature on cognitive mechanisms associated with voice-hearing in both clinical and non-clinical groups. Moreover, the structure of the theoretical section follows the rationale of the research design and provides a theoretical background for hypotheses addressed in the empirical section of the thesis.

The first chapter elaborates on history, categorization and prevalence of auditory hallucinations across clinical samples and in the general population. Furthermore, the first chapter describes psychosis models and the influence the general population prone to experience hallucinations had on a paradigm shift in hallucination research.

The second chapter describes cognitive mechanisms of misattribution and externalization that have been observed to play a significant role in the creation of the auditory hallucinations. Namely, self-monitoring which introduced a significant hypothesis into hallucination research that hallucinations might arise as misattribution of internal cognitions to external sources. Next, the chapter explores the source monitoring framework which established another auxiliary hypothesis in hallucination research about a presence of externalizing bias.

In the third chapter, the inner speech models of auditory verbal hallucinations are described. Inner speech is most likely the 'raw cognitive material' that is misattributed and externalized. Thus, one might experience hallucinations due to atypical changes in inner speech. Moreover, the chapter describes the association between verbal working memory and hallucinations.

The fourth chapter covers the possible role of cognitive inhibition in the origin of the hallucinations. Moreover, the role of hemispheric language lateralization is detailed. In the fifth chapter, the association between traumatic experiences and hallucinations is explored in conjunction to mechanisms that might interconnect voice-hearing and trauma. Lastly, chapter six briefly overviews some of the personality characteristics associated with hallucinations and hallucination proneness.

The empirical section presents the experimental design which follows each chapter of the theoretical section. In the empirical section, the rationale of the research is described together with research aims and hypotheses. Next, experimental tasks described in the theoretical section are covered in closer detail in the methods section. Furthermore, analysis plan and sample are described together with results. Lastly, some explanatory analyses are conducted on the collected dataset and results from the present thesis are compared to the results from the larger international study. Due to the collaborative nature of the study, authors unique contributions are detailed in the empirical section.

Theoretical section

1. Hallucinations and ‘voices’

Hallucinations are defined as perceptual experience without external stimuli. Hallucinatory experiences may involve different modalities, however, in the most psychiatric and organic conditions auditory or visual hallucinations occur (Allen et al., 2008). In psychiatric disorders, auditory verbal hallucinations (AVHs) are the most common, particularly in the schizophrenia (SZ) patients who often experience AVHs as a distressing symptom that is chronic and resistant to treatment (Upthegrove et al., 2016). Visual hallucinations are mostly observed in patients with organic disorders as well as in individuals intoxicated with alcohol or psychoactive substances. Moreover, patients with an organic deficit or neurological disease can recognize that hallucinations are a pathological phenomenon as opposed to psychiatric patients (Peyroux & Franck, 2013).

AVHs occur in various forms and with different phenomenological features. ‘Voices’ might be heard as a singular individual or as multiple people, as one or both genders and hallucinator might hear voices that are familiar or unknown (Upthegrove et al., 2016). This phenomenological plurality leads to a number of subclassifications of AVHs with an underlying assumption that phenomenological differences are a result of different causal mechanisms (Blom & Sommer, 2011). Besides, phenomenological differences are even more pronounced across cultures. In non-Western cultures, AVHs are often seen as a result of spirit possession (Peyroux & Franck, 2013).

Hallucinations were historically differentiated into ‘true hallucinations’ and ‘pseudo-hallucinations’. True hallucinations are indistinguishable from a veridical perception. AVHs present in SZ patients are categorized as a subset of true hallucinations due to their complexity. On the other hand, auditory hallucinations (AH) are less complex, more elementary sensations such as noises or single words. AVHs are rich in sensory qualities, have characteristics of objective experience and they are experienced as coming from external space (Larøi et al., 2012). The theoretical construct of pseudo-hallucinations is associated with the sensory quality of ‘images’ that occur within inner space (as opposed to external perception). These images have an incomplete structure and are dependent on the will of the person experiencing the image. The differentiation between true and pseudo-hallucinations is significant for the diagnostic purposes, as the true hallucinations signal a serious mental illness (Upthegrove et al., 2016).

Even though AVHs are seen as a core symptom of schizophrenia, they have also been documented in the context of other disorders. Particularly, AVHs have been observed in 70% of SZ patients and in 46% of patients with a borderline personality disorder who share similar phenomenological features of AVHs with the SZ patients (Merrett, Rossell, & Castle, 2016). Next, AVHs occur in 23% of patients with bipolar disorder. Moreover, AVHs are also present in depression, anxiety and post-traumatic stress disorder (Upthegrove et al., 2016, van Os and Reininghaus, 2016). Furthermore, AVHs also occur in the normal population with estimates between 10–20% (Upthegrove et al., 2016). This suggests that there might be general mechanisms that underpins hallucinations across modalities and diagnostic categories (Waters et al., 2012).

1.1 AVHs and models of psychosis

The presence of AVHs both in the clinical and general population lead some to argue that hallucinations are continuous rather than categorical phenomena (van Os et al., 2000). The first study documenting the presence of hallucinations in the general population dates to 1894 to a study by Sidgwick et al. (in Blom & Sommer, 2011) on a sample of 17 000 British people. Authors observed that 10% of individuals from a healthy population experienced either auditory, tactile or visual hallucinations. Similar numbers were observed almost a hundred years later by Tien (1991) in the US sample in which 13% of healthy individuals experienced auditory, tactile or visual hallucinations.

Historically, voice-hearing was rooted within a conceptual framework of psychoses and AVHs represented and still represent a 'first-rank' symptom of schizophrenia in discrete, categorical models used for diagnostic classification of mental disorders (van Os et al., 2000). Individuals who experience AVHs and don't need clinical care are referred to as 'healthy' or 'non-clinical' voice-hearers. Non-clinical individuals with hallucinatory experiences spurred a reconceptualization of psychosis and categorical models of mental illness in general. Evidence from healthy voice-hearers suggests that AVHs and hallucinatory experiences are not uncommon in healthy individuals and therefore voices-hearing might not always be a hallmark of the insane (Baumeister et al., 2017). On the contrary, a number of healthy individuals often experience symptoms resembling psychosis during childhood, adolescence or bereavement (de Leede-Smith & Barkus, 2013) or during the transition from an awake state to sleep (*hypnagogic hallucinations*) and during the transition from sleeping to an awake state (*hypnopompic hallucination*s; Jones, Fernyhough, & Meads, 2009).

An interesting group of voice-hearers on the continuum from healthy to clinical voice-hearers are ‘clairaudient’ psychics, who receive auditory messages from the ‘beyond’. In the study by Powers, Kelley and Corlett (2016), clairaudient psychics did not differ from clinical-voice hearers in acoustic characteristics or content and frequency. Differences were observed mainly in the affective response to the voices and perceived control over them and reported ability to control their on- and off-set. Contrary to non-clinical voice-hearers who have more transient and context-dependent AVHs, psychics seek out and report a more continual experience of voice-hearing (Powers et al., 2016). However, in general, clinical and non-clinical populations differ most in the phenomenological characteristics of emotional content and the sense of control over the AVHs (Daalman et al., 2011a). On the other hand, similarities between the clinical and non-clinical voice-hearers were observed on the perceived location of the voices, their number, loudness and non-self recognition (Waters et al., 2012).

Given these epidemiological, phenomenological and empirical findings, categorical models have been increasingly criticized for a lack of empirical evidence and their validity (Bentall, 2003; Linscott & van Os, 2010; van Os et al., 2000). Therefore, the paradigm surrounding AVHs started transitioning to continuum models (Bentall, 2003). Continuum models place anomalous experiences on a dimension between clinical voice-hearers and non-voice-hearing individuals. The proneness to anomalous experiences is distributed in the population with only a proportion of individuals who exhibit extreme forms of AVHs and need professional care (Baumeister et al., 2017). Studying non-clinical voice-hearers might be an influential strategy for a better understanding of mechanisms that are underlying AVHs, as the non-clinical voice-hearers do not have other confounding factors of SZ population such as other symptoms, medication, development or deterioration of mental illness as well as possible effects of stigmatization (Waters et al., 2012). Thus, the study of hallucination proneness not only contributes to the understanding of non-clinical voice-hearing, but it also furthers paradigms associated with psychosis models and hallucinatory experiences in clinical voice-hearers who are distressed by the hallucinations.

2. Misattribution and externalization bias

Cognitive approaches studying auditory verbal hallucinations intend to uncover specific cognitive mechanisms like processing abnormalities or biases associated with proneness to experiencing hallucinations (Allen et al. 2007). Several different models have been proposed to explain the origin AVHs, most of them converge on the importance of attributional processes, suggesting that auditory hallucinations are a product of misattributing internal cognitive events to external sources (Brookwell, Bentall, & Varese, 2013). However, misattribution alone cannot account for the external or alien nature of voices that is often reported from groups of voice-hearers. Therefore, a specific “externalizing” bias has to be present (Bentall & Slade, 1990).

To measure both misattribution and externalizing bias, different experimental paradigms have been used. The process of distinguishing between internal and external cognitive events has been variously termed as *self-monitoring*, *source monitoring* or *reality monitoring* (Moseley, Fernyhough, & Ellison, 2013). Self-monitoring refers to the process that distinguishes between self- and non-self generated internal cognitions (Frith, 1992). Reality monitoring refers to the process that differentiates between externally and internally generated events (Johnson & Raye, 1981). Furthermore, reality monitoring provided a theoretical basis on which the source monitoring framework was developed. In its turn, source monitoring refers to the same processes of differentiating the external and internal cognitive events, however, source monitoring provides a more detailed theoretical background (Johnson, Hashtroudi, & Lindsay, 1993).

2.1 Self-monitoring

Self-monitoring has been used to describe the ability to monitor the planning and execution of actions. In general, most self-monitoring studies involve tasks where participants monitor self-made actions or vocalisations (Frith, 1992). Impaired self-monitoring results in disruption between action and the sense of initiating the action. Therefore, an individual with impaired self-monitoring might be unable to recognize internal actions as self-generated, this inability has been proposed to play a significant role in the pathogenesis of positive symptoms in schizophrenia (SZ; Frith, 1987).

The disruption between action and the sense of initiating the action has been proposed to be caused by a mechanism known as *corollary discharge* or *reafference*. Corollary discharge was first termed by Sperry (1950 in Frith, 1992) and its possible significance in the origin of

AVHs has been proposed by Feinberg (1978) and further developed by Frith (1992). Generally, corollary discharge mechanism functions in the following way: when a motor plan is generated, an ‘efference copy’ of the motor plan is also created and sent to the sensory areas to attenuate them to the forthcoming action. When the planned motor action occurs and sensory information corresponds with the efference copy, the action is recognized as self-generated. However, if the received sensory information is not matched with the efference copy, the action is experienced as non-self-generated (Ford & Mathalon, 2005).

Self-monitoring and corollary mechanism represent a mechanistic approach to the study of AVHs. The mechanistic approach contrasts popular ‘symptom-capture’ studies which represent a naturalistic approach that attempts to use different imaging methods to uncover structural and functional changes in the brains of voice-hearers (Ford & Mathalone, 2005). The mechanistic approach attempts to identify a fundamental psychological mechanism and an underlying neurobiological process (Silbersweig & Stern, 1996). Ford and Mathalone (2005) argue that self-monitoring represents the fundamental psychological mechanism and corollary discharge serves as the underlying neurobiological mechanism in the origin of AVHs.

Several models tried to explore the role of self-monitoring, corollary mechanism and AVHs. Among first was the Neurocognitive Action Self-monitoring System (NASS; Blakemore, Wolpert, & Frith, 1998), the NASS model was created to explain the passivity experiences associate with SZ such as delusion of control (Blakemore & Frith, 2003). However, the NASS model was applied only to overt behavior.

Seal, Aleman and McGuire (2004) applied the NASS model to AVHs. Importantly, Seal et al. emphasized the role of inner speech as the material that is misattributed during AVHs and the authors further theorized that inner speech is a form of motor action. Moreover, Seal et al. applied the NASS model to a feeling of ‘unintendedness’ a significant phenomenological feature accompanying AVHs. In their model, the feeling of unintendedness is a result of distorted or absence of efference copy of motor action surrounding inner speech. Due to the absence of efference copy sensory cortical areas are not attenuated to the incoming sensory information of the inner speech which results in the inner speech being registered as non-self-generated.

Another expansion of the NASS model was proposed by Jones and Fernyhough (2007). In contrast to Seal et al.'s model that sees the feeling of unintendedness as the result of a faulty discharge mechanism, Jones and Fernyhough propose that failed predicted state leads to the absence of emotion of self-authorship and therefore to a feeling of other-authorship of inner speech (Jones & Fernyhough, 2007).

To summarize, impaired self-monitoring might lead to AVHs as the efference copy predicting consequences of self-produced action is either disrupted or delayed. To test the self-monitoring theory the verbal self-monitoring paradigm (VSM) has been used. In the VSM paradigm participants are instructed to speak a word into a microphone, the recording is immediately played back to the participants in one of the following conditions: i) the recording is played back undistorted, ii) the participants recording is distorted, iii) a recording with the same stimuli is pronounced by a different person, iv) a recording with the same stimuli is pronounced by a different person and the recording is distorted. The objective of the task is for a participant to decide whether the recording they heard was their voice or someone else's (McCarthy-Jones, 2012). Hallucinating patients have been shown to attribute their own self-generated speech to external sources at a higher frequency than non-hallucinating controls (Franck et al., 2001; Frith and Done, 1989; Johns et al. 2001).

In all, self-monitoring deficits are a well documented and replicated finding amongst SZ patients, thus erroneous self-monitoring likely accounts for some of the psychotic experiences. Furthermore, Blackmore et al. (2000) documented that individuals with SZ show decreased differentiation between tickle sensation evoked by themselves or by others. This effect has not been observed in healthy controls or SZ patients without AVHs. Blackmore et al.'s findings might indicate that SZ individuals with AVHs might have a global deficit in self-monitoring (Moseley, 2015).

2.2 Source monitoring

Source monitoring represents a prominent approach to study AVHs which expands on the self-monitoring theory because a deficit in self-recognition alone fails to sufficiently explain processes leading to misattribution of internal events to external sources (Brookwell et al., 2013). Therefore, AVHs are theorized to interact with source monitoring processes as they are responsible for distinguishing between internally and externally generated events (Woodward & Menon, 2011).

Generally, source monitoring refers to a set of processes involved in deciding the origin (*source*) of remembered information (Johnson et al., 1993). Source Monitoring Framework (SMF) extends the Reality Monitoring Framework (Johnson & Raye, 1981) which describes *reality monitoring* as a process that distinguishes between internal and external cognitive events such as whether a word was spoken by oneself or by a different individual. Reality monitoring represents one of three processes that constitute the term 'source monitoring'. The second process, *internal source monitoring*, distinguishes between different internal sources, for example, whether a word was imagined or spoken aloud. Finally, *external source monitoring* is the third process that differentiates between multiple external sources, for example, whether a word was spoken by a one person or another (Johnson et al., 1993).

The central hypothesis underlying the SMF is that memories are not retrieved with abstract 'tag' or 'label'. Instead, source information is retrieved from memory using perceptual, semantic, spatial, temporal and affective characteristics (Johnson et al., 1993). These characteristics are used when attributing memories to a particular source through decision processes involved in memory retrieval. Decision-making processes involved in the source monitoring use average differences between characteristics typical for an internal or external source. Ordinarily, internally generated events involve more information on cognitive operations, on the other hand, externally generated events contain more perceptual, temporal, affective and spatial information (Johnson et al., 1993).

Bentall (2003) further directs attention to the hypothesis of SMF stating that perceptual information is not "labelled" as real or imaginary. This distinction between perceptual and labelling processes represented an important milestone in hallucination research, as early studies focused mostly on erroneous perception (Frith, 1992). Even though researching the perceptual systems represents a prominent and important line of research, the study of decision processes involved in source monitoring also provided critical insight into the processes underlying AVHs (McCarthy-Jones, 2012).

To better understand the likely overlap between source monitoring processes and AVHs, Ditman and Kuperberg (2005) argue that impaired source monitoring might contribute to AVHs in the following two ways. First, AVHs might have increased sensory quality and therefore resemble veridical percepts. According to SMF, memories from different sources are unique in their characteristics. Therefore, perceptual, spatial, semantic and affective characteristics are dominant in 'real' memories. On the other hand, internally generated events involve more information about cognitive operations (Johnson et al., 1993). If AVHs have increased perceptual quality, errors in source monitoring are likely to occur as the characteristics of a source would not match expectations. Second, AVHs might lead to perceiving external events with a decreased amount of detail. Consequently, leading individuals to misattribute internally generated events as external, due to the similarity of source characteristics. However, there is little evidence suggesting that AVHs are a result of increased or decreased level of details in particular characteristics. Therefore, a general impairment in the source monitoring process is more likely (Ditman & Kuperberg, 2005).

Indeed, studies exploring the role of source monitoring in AVHs consistently observe an externalizing bias, a tendency to identify internal cognitive events as external in origin (Bentall, Baker, & Havers, 1991). Externalizing bias is supported by studies where clinical voice-hearers tend to externalize internally generated events to external sources (Bentall et al., 1991; Brébion et al., 2000; Woodward, Menon, & Whitman, 2007). Moreover, this bias has been also observed in the group of non-clinical voice-hearers (Larøi, Van der Linden, & Marczewski, 2004b). Interestingly, a bias to perceive imagined words as spoken aloud by the SZ patients with AVHs was observed which suggests impairments in the internal source monitoring (Franck et al., 2000; Gawęda et al., 2013). Finally, the tendency to misremember internally generated events as external in origin amongst voice-hearers has been supported by meta-analytic evidence (Brookwell et al., 2013).

To summarize, AVHs might be conceptualized as internal cognitive events misattributed to an external source. Source monitoring likely has an important role in the creation and proneness to AVHs (Woodward & Menon, 2013). Source monitoring deficits associated with hallucinatory experiences are mostly tested with two experimental paradigms, the source memory task and the signal detection task (Waters et al., 2012).

2.3 Source memory task

Source Memory Task (SMT) is an experimental paradigm used to measure externalizing bias. During SMT, participants are asked to distinguish between memories of self-generated material and memories of externally-generated material (Johnson et al. 1993). Typically, participants are presented with a set of words that are either individually pronounced out loud by the experimenter (via headphones) or read by participants. Later, participants are required to determine the source of the previously presented words as either 'imagined' (words read by participants) or 'heard' (words read by the experimenter).

SZ patients with AVHs as opposed to healthy participants or SZ patients without AVHs ordinarily misattribute words spoken by the experimenters as read by themselves (*other-to-self misattribution*), showing externalising bias in source monitoring (Woodward et al., 2007). Although researchers observed association between hallucinations and other-to-self misattributions in both clinical (Bentall et al. 1991) and non-clinical samples (Larøi et al. 2004b), however, no such association was found for other types of misattribution errors.

Some have argued that SMT is an 'offline' measure of source monitoring because identification of the source occurs after a time delay. To test whether individuals have impaired monitoring of intentions the 'real-time' paradigm is used where participants determine the source of stimulus immediately as they encounter it (Ditman & Kuperberg, 2005). To this extent, the Verbal Self-Monitoring paradigm (VSM) associated with self-monitoring is used (described in the previous section) (McCarthy-Jones, 2012).

2.4 Signal detection

Signal detection task (SDT) constitutes another paradigm to empirically examine source monitoring approach to AVHs (Waters et al., 2012). SDT is based on the framework of signal detection theory developed to examine the accuracy of pattern-recognition systems. Essentially, signal detection theory represents a mathematical model describing how individuals detect stimuli and make decisions in an uncertain environment (Green & Swets, 1966 in McCarthy-Jones, 2012). Therefore, SDT is utilized to test the decision processes involved in source monitoring. Moreover, SDT represents an empirical paradigm to measure proneness to false perceptions (Barkus et al., 2007).

During SDT individuals need to detect stimuli (*signal*) in a situation of uncertainty, where auditory signals (voice or voices) are hidden in background noise. Ordinarily, SDT requires participants to listen to bursts of noise via headphones and for each burst, participants need to determine whether they believe a voice was present (Moseley, 2015). According to signal detection theory, two parameters influence performance in the signal detection task. First, *the perceptual sensitivity* which represents a measure of the acuity of the perceptual system. Second, *the response bias* which refers to a criterion used to make judgements whether the signal is present under conditions of uncertainty. Decreased response bias serves as a measure of externalizing bias (Bentall, 1990).

Generally, four different outcomes are possible: i) the signal is present and it is recognized by the participant (*a hit*); ii) the signal is present but not detected by the participant (*a miss*); iii) the signal is absent, but the participant decides it is present (*false alarm*); iv) the signal is not present, and the participant decides there is no signal (*correct rejection*; Green and Swets, 1966 in McCarthy-Jones, 2012). Individuals with AVHs are expected to perform with fewer misses and an increased amount of false alarms. This pattern of responding suggests that an individual is likely to decide that an ambiguous percept is 'real' (a voice is present in ambiguous noise). In other words, individuals prone to and experiencing AVHs are biased towards labelling internally generated percept as external in origin (Moseley, 2015).

Bentall and Slade (1985) conducted the first study examining hallucinations as a result of erroneous decisions associated with response bias, hypothesizing that hallucinators would be more willing to believe that a perceived event was real. Prior to their study SDT was used to examine perceptual abnormalities and therefore perceptual sensitivity of SZ patients. Bentall and Slade (1985) conducted two different experiments using SDT on samples of clinical and non-clinical voice-hearers. Results show that non-clinical voice-hearers don't differ in their perceptual sensitivity, but clinical individuals examined decreased response bias. This finding has been replicated in both non-clinical groups and clinical groups (Barkus et al., 2007, 2011; Varese et al., 2012a). Moreover, Barkus et al. (2007) observed, that decreased response bias could differentiate patients with SZ and healthy controls.

Besides source monitoring, SDT has been used within other frameworks studying AVHs. Notably, theory utilizing the signal detection paradigm proposes AVHs to be a result of perceptual hypervigilance (theorized to be linked to anxiety). Perceptual hypervigilance supposedly enhances the response bias and leads to a higher likelihood of erroneous cognitive processing (Dodgson & Gordon, 2009). Furthermore, poor performance on the SDT is not specific to AVHs. The ability to make overconfident perceptual judgments is a processing style linked to delusions – presenting a plausible hypothesis that underlying mechanisms of hallucinations may be shared with other positive symptoms (Harvey, 1985).

To summarize, self-monitoring together with corollary discharge mechanism and source-monitoring are not mutually exclusive approaches to study AVHs. Rather, a disrupted corollary discharge mechanism might lead to a decreased response bias that would further increase the likelihood that self-generated actions would be perceived as non-self-generated. Possibly, self-monitoring represents a lower-level mechanism involving motor actions, whereas source monitoring might represent higher-level decision-making processes associated with non-clinical proneness to experience AVHs. Moreover, similar brain activation involving temporal lobe regions is observed in both self-monitoring and source monitoring, implying that the two processes might be measuring the same cognitive mechanism (Moseley, 2015).

3. Inner speech models of AVHs

The significance of misattribution has been argued for several decades now. Self-monitoring and source monitoring have been rigorously tested and most of the axiomatic hypotheses have been well established using different empirical paradigms. Yet, different viewpoints on 'what' is being misattributed exist. Multiple claims have been made as to what is 'raw material' of AVHs (McCarthy-Jones, 2012). Various researchers argue that the material for AVHs are aberrant memories (Waters et al., 2006), unbidden thoughts (Hoffman et al., 2011), or hypervigilant attention (Dodgson & Gordon, 2009). However, arguably the most endorsed theory suggests that AVHs arise as a result of misattributed inner speech (Brookwell et al., 2013).

Inner speech plays an important role in multiple cognitive processes. Atypical changes in inner speech have been linked to different clinical conditions besides AVHs and psychosis, particularly to deficits in self-regulation, mood and anxiety disorders (Alderson-Day & Fernyhough, 2015). A better understanding of inner speech might provide not only a strong theoretical insight into the aetiology of AVHs but an additional understanding into atypical and normal cognition (Alderson-Day et al, 2016). However, inner speech is a complex experience with many phenomenological accounts and different theoretical conceptualizations. Jones (2010) reviewed some of the definitions used to describe inner speech and noted that inner speech was variously referred to as 'having an auditory-articulatory image of speech without producing any sound', 'experience of talking to oneself', or 'overlap between thought and speech'. This plurality in definitions represents a likely confounding effect in methodological approaches studying inner speech and its role in AVHs.

3.1 Empirical evidence interconnecting inner speech and AVHs

Some of the first evidence of possible interconnection between inner speech and AVHs comes from subvocalization studies (McCarthy-Jones, 2012). Subvocalization is the activity of vocal musculature present during the inner speech. This research supports Fernyhough's (2004) argument, that inner speech is a form of motor action. Also, Fernyhough's argument has been recently supported by observing that corollary mechanism accompanies inner speech (Jack et al., 2019). Moreover, similarly to early subvocalization studies that showed increased subvocalization during AVHs (Gould, 1948 in Frith, 1992; McGuigan 1966 in McCarthy-Jones, 2012) recent studies following the same paradigm replicated increased subvocalization during AVHs (Rapin et al., 2013).

Furthermore, other paradigms have been used to assess whether inner speech is taking place during AVHs. Bick and Kinsbourne (1987) asked individuals experiencing AVHs to open wide their mouth for a minute – a task that, in theory, would interfere with inner speech. Bick's and Kinsbourne's experiment suggests that this task lowered the frequency of AVHs. However, a 1990 study conducted by Green and Kinsbourne failed to replicate some of the original findings using additional tasks proposed to reduce inner speech, such as humming and 'biting' a tip of a tongue (Green & Kinsbourne, 1990).

More evidence on the role of inner speech during AVHs comes from neuroimaging studies examining brain activity. Generally, a similar activation during inner speech and AVHs, activity is observed, primarily in the left hemisphere, particularly in the left superior temporal gyrus (involving Wernicke's area) and in the left inferior temporal gyrus (Broca's area), supplementary motor area and insula (Green & Preston, 1981, Shergill et al., 2001). Inner speech and AVHs activation differed in lower activation of the supplementary motor area (Raij & Riekki, 2012). Furthermore, Vercament et al. (2010) demonstrated reduced functional connectivity between the left temporoparietal junction and the right homologue of Broca's area (right inferior temporal gyrus). This right hemisphere activation is consistent with some of the phenomenological accounts of AVHs that consist of short and negative sentences. Therefore, the right hemisphere might be important for creating the 'context' of AVH including emotional valence and attentional salience (Moseley et al., 2013).

Inner speech models of AVHs have been criticized for a poor fit with the phenomenological accounts from voice-hearers. A common image of inner speech as 'thinking in words' does not correspond with reports on the experiential qualities of AVHs (Jones, 2010; Nayani & David, 1996). Voice-hearers often describe 'voices' as alien or not self-generated, usually in the voice of another person or multiple people. At the same time, voice-hearers are often aware that the 'voices' arise from within themselves (Nayani & David, 1996). Furthermore, AVHs are commonly studied as unitary phenomena but in fact, they might be not (Jones, 2010). Therefore, AVHs might have multiple, separate forms and only some of AVHs might be seen as a result of misattributed inner speech. To bridge the phenomenological accounts with inner speech models of AVHs Fernyhough (2004) expands on Vygotsky's conceptualization of inner speech which emphasizes its dialogic structure.

3.2 Dialogic structure of inner speech

Dialogic structure of inner speech provides an explanation as to why inner speech might be experienced as alien or external. Vygotsky (1934 in Fernyhough, 2004) posits that inner speech is the result of internalizing external dialogues during natural development. Therefore, the inner speech likely takes a form of an internal dialogue that contains voices other than our own. Thus, this 'inner conversation' arises as a result of social interactions in childhood which are transformed into an internal dialogue, representing a broad idea of Vygotsky that during the developmental process every mental function appears twice. First, in interaction with other individuals (interpsychological form) and second in an internalised form (intrapsychological; McCarthy-Jones, 2012).

An important stepping stone for Vygotsky's inner speech theory was children's private speech during which children talk to themselves while engaged in a task requiring mental efforts. The private speech is theorized to be a transitional stage in the process of internalization of dialogues. Vygotsky saw a primary role of the inner speech in the self-regulation of cognition and behavior (Alderson-Day & Fernyhough, 2015).

Using Vygotsky's conceptualization of inner speech, Fernyhough (2004) differentiates two different forms of inner speech – i) *expanded* and ii) *condensed* inner speech. The expanded inner speech represents internal dialogue that has a structure of an external dialogue complete with syntax. However, the condensed inner speech is semantically and syntactically condensed and abbreviated (Alderson-Day & Fernyhough, 2015). Interestingly, the condensed inner speech can account for some of the rare hallucinatory experiences. Condensed speech loses its acoustic and structural qualities and is often perceived as a 'thinking in pure meanings', corresponding with 'soundless voices' a type of AVH conveying meaning without being actually heard (Jones, 2010). Moreover, voice-hearers might have underlying atypical changes in the condensed inner speech which at some point might 're-expand' and lead to AVHs (Fernyhough, 2004; Jones & Fernyhough, 2007).

Dialogical structure of inner speech led to the development of a self-report instrument – The Varieties of Inner Speech Questionnaire (VISQ). When examining hallucination prone individuals using VISQ, AVHs were predicted by more pronounced dialogic items (McCarthy-Jones & Fernyhough, 2011).

As mentioned above, research on inner speech comes with methodological difficulties due to the plurality of definitions of inner speech and methods used to elicit it. Most evidence from neuroscientific studies operationalizes inner speech as a first-person monologue (Simons et al., 2010). However, inner speech and its subjective experience are more complex and varied phenomena than a first-person monologue. Therefore, Alderson-Day et al. (2016) conducted a neuroimaging study using the dialogic model of inner speech. Authors of the study proposed that dialogic structure of inner speech has to involve some of the networks associated with the theory of mind, generation and control of mental imagery and auditory verbal imagery (imagining auditory stimuli in another person's voice). Indeed, Alderson-Day et al. (2016) concluded that other networks areas of speech processing are involved in inner speech, including right superior temporal gyrus associated with the theory of mind and social cognition, suggesting that study of AVH should focus not only on speech processing pathways to better understand neuroscientific underpinnings of AVH. Furthermore, these findings correspond with previous studies documenting the right-hemispheric activity observed during AVHs that was proposed to involve a perspective-taking mechanism that is typically observed in tasks assessing theory of mind (Young et al., 2010). This finding might explain an inability to distinguish the dialogic nature of inner speech (Moseley et al., 2013)

3.3 Working memory and inner speech

Inner speech also plays a role in Working Memory (WM) which might be defined as 'a system for the temporary holding and manipulation of information during the performance of a range of neurocognitive tasks such as comprehension, learning and reasoning' (Baddeley, 1986 in Alderson-Day & Fernyhough, 2015). Inner speech is particularly involved in one of the subsystems of WM, the *phonological loop* that is responsible for the representation of acoustic, verbal and phonological information (Alderson-Day & Fernyhough, 2015).

Individuals with AVHs show a deficit in WM (Daalman et al., 2011b). Particularly, verbal working memory, a core cognitive function that is ordinarily impaired in SZ patients (Rossi et al., 2016). Verbal working memory deficits are not associated with the severity of AVHs in the SZ population, even after controlling for severity of psychosis symptoms, general executive functions (Gisselgard et al., 2014). Moreover, a meta-analysis by Forbes et al. (2009) showed a lack of association between deficits in working memory and IQ, suggesting a specific WM deficit rather than general cognitive impairment. Similar impairment has been documented in non-clinical voice-hearers (Daalman et al., 2011a) and in first-degree relatives of SZ patients (Rossi et al., 2016).

Impaired WM likely plays a role in the next prominent approach to AVHs that is associated with top-down processing, as working memory is associated with executive dysfunction and cognitive inhibition, which are proposed to be a significant factor in the pathogenesis of AVHs (Gisselgard et al., 2014).

4. Top-down inhibitory control

4.1 Perceptual model

Inner speech models do not account for all phenomenological features described by individuals with AVHs (Jones, 2010). However, both clinical and non-clinical voice-hearers describe that voices 'speak to them'. Although much of this was addressed by Jones and Fernyhough (2007) and the dialogic structure of inner speech, other theories attempted to bridge the gap between reports of voice-hearers and different theoretical approaches to AVHs.

Hugdahl (2009) established a perceptual model to study AVHs. The perceptual model posits that AVHs are better understood as inner hearing rather than inner speech. Hugdahl's conceptualization of AVHs draws from neuroscientific evidence documenting parallels between brain activity during AVHs with that of normal speech perception (Lennox et al., 2000). Therefore, Hugdahl (2009) argues that AVHs might be better understood as erroneous speech perception rather than a result of misattributed inner speech.

The perceptual model claims to have an additional advantage in the study of AVHs. Besides, offering a better phenomenological fit, Hugdahl (2009) argues that perceptual model allows for the generation of hypotheses examining exact neurological underpinnings of hallucinatory experiences. Conceptualization of AVHs as inner hearing suggests atypical changes in auditory sensory cortex, particularly the role of the peri-Sylvian region was implicated as significant for the creation of AVHs.

Hugdahl's (2009) perceptual model further contributed to hallucination research by exploring the role of top-down processes in the creation of AVHs. Given the clinical accounts of voice-hearers, AVHs are accompanied by an inability to ignore the voices and incapacity to shift attention away from them – leaving patients helpless to often negative comments or commands. Importantly, the reported inability is conceptualized as a failure of top-down inhibitory control (Hugdahl, 2015). Therefore, to fully understand the origin of hallucinatory experiences the role of top-down cognition, particularly inhibitory control must be explored (Hugdahl, 2009). Although other researchers connected hallucinations with top-down processes (Aleman et al., 2003), Hugdahl's (2009) perceptual model provided novel insight into the field as well as a broadly utilised experimental paradigm to study AVHs and processes associated with top-down inhibitory control.

To summarize, the perceptual model emphasizes the interplay between bottom-up and top-down processes and implicates the auditory sensory cortex as key for the origin of hallucinations.

4.2 Top-down processing: cognitive control, inhibition and executive processes

Top-down processing is a polysemic term that includes many processes. Often, the AVHs research addresses attention, cognitive control and cognitive inhibition in an interchangeable manner. Inhibition is a broad construct generally referring to prefrontal executive control that is associated with different cognitive processes such as attention, memory and learning (Jardi et al., 2016). Furthermore, cognitive inhibition represents a set of different processes varying in the object of inhibition (e.g., thoughts or behavior) and the manner in which is inhibition occurring (e.g., external cue or environmental context; Badcock & Hugdahl, 2014). Moreover, cognitive inhibition is an umbrella term with different meanings and while inhibition is tied to hallucinatory experiences, not all cognitive mechanisms of inhibition might be relevant for AVHs (Jardi et al., 2016).

As previously mentioned, cognitive inhibition is often used interchangeably with cognitive control. Cognitive control has been defined as the system for formation, maintenance and realization of internal goals and has been linked to activity in the frontal lobes (Miller & Cohen, 2001). Involvement of prefrontal areas is associated with a wide range of different cognitive functions, including response selection, executive control, working and episodic memory and problem-solving (Duncan & Owen, 2000). Also, the concept of cognitive control overlaps with other cognitive functions and cognitive control is often used interchangeably with executive functions – a term mostly present in neuropsychological literature (Hugdahl, 2015). Cognitive control allows an individual to shift their attention, adapt to diverse situations and inhibit inappropriate behaviors (Miller & Cohen, 2001). Throughout this thesis, I will hearafter refer to cognitive inhibition representing top-down processing associated with prefrontal cortex activity.

Though the failure of cognitive inhibition is well documented amongst clinical groups of voice-hearers, there is relatively little research examining this phenomenon (Hugdahl, 2015). Cognitive inhibition has been mostly explored by Waters et al. (2006) when studying the inability to inhibit intrusive thoughts. However, cognitive inhibition might account for differences between clinical and non-clinical groups of voice-hearers (Hugdahl et al., 2009b). Non-clinical voice-hearers might be able to cope with distressing perceptual experiences by utilizing cognitive inhibition. Moreover, patients with SZ report that they are able to distinguish their own inner speech from the 'voices' based on the perceived sense of control (Hoffman et al., 2008). Therefore, non-clinical voice-hearers might have intact top-down processing and impaired bottom-up processing while voice-hearers with a clinical condition have impaired both processing systems. Also, decreased cognitive inhibition is fitting with widely reported phenomenological feature surrounding AVHs – a strong 'attentional shift' towards the voice (Hugdahl, 2009).

The role of top-down processing has been recently examined within a computational framework trying to account for AVHs and for the functioning of the human mind in general. Within this framework, the brain is seen as an adaptive system that actively works with input coming from bottom-up processes. Computational modelling theorizes that perception is in large affected by one's expectations from previous experiences. This idea represents an auxiliary premise of Bayesian models describing the functioning of perception (Stocker & Simoncelli, 2006). van Berkum (2010) argued that a brain is essentially a 'prediction machine' which tries to continuously predict bottom-up information using top-down expectations. Therefore, AVHs might be conceptualized as active top-down sensory expectations without a real bottom-up sensory input (de Boer et al., 2019). This conceptualization expands the hypothesis that AVHs arise due to the imbalance between bottom-up and top-down processes (Aleman et al., 2003; Hugdahl, 2009). In all, recent research combining computational modelling and neuroimaging (Powers et al., 2017), or modelling and cognitive tasks together with psychometric tests seem to support the 'disbalance' hypothesis between top-down and bottom-up processes (de Boer et al., 2019).

Historically, cognitive inhibition has been examined using different experimental tasks, however, the most known might be the Stroop task (Stroop, 1935 in Miller & Cohen, 2001). Stroop task presents participants with words conveying a color written in a conflicting color (thus word "blue" might be written in green ink). Researchers observed a robust tendency to respond with the word conveying color (*semantic information*) rather than, with the ink color (*non-semantic information*) as instructed. Thus, the Stroop task invokes cognitive inhibition by perceptually salient environmental stimuli that trigger default action tendencies (Miller &

Cohen, 2001). Other tasks have been used, such as the Flanker task (Eriksen & Eriksen, 1974 in Miller & Cohen, 2001) and the Wisconsin Card Sorting Test (Miller & Cohen, 2001).

However, for the study of AVHs, Hugdahl (2009) proposes dichotic listening task as a fitting experimental paradigm to test cognitive inhibition. By varying instructions during dichotic listening a conflicting situation is introduced which elicits top-down inhibitory processes (Hugdahl et al., 2009). Miller and Cohen (2001) proposed that situations presenting the individual with cognitive conflict are a good way how to elicit top-down inhibitory processes. Additionally, the dichotic listening paradigm is easy to use and prevents fatiguing participants, a factor particularly important when making comparisons to healthy controls. Finally, the simplicity of the tasks favours its use in neuroimaging studies, this is of particular importance for testing of the perceptual model (Hugdahl, 2009).

4.3 Dichotic listening

Dichotic listening (DL) is a method widely used to study the lateralization of speech perception. During DL participants are presented with two different sounds at the same time – each in a different ear. The task usually consists of 100-200 trials. Generally, sounds represent a combination of consonants paired with the vowel ‘a’ (e.g., ba, da, pa, ta). On each trial participants are instructed to report which syllable they perceived (Hugdahl, 2009).

Generally, DL results in a tendency to report stimuli presented in the right ear, a tendency known as *right ear advantage* (REA). REA arises due to the preponderance of contralateral input. Even though perceptual input reaches auditory sensory areas both ipsi- and contra-laterally the input ‘competes’ under dichotic rivalry. Essentially, the right ear input reaches the auditory cortex located in the left hemisphere directly while attenuating the ipsilateral input from the left ear (Hugdahl, 2009). The right ear advantage is a well established and robust effect that has been documented across different ages ranging from young children to the elderly (Traykov et al., 2007). Additionaly, REA is consistently observed across genders and it does not depend on handedness (Hugdahl, Carlsson, & Eichele, 2001). Interestingly, patients with schizophrenia exhibit decreased REA (Løberg, Jørgensen, & Hugdahl, 2004). Sommer et al. (2001) documented that healthy parents of children with schizophrenia also examine a decreased REA. Furthermore, SZ patients with more pronounced positive symptoms show even further decreased REA when compared with SZ patients with primarily negative symptoms (Hugdahl, Løberg, & Nygård, 2009a).

Early research on AVHs utilized dichotic listening to assess the lateralization of language. Language lateralization has been theorized to be an important avenue into a better understanding of AVHs as atypical language lateralization may be an important aetiological factor in developing schizophrenia. Interestingly, SZ was even labelled as a left hemisphere disorder (Aase et al., 2018). Therefore, lateralization is likely associated with AVHs. Ocklenburg et al. (2013) conducted a meta-analysis on dichotic listening, language lateralization and AVHs. The meta-analysis compared healthy controls with SZ patients without AVHs. In addition, healthy controls and SZ patients with AVHs were meta-analytically contrasted. In the latter analysis, SZ patients showed weaker lateralization when compared to controls (Hedge's g = -0.26). However, effect size increased when comparing SZ patients with AVHs to healthy controls (g = -0.45), suggesting even further reduced language lateralization.

4.3.1 Forced-attention dichotic listening

Dichotic listening is a perceptually driven task assessing mostly bottom-up processes. To measure the effects of top-down processing DL paradigm must be extended. Therefore, forced-attention dichotic listening might be used which is constructed to involve both top-down processing that is instruction driven and bottom-up processes that are stimulus driven (Hugdahl, 2009). The forced-attention DL presents the syllables stimuli in three blocks, each with different instructions. Participants need to either pay attention to the stimulus presented in the right ear (*forced-right condition*, FR) or to the left ear (*forced-left condition*, FL). The last block is without a specific instruction (*non-forced condition*, NF). The non-forced condition naturally leads to REA. On the other hand, the forced-left condition involves a conflict between bottom-up and top-down processes. While bottom-up processes naturally lead to the REA, the top-down processes are required in the FL condition to override perceptually drive REA effect. In this way, the FL condition contrasts FR condition where the bottom-up and the top-down processes function synergically (Hugdahl, 2009).

The forced-attention DL should elicit three distinct cognitive processes – perceptual processes (NF), attention processes (FR) and inhibitory control processes (FL). While non-clinical voice-hearers might have only a bottom-up impairment they should perform normally in the FL condition, but poorly NF condition. However, clinical voice-hearers should exhibit impaired performance both in the FL and the NF condition. Therefore, the forced-attention

DL paradigm represents a useful paradigm to study the effects of both bottom-up and top-down processes on AVHs (Hugdahl, 2009).

Individuals with schizophrenia demonstrate impaired performance in top-down cognitive control when compared to healthy controls (Rund et al., 2006). Compromised cognitive inhibition is a likely explanation as to why patients fail at the FL condition, but not in the FR condition. This assumption is further supported by neuroimaging findings. Healthy individuals show activation prefrontal areas and anterior cingulate cortex when involved in task design to involve cognitive inhibition. In contrast, SZ patients engaged in the forced-attention DL fail to exhibit similar activation (Hugadahl et al., 2009b; Thomsen et al. 2004). Moreover, Hugdahl et al. (2009b) report that when a healthy control group is instructed to focus attention on the right ear, the REA significantly increases. On the other hand, when attention must be focused on the left ear stimuli, the REA significantly decreases. This effect, however, was not observed in SZ patients, they demonstrated an inability to modulate their attention. Furthermore, voice-hearers are not the only group that should perform worse in the FL condition. Decreased performance in the FL condition might be expected amongst the elderly. Hugdahl et al. (2009b) examined this hypothesis comparing two groups of participants (ages 20-30 and ages 60-89), while both groups showed no difference in the FR and the NF condition – they differed in the FL condition.

Forced-attention DL paradigm allows testing hypotheses of the perceptual model about neurological underpinnings of hearing voices. Hugdahl (2009) theorized that hallucination arise within a cortical network of peri-Sylvian regions (the sensory area responsible for speech perception), prefrontal cortex (underlying top-down inhibitory control) and parietal cortex (associated with attention). Furthermore, Hugdahl et al. (2009b) theorize that healthy individuals should show a temporal lobe deficit, but not a prefrontal deficit. In their turn, clinical voice-hearers should show a deficit in both areas.

5. Trauma and hallucinatory experiences

An important development over the decades has been changing the assumption that hallucinations are merely a symptom of severe psychopathology devoid of any meaning. Rather, hallucinations have been acknowledged as a likely meaningful experience often intertwined with early trauma (Romme & Escher, 1993). Ever since this theoretical and empirical shift, proneness to hallucinations has been researched in relation to trauma and abuse. Studies on traumatic events and psychotic symptoms documented an increased rate of anomalous perceptual experiences amongst individuals with a history of abuse or traumatic experiences (Read et al., 2005). Luhrmann et al. (2019) note that there is often an implicit assumption surrounding the causal role between trauma and hallucinations. To this extent, different theoretical explanations have been put forward to explain this relationship.

In the existing literature, generally, three theoretical models of how trauma impacts hallucinations have been described. First, trauma might affect the content of 'voices'. Second, trauma might represent a biological or psychological trigger for hallucinations. Third, dissociation resulting from a traumatic event might contribute to the origin of hallucinations (Luhrmann et al., 2019). Covering the first model is outside the scope of this thesis. While briefly addressing it, the manuscript will hereafter refer to the second two models; for a detailed review of the first model see Bentall and Fernyhough (2008) or Luhrmann et al., (2019).

Some of the first studies documented the impact of traumatic experiences on hallucination came from a group of female incest survivors who have reported hallucinations across different modalities, but most reports clustered around auditory verbal hallucinations (Ellenson, 1986). Furthermore, Romme and Escher (1989) observed that 70% of individuals experienced AVHs following a traumatic event. Read et al. (2005) observed that individuals who experienced childhood sexual abuse (CSA) or childhood physical abuse (CPA) have earlier first admissions, are hospitalized more frequently and for longer time periods, receive more medication, are more likely to self-mutilate or attempt suicide and have higher global symptom severity. Furthermore, reports show that 30-50% of patients with psychopathology report CSA or CPA and up to 56% of first admitted individuals with psychosis experienced CSA (Morrison, Frame, & Larkin, 2003). However, CSA or CPA are not the only traumatic experiences linked to experiencing hallucinations. A set of environmental factors contribute to psychosis, such as social adversity (van Os, Kenis, & Rutten, 2010), unwanted pregnancies (Myhrman et al., 1996), or early parent separation (Morgan et al., 2007).

Moreover, the association between early trauma and auditory verbal hallucinations demonstrates the strongest association between physical and sexual abuse both in clinical and non-clinical voice-hearers (Daalman et al., 2012). Furthermore, Varese et al. (2012b) analyzed the effects of specific childhood traumas and discovered that effectively all types of childhood adversity are associated with an increased risk of psychosis. This is consistent with early data suggesting that early trauma effectively doubles the risk of hallucinations (Whitfield et al., 2005).

Even though the relationship between child abuse and AVHs seems to hold for both clinical and non-clinical individuals (Andrew et al. 2008), individuals with a clinical diagnosis report more distressing and malevolent voices. On the other hand, non-clinical individuals have more benevolent, less stressful voices (Daalman et al., 2012). Phenomenological characteristics of voices might be affected by the severity of trauma (McCarthy-Jones, 2011).

To summarize, child abuse is a significant, causal factor in many mental disorders, particularly depression, anxiety, personality and dissociative disorders, post-traumatic stress disorder as well as suicidality (Read et al., 2005). Moreover, a role of childhood trauma is especially pronounced in association to psychosis, this association has been well documented and replicated (Bebbington et al., 2011; Bentall et al., 2012; Shevlin et al., 2007). Furthermore, the methods used to examine a possible relationship between childhood trauma and hallucinatory experiences, often being various scales rely on answers to questions about childhood adverse experiences in retrospection. However, patients with psychosis proved to have accurate reports of childhood trauma when compared to reports of siblings, furthermore, their reports are stable over time and unaffected by presence or absence of symptoms (Fisher et al., 2011).

5.1 Atypical brain changes and source-monitoring deficits

Additional insights are likely to come from a recently founded discipline of developmental traumatology (Crozier et al., 2011) studying the neurobiological impact of trauma on child development (McCarthy-Jones, 2011). Many of the structural brain changes resulting from childhood trauma (changes in the anterior cingulate cortex or superior temporal gyrus volume) resemble changes that have been observed when studying brain anomalies and aberrant activity in individuals experiencing AVHs (Allen et al., 2008). Daalman et al.'s (2012) findings suggest that childhood trauma makes the brain more vulnerable to AVHs. Thus, childhood adversity is likely to be related to the presence of AVHs in general. These and other atypical cerebral changes are likely interfering with the normal functioning of cognitive mechanisms associated such as self-monitoring and source-monitoring that are documented to be significant in the production of hallucinations (McCarthy-Jones, 2011).

Childhood trauma, particularly CSA was hypothesized to lead to impaired source monitoring process that discriminates between internal and external cognitive events (Bentall & Fernyhough, 2008). This assumption was supported by Varese et al. (2012a) who compared hallucinating clinical patients as well as remitted hallucinating patients and non-hallucinating patients on the signal detection task. Their findings reveal an impaired source monitoring in both hallucinating and remitted patients.

McCarthy-Jones (2011) further argues that source-memory errors have been theorized to be associated with the amount of cognitive effort required as the cognitive events low in the cognitive effort (internally generated cognitions) are more likely to be misattributed to an external source (Johnson et al., 1993). This assumption might be supported by research on intrusive memories following CSA (Hammersley et al., 2003). These memories are automatically and periodically protruding into the consciousness of CSA survivors, particularly with little to no cognitive effort required. This provides more theoretical grounding for source monitoring approach to AVHs.

5.2 Dissociative processes and cognitive inhibition

Dissociative processes represent another theoretical approach to connecting hallucinations with traumatic experiences. To this point, Moskowitz and Corstens (2007) argued that the association between psychotic symptoms and trauma might be due to dissociative processes. Dissociation is defined as ‘lack of normal integration of thoughts, feelings and experiences into the stream of consciousness and memory' (Bernstein & Putnam, 1986 in Varese et al., 2012a).

Among patients with psychosis, exposure to traumatic experiences correlated with increased dissociative tendencies when compared to patients without reported traumatic events (Dorahy et al. 2009; Perona-Garcelan et al. 2010). Furthermore, dissociative tendencies have been linked to hallucinations more so than to other psychotic symptoms (Kilcommons & Morrison, 2005). Moreover, dissociation predicted preservation of hallucinations in a longitudinal study on adolescents experiencing AVHs (Escher et al., 2002).

Recently, Varese, Barkus and Bentall (2012a) examined the association between dissociation and cognitive mechanisms underlying hallucinatory experiences. They observed a mediation between past trauma and AVHs, particularly in the case of CSA. Cognitive inhibition is a mechanism through which dissociation likely affects hallucinations. The role of cognitive inhibition is well established in hallucination research (Hugdahl, 2009; Waters et al., 2006). On the basis of empirical findings, Varese et al. (2012a) propose a 'two-hit' model of AVHs. First, impaired source monitoring presents a vulnerability to psychosis that likely predates the onset of hallucinations. Second, increased dissociation (due to previous traumatic experiences) triggers the onset of psychosis.

6. Personality traits associated with hallucinations

Stable differences in personality among SZ patients are well documented and these changes likely predate the onset of SZ (Lysaker & Taylor, 2007). Particularly, an important set of traits linked to proneness to AVHs is *schizotypy* (Davidson et al., 2016). Schizotypy in healthy individuals shows similar features that are observed in schizophrenia patients (Everett & Linscott, 2015). Ordinarily, schizotypy traits include hallucinatory or other positive symptoms and negative symptoms like social or affective difficulties (Davidson et al., 2016). These traits can be present at a clinical level and indicate a schizotypal personality disorder. However, set of schizotypy traits is not exclusive to SZ spectrum disorders as their increase has been documented amongst individuals on the autistic spectrum (Dinsdale et al., 2013). Generally, the presence of schizotypy at non-clinical levels accounts for variability in social and personal functioning (Davidson et al., 2016).

Some personality traits have been linked to proneness to hallucinatory experiences and phenomenological characteristics of AVHs, such as neuroticism (Larøi et al., 2005). Psychotic individuals with increased levels of neuroticism are more likely to experience hallucinations (Bell et al., 2011). Moreover, epidemiological studies show that individuals with high neuroticism have an increased chance of experiencing psychosis, which might suggest that neuroticism represents a factor making individuals more vulnerable towards psychosis (van Os et al., 2001). Similarly, SZ individuals with high neuroticism seem to experience more severe positive symptoms (Lysaker & Taylor, 2007).

So et al. (2016) examined the association between AVHs, trauma and neuroticism. Non-clinical voice-hearers scoring high on neuroticism are likely to respond to voices in a similar manner as patients with psychosis even though in an attenuated way. Moreover, there seems to be an association between levels of neuroticism and distress experienced during hallucinatory experiences. Neuroticism is likely affected by developmental and environmental factors. In particular, trauma might underlie the development of neuroticism and hallucination proneness. Therefore, trauma might not only lead to increased emotional reactivity, but also to a sense of uncontrollability which is a prominent phenomenological feature of AVHs (So et al., 2016). Besides neuroticism, other interpersonal factors have been implicated as significant in the SZ population experiencing AVHs, namely extraversion (Lysaker & Taylor, 2007) and increased levels of depression have been linked to hallucinatory experiences (Sorrell et al., 2010).

More studies opt to study individuals who are prone to AVHs. To assess hallucination proneness self-report scales are often used, these instruments are also used in the psychosis continuum research (Bell et al., 2011). This thesis will use the Cardiff Anomalous Perception Scale (CAPS) as well as the Launay-Slade Hallucination Scale – Extended (LSHS-E) to assess hallucination proneness in the general population. Both CAPS and LSHS-E include other psychological constructs associated with hallucinations besides AVHs like daydreaming, intrusive thoughts and different modalities in which individuals might have hallucinatory experiences (Waters et al., 2012). These instruments will be described in more detail in the empirical section of the thesis.

Empirical section

7. Research aims

The present empirical section is associated with research that was conducted within a large international collaboration coordinated by the International Consortium on Hallucination Research (ICHR) and National Institute of Mental Health (Národní ústav duševního zdraví; NÚDZ). Purpose of the research was two-fold.

First, to address variability in methodological findings on mechanisms associated with proneness to auditory hallucinations. The theoretical section explored available evidence on different mechanisms underlying AVHs. To briefly summarize, AVHs studies linked hallucinations and hallucination proneness to impairments in source monitoring, verbal working memory as well as atypical changes in language lateralisation and cognitive inhibition. To this extent, each cognitive mechanism was assessed with a standardized experimental measure and compared with a self-report measure of hallucination proneness.

Second, even though all of the mechanisms have been well researched, academic research on the topic has been inconclusive. Furthermore, effects differ in clinical and non-clinical groups. Even though some of the mechanisms have been supported by meta-analytic evidence (particularly source monitoring deficits; Brookwell et al., 2013; Waters et al., 2012), these results proved inconsistent as the recent studies examining non-clinical voice-hearers failed to replicate some of the previously reported associations (Alderson-Day et al., 2019; Garrison et al., 2017). These conflicting results are likely due to the variability in methodologies used in the hallucination research. A notable measurement plurality exists in the assessment of cognitive processes and in the measurement of hallucination proneness. Therefore, to address methodological variability in the current scientific literature, a centralized test battery was constructed.

The test battery consists of:

- Source memory task,
- Dichotic listening task,
- Backward digit span,
- Matrix reasoning
- Signal detection task,
- Adverse Childhood Experiences Scale
- Cardiff Anomalous Perceptions Scale

- Launay-Slade Hallucination Scale - Extended
- Depression Anxiety and Stress Scale
- Schizotypal Personality Questionnaire

8. Hypotheses

Following hypotheses were constructed around different cognitive mechanisms elaborated on in the theoretical section. Hypotheses aim to explore the association between a cognitive mechanism and proneness to hallucinatory experiences in the non-clinical, student sample:

- Hypothesis 1 - Source monitoring: In the source memory task, number of externalization-type errors (imagined words incorrectly recalled as heard) will be positively associated with hallucinations.

- Hypothesis 2 - Dichotic listening: In the dichotic listening task, first, the number of correct right ear responses in the non-forced condition will be negatively associated with hallucinations (2.1). Second, the number of correct left ear responses in the forced-left condition will be negatively associated with hallucinations (2.2).

- Hypothesis 3 - Verbal working memory: Verbal working memory performance measuring by the backwards digit span will be negatively associated with hallucinations.

- Hypothesis 4 - Signal detection: False alarms on the auditory signal detection task will be positively associated with hallucinations (4.1). Moreover, response bias will be negatively associated with hallucinations (4.2).

- Hypothesis 5 - Adverse childhood experiences: Higher score on the Adverse Childhood Experiences Scale will be positively associated with hallucinations.

For the specific context of the present research questions and hypotheses, a quantitative methodology and experimental design were used. Complete design of the ICHR included two separate forms of the study – a laboratory study and online study. No online data was collected in the Czech Republic, and the present thesis focused only on a laboratory study.

9. Ethics and reproducibility

Ethics approval was secured by the National Institute of Mental Health (NÚDZ). Experiment posed no obvious risks to the participants. Each participant was briefed on the nature of the experiment and on the fact, that they can stop the experiment at any moment. Moreover, participants were informed that there are some questions addressing early traumatic experiences and that they might feel free to skip them if it causes them any distress. Additionally, participants were informed that all data would be anonymized and used only for research purposes with no possible way to identify them. Finally, participants signed a printed consent form.

9.1 Reproducibility

To avoid questionable research practices the entire study was preregistered on Open Science Framework (https://osf.io/cyu6j) with complete analysis plan and exclusion criteria. All participants' data would be disregarded if a participant fails two out of two attention checks (e.g.: '*Have you ever had a fatal heart attack when watching television?*').

For each task, exclusion criteria were introduced to filter for participants who did not perform on the task adequately; exclusion criteria were designed to measure either hearing deficits or fluctuations in attention. Exclusion details for each task will be described in the section bellow.

10. Methods

10.1 Procedure

Participants were tested in a quiet room with a laptop and a pair of headphones for tasks that contained auditory stimuli. The whole experiment and every measure was computerized and took approximately 65 minutes to finish. The experiment commenced with the headphone check and followed with dichotic listening, source memory task, matrix reasoning, backwards digit span, and auditory signal detection task. Next, participants were presented with several questionnaires.

Author of this thesis was responsible for back-translating all tasks and scales, furthermore, for qualitative assessment with NÚDZ research group and quantitative testing of the experiment to assure valid adaptation of each measure to the Czech environment. The experiment was piloted on ten participants who were not included in the main sample. Furthermore, the author of the thesis collected all data as well as analysed them. Every significant step decision was collaborated on and supervised by a research group involving a psychologist and a psychiatrist in the NÚDZ.

10.2 Source memory task

Source memory task (SMT) presents participants with words either through headphones (*hear trials*) or on the screen with a simple instruction to 'read the words in their mind' (*imagine trials*). The SMT task consisted of two sections.

In the first section, participants were presented with words in the centre of the screen for 3 seconds, each word stimuli preceded either instruction 'HEAR' („POSLOUCHEJTE") or instruction 'IMAGINE' („PŘEČTĚTE SI V DUCHU") for the duration of 1 second. During each 'hear' trial when participant heard a word (in a neutral male voice), the word was also presented in the centre of the screen. During the imagine sequence, a word was presented on the screen in the same manner, but no recording was played. The second section of the SMT immediately followed the first part. Participants were presented with all of the previously encountered words (48 in total) in random order together with 24 new words. For each word presented in the second part of the task, participants needed to decide whether the word was read to them, if they imagined reading it or whether the word is new.

The main variable related to hallucination proneness was the number of words which participants misjudged as heard even though the word was only read in their own minds (*other-to-self misattribution errors*). In this manner, *externalizing bias* – a tendency to misjudge internal cognitive events to external sources was assessed.

Participants' data from the SMT would be excluded if he or she has 100% of correct responses, less than 33% correct responses or if the participant does not perform above 50% in recognizing the new items from the items there were actually in the task.

10.3 Auditory signal detection task

During the auditory signal detection task (SDT) participants decided whether they believed a speech was present in a recording of static noise. Participants were presented with 72 recordings of noise lasting for 3.5 seconds. In 36 trials speech was present (male voice in a neutral tone) leaving the other 36 trials with no speech. Each trial was followed by a question whether the participant heard a voice in the recording.

The variable of interest was the *false alarm rate* which represents a number of trials identified as 'voice present' even though the voice was absent. Additionally, *response bias* which might be operationalized as another measure of externalizing bias represents another variable of interest. Generally, hallucination prone individuals who would hear a recording of static noise would be more likely to think that a voice recording was present (*false alarms)*. Moreover, individuals with decreased response bias tend to label ambiguous stimuli as external in origin (*response bias*).

Lastly, *perceptual sensitivity* representing the accuracy of participants' hearing was calculated and used as an exclusion criterion for the SDT task. Moreover, participants were excluded if they made 100% correct responses or less than 10% of correct responses.

10.4 Dichotic listening

The dichotic listening task (DL) assesses both language 46iased46ization and cognitive inhibition and attentional control. Participants are simultaneously presented with two clips containing different syllables in each ear. Six consonant-vowel syllables were used, particularly 'ba', 'da', 'ka', 'ta', 'pa' and 'ga'. Each clip was presented for 350ms.

During the DL, instructions change to elicit different cognitive processes (covered in more detail in the theoretical section). In the non-forced condition, participants were instructed to pick the syllable that they heard most clearly. However, in the forced-right and forced-left conditions participants were instructed to select the syllable they believe was presented to the ear they should have attended to. Each condition had 36 trials, and additional 6 trials were presented to the participant where the same syllable was presented to both ears to serve as a check of perceptual quality.

Two variables were of particular interest. First, the performance in the non-forced condition was calculated as the number of correct responses in the right ear; in this manner, bottom-up cognition and language lateralization are assessed. The second variable focuses on the number of correctly identified syllables in the left ear in the forced left condition, this serves as a measure of cognitive inhibition.

Data from this task were excluded if a participant had less than 20% of correct responses or if a participant had a *laterality index* of 100% to the right or left ear. Laterality index indicates whether a participant has the tendency to be 47iased towards one ear in the non-forced condition. Thus, the laterality index of 100% would indicate that the participant responded on all trials with syllables presented to either the right or the left ear.

10.5 Backwards digit span

The backwards digit span assesses working memory performance. During each trial, the participant sees a numeric digits string and then recalls presented digits in reverse order. Digits range from 1 to 9 and they were randomly sampled and presented in the centre of the screen for the duration of 1 second. Participants started at 2 digits and the number of digits increased by 1 each time a digit string was recalled correctly. Similarly, two successive incorrect responses lead to a decrease in length by 1 digit. In total, each participant completed 14 trials.

The primary variable is the participant's mean span. Furthermore, the mean span was used to exclude participants from the task if they had mean lower or equal to 3 or higher or equal to 12.

10.6 Matrix reasoning

Matrix reasoning is a task assessing participants' non-verbal reasoning ability. Participants will be presented with ten 3x3 grids of shapes and choose one missing element from six options within 60 seconds. The non-verbal reasoning was measured as a raw number of correct responses. Participant's data will be excluded from this task if their mean response time is lower than 8 seconds.

10.7. Questionnaires

10.7.1 Adverse Childhood Experiences Scale

Adverse Childhood Experiences Scale or ACES is a scale developed to assess childhood adverse experiences, including early trauma (Felitti et al., 1998). ACES has 17 items with closed 'Yes'/'No' responses. A total sum of the 'Yes' responses represents the level of traumatic experiences ranging from 0 to 17. Items included a range of traumatic experiences, for example: '*While you were growing up in the first 18 years of life, did a parent or other adult in the household often or very often hit you so hard that you had marks or were injured?*', '*While you were growing up in the first 18 years of life, did an adult or person at least 5 years older ever attempt oral, anal, or vaginal intercourse with you?*', or '*Was your mother sometimes, often, or very often pushed, grabbed, slapped, or had something thrown at* *her?*' for the full list of items see Appendix I which will include all questionnaires used in this study.

10.7.2 Cardiff Anomalous Perceptions Scale

Cardiff Anomalous Perception Scale or CAPS is a scale designed to be a comprehensive self-report measure that captures a range of perceptual anomalies across different sensory modalities including five senses, proprioception, somatosensory and body distortion, time perception and perceptual intensity. Furthermore, CAPS items were constructed with reports from psychiatric and neurological literature (Bell et al., 2011).

CAPS is used as the primary assessment of the hallucination proneness with 32 items with 'Yes' and 'No' options; e.g.: '*Do you ever hear your own thoughts repeated or echoed?*', '*Do you ever hear your own thoughts spoken aloud in your head, so that someone near might be able to hear them?*' or '*Have you ever heard two or more unexplained voices talking with each other?*'.

The main variable of interest in this study is the total number of 'Yes' responses ranging from 0 to 32, with higher scores indicating increased hallucination proneness.

10.7.3 Launay-Slade Hallucination Scale – Extended

Launay-Slade Hallucination Scale or LSHS-E was included for a secondary assessment of hallucination proneness as the LSHS-E is well established in studying AVHs in the non-clinical groups (Larøi, Marczewski, & Van der Linden, 2004a).

LSHS-E consists of 16 items and participants are asked to respond on a 5-point Likert scale (0 = 'Certainly does not apply to me', 4 = 'Certainly applies to me'). The main variable is the overall score is the sum of each item ranging from 0 to 64. For example, items might look like: '*In the past I have had the experience of hearing a person's voice and then found that there was no-one there.*', '*I have been troubled by hearing voices in my head.*' Or '*I often hear a voice speaking my thoughts aloud.*'.

10.8 Additional measures

These measures will not be used in the main analysis and thus are not related to any of the hypotheses. However, the following measures were included in the test battery and they were adapted to the Czech environment. Moreover, additional measures might provide insight into the exploratory analysis section as they represent and assess constructs well linked to the hallucination research.

10.8.1 Depression Anxiety and Stress Scale

Depression Anxiety and Stress Scale (DASS) has been developed as a measure to maximize discriminant validity in a single measure assessing these three different psychological constructs. The scale consists of 42 items in total, each construct is assessed by 14 items and participants are asked to respond on a 5-point Likert scale (0 = 'Did not apply to me at all', 4 = 'Applied to me very much'). The present thesis uses shortened version DASS-21 with 21 items, 7 per each scale (Gloster et al., 2008).

10.8.2 Schizotypal Personality Questionnaire

Schizotypal Personality Questionnaire or SPQ is a self-report measure assessing schizotypy. In total, SPQ has 32 items that have Likert-type five-point responses (0 = 'Strongly disagree', 4 = 'Strongly agree') with greater scores indicating increased schizotypy (Davidson et al., 2016).

11. Analysis

To examine a possible association between each hypothesis, the results of the above-described tasks were correlated with the CAPS score, which represents the main measure of hallucination proneness. Similarly, for a secondary assessment of hallucination proneness, LSHS-E was correlated with the participants' performance on the tasks assessing different cognitive mechanisms. Data were checked for normal distribution and due to non-normal distribution, Spearman's correlation coefficient was used. In the demographic section, CAPS score was correlated with measures of alcohol, cigarette, and cannabis consumption as well as a short measure of non-verbal reasoning.

A correlational analysis is a versatile tool, however, it has a somewhat limited inferential ability. Therefore, the present thesis utilizes *equivalence testing* to improve theoretical inferences of the study. Often when a study reports a nonsignificant result the overall conclusion is that no effect is present (Lakens, 2017). Equivalence testing compares observed effects (correlations) to s*mallest effect size of interest* represented by two *equivalence bounds* (lower and upper). Next, equivalence testing uses classical *null hypothesis significance testing* (NHST) to compare each equivalence bound to zero. The null hypothesis states that the observed effect (correlation) within the equivalence bounds is practically indistinguishable from zero; thus, if a *p-value* of less than 0.05 is observed, the tested effect is likely to be equivalent to zero within the equivalence bounds. The present thesis followed Laken's (2017) TOST ('two one-sided tests') procedure for equivalence testing and used the 'TOSTER' R package for the analysis. Symmetrical equivalence bounds were constructed around r = -0.3 and 0.3 representing a moderate effect size; this decision is further elaborated on in the next section. Equivalence testing was calculated only for the primary measure of hallucination proneness (CAPS). In general, equivalence testing was included to support theoretical inferences which might be drawn from the present study together with good research practices (power calculation, preregistered exclusion criteria), standardized measures and laboratory data collection.

Furthermore, the analysis included an assessment of the basic psychometric properties of the adapted measures – CAPS and LSHS-E. These measures have not been standardized in the Czech environment. CAPS has dichotomous responses, therefore, the Kuder-Richardson formula (KR-20) was used to calculate the reliability of the scale; for the LSHS-E Cronbach's alpha was used. Content validity of CAPS and LSHS-E was qualitatively deliberated on within the research team prior to double-translating these scales as well as after their translation.

Moreover, additional exploratory analyses were conducted on the collected dataset. Namely, a correlation between anxiety and SDT performance was measured to reflect the possible relationship between anxiety (*perceptual hypervigilance*) and SDT performance. Furthermore, the correlation between SMT and SDT performance was measured as both tasks have been hypothesized to be linked to the same underlying process. Last, schizotypy was correlated with CAPS to examine whether CAPS might measure other constructs that are associated with hallucination proneness like schizotypy but which are not of particular interest in the present thesis.

12. Sample

The present study collected data on 52 participants. Participants were recruited through the participants' pool with the help of the Prague Laboratory for Experimental and Social Sciences. Data collection proceeded from 11.11. to 19.12. 2018.

Student samples can often be problematic in the context of psychological research. However, the present study opted to examine non-clinical populations among which the student sub-population has particular importance in hallucination research. In Western countries, up to 70% of students experienced a hallucinatory experience at least once (Tien, 1991). Therefore, studying hallucination proneness in the student sample represents an interesting avenue into a better understanding of hallucination proneness on the continuum model of psychosis. Moreover, beyond the scope of this thesis, a larger dataset was collected which achieved representativity by including an online version of the same experimental design where only the signal detection task was not present. The laboratory part of the study lasted on average over an hour and participants could not be financially compensated. Furthermore, power calculation estimated the lowest number of participants at $N \geq 40$; given the laboratory nature of data collection and time-intensive administration without compensation, the student population has been deemed as fitting for this particular research context.

To account for the specific nature of the student sample, higher bounds had been set for the equivalence testing $r = -0.3$ and 0.3 as moderate effects should be observed given the higher prevalence of hallucinatory experiences in the student population. In comparison, the international study with a more representative sample set equivalence bounds at $r = -0.1$ and 0.1.

Collected sample ($N = 52$) consisted of 43 women, 8 men and 1 person who identified as other. Mean age was 21.9 years with the standard deviation of 6.3 years. In total, 80 participants were scheduled, however, only 52 attended. Most participants self-reported average SES on the scale from 1 to 5, $M = 3.2$ $SD = 0.5$. Of total 52 participants, 48 were university students. However, the remaining 4 participants were high school students who planned to apply for university. Out of 52 participants, 8 reported (4%) having a diagnosed psychiatric disorder. Those who disclosed their condition were diagnosed with borderline personality disorder ($N = 1$), depression ($N = 2$) and panic disorder ($N = 1$) and with not closely specified ‘anxiety’ ($N = 2$).

Participants were asked to indicate their alcohol, cigarette and cannabis use. On a scale from 0 – 4. Participants reported average alcohol use $M = 1.7$ with $SD = 0.9$, *range* = 0 – 3; On the same scale participant reported average cannabis use $M = 0.5$ with $SD = 0.9$; *range* 0 – 4. Lastly, participants were asked to indicate how many cigarettes they smoke in a day; the vast majority of participants were non-smokers (85%) with an average of smoked cigarettes per day M = 0.33 with SD = 0.9.

13. Results

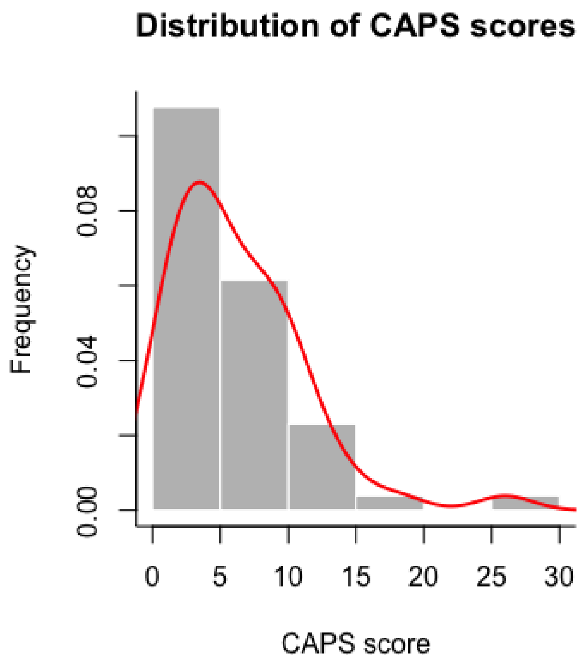
13.1 Measuring hallucination proneness

13.1.1 CAPS

Collected sample scored on average M = 6.2 on the CAPS scale (M*dn* = 5; SD = 4.9). CAPS scores were highly positively skewed (*skewness* = 1.55) and leptokurtic (*kurtosis* = 3.94). Majority of participants reported relatively few hallucinatory experiences, however, a smaller proportion of participants reported a larger number of hallucination-like experiences (*range* = 0 – 26; maximum possible score = 32).

Using Kuder-Richardson formula 20 (KR-20) internal consistency of CAPS was assessed. The reliability was measured at r = 0.83. Together with qualitative assessment for content validity observed reliability suggests good psychometric properties of the scale. Furthermore, CAPS showed a strong positive correlation with the second measure of hallucination proneness LSHS-E $r_s = 0.68$, $p = 0.01$ and moderate correlation with SPQ cognitive-perceptual subscale $r_s = 0.32$, $p = 0.02$. Even though correlation with the SPQ is not strong, cognitive-perceptual subscale had the largest correlation of other SPQ subscales.

Figure 1: Distribution of scores on the CAPS



CAPS was positively correlated with alcohol use r_s = 0.18, p = 0.19. Furthermore, correlations were calculated for cigarette use r_s = -0.04, p = 0.79 and cannabis consumption r_s = -0.05, p = 0.72. These correlations, however, showed no association with the primary measure of hallucination proneness. No association was observed between psychiatric diagnosis and CAPS score η_p^2 = 0.03, p = 0.21. Similarly, no correlation was observed between CAPS and socio-economic status r_s = 0.06, p = 0.32. However, a small positive correlation was observed between CAPS and brief assessment of non-verbal reasoning abilities measured by the matrix reasoning r_s = 0.20, p = 0.07.

13.1.2 LSHS-E

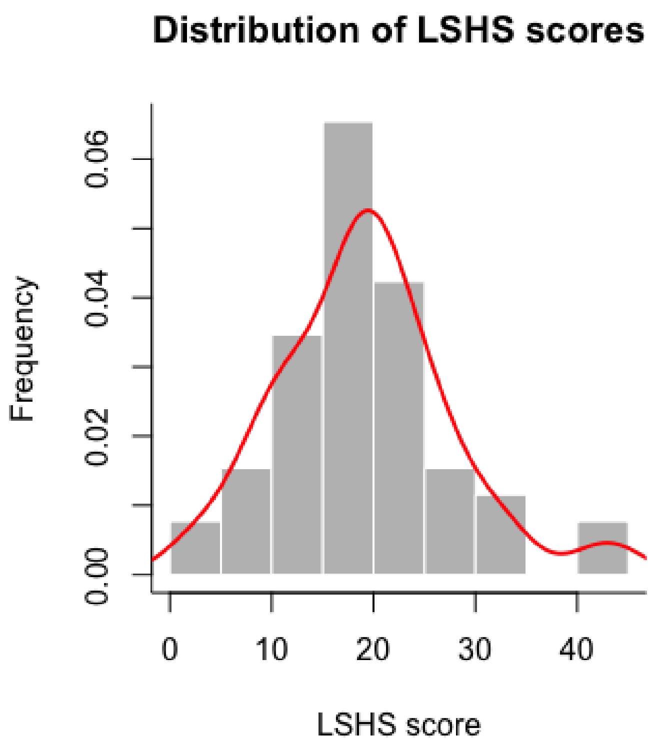
Participants scored on average M = 19.2 on the CAPS scale (M*dn* = 19.5; SD = 8.53). LSHS-E scores were approximately symmetrically distributed with slightly positive skewness (*skewness* = 0.58; *kurtosis* = 1.05). Even though participants reported some experiences of the hallucinatory character, most had relatively few of such experiences with distribution being slightly positively skewed. The peak of the curve still indicates a relatively low number of hallucinatory experiences with short right tail at the end of which another small peak appears, suggesting that very low number of participants self-reported higher number of hallucinatory experiences (*range* = 2 – 44; maximum possible score = 64).

Interestingly, in comparison to CAPS, LSHS-E seems to have higher sensitivity as every participant indicated that they had experienced some hallucinatory experience which was not the case in the CAPS.

Table 1: Reliability of Launay-Slade Hallucination Scale – Extended (LSHS-E)

Scale	*Reliability – Cronbach's alpha*
Overall scale reliability	r = 0.77
Subscale of auditory and visual hallucinatory experiences	r = 0.38
Subscale of vivid daydreams	r = 0.65
Subscale of intrusive thoughts	r = 0.67
Subscale of multisensory experiences	r = 0.50

Figure 2: Distribution of scores on the LSHS-E



13.2 Hypothesis 1: Hallucination proneness and source memory task

For SMT no data were excluded. Thus, N = 52 were included in the analysis. However, no correlation was observed between *imagine-to-hear errors* and CAPS score r_s = -0.03, p = 0.41. Using LSHS-E as the secondary assessment of hallucination proneness also did not show any correlation r_s = 0.03, p = 0.59.

The equivalence testing reported a significant p-value p = 0.03, meaning that within equivalence bounds representing moderate effect size, the observed correlation was practically equivalent to zero.

13.3 Hypothesis 2: Hallucination proneness and dichotic listening

Two participants were excluded due to the 100% laterality index which indicates that they did not differentiate between a stimulus presented to different ears. Thus N = 50 were included in the analysis.

Hypothesis 2.1 predicted a negative correlation between the non-forced condition and CAPS. However, a positive correlation was observed r_s = 0.24, p = 0.96. On the other hand, hypothesis 2.2 predicted a negative correlation between the forced-left condition and CAPS, which was observed r_s = -0.27, p = 0.02. Moreover, equivalence testing rejected the null hypothesis (p = 0.42), which indicates that equivalence testing fails to support the null hypothesis that the observed is equal to zero within the interval of r = -0.3 – 0.3.

These results were also observed when using LSHS-E as a secondary measure. Hypothesis 2.1 showed positive correlation r_s = 0.33, p = 0.99. On the contrary, hypothesis 2.2 resulted in a negative correlation of r_s = -0.15, p = 0.15.

13.4 Hypothesis 3: Hallucination proneness and working memory

No participant was excluded, thus N = 52 were included in the analysis. Due to an association between impaired working memory and hallucinations a negative correlation between the working memory tested by the backwards digit span and CAPS was expected. Results do not support this hypothesis with a positive correlation between the two measures r_s = 0.12, p = 0.80. However, using LSHS-E showed a very weak negative correlation r_s = -0.05, p = 0.35.

The two measures assessing hallucination proneness documented conflicting results, however, the main measure showed a weak positive correlation; the equivalence testing failed to reject the null hypothesis p = 0.06 about equivalence of effect to zero and thus within the interval of moderate effect size an effect between working memory and hallucination proneness likely exists.

13.5 Hypothesis 4: Hallucination proneness and signal detection task

Due to the 100% of correct responses, five participants have been excluded, thus N = 47 was used in the analysis. According to the fourth hypothesis association between CAPS and *false alarm rate* should exist. This association was indeed observed as CAPS score correlated with the false alarm rate r_s = 0.15, p = 0.15.

Moreover, further correlations between CAPS and the two parameters – *perceptual sensitivity* and *response bias* follow theoretical reasoning underlying signal detection theory and hallucinatory experiences. CAPS did not correlate with perceptual sensitivity r_s = -0.03, p = 0.49 supporting the assumption that hallucination prone individuals do not differ in their perceptual systems. On the other hand, a negative correlation was observed between CAPS scores and response bias r_s = -0.21, p = 0.07. Thus, providing evidence for a reduced threshold for response bias.

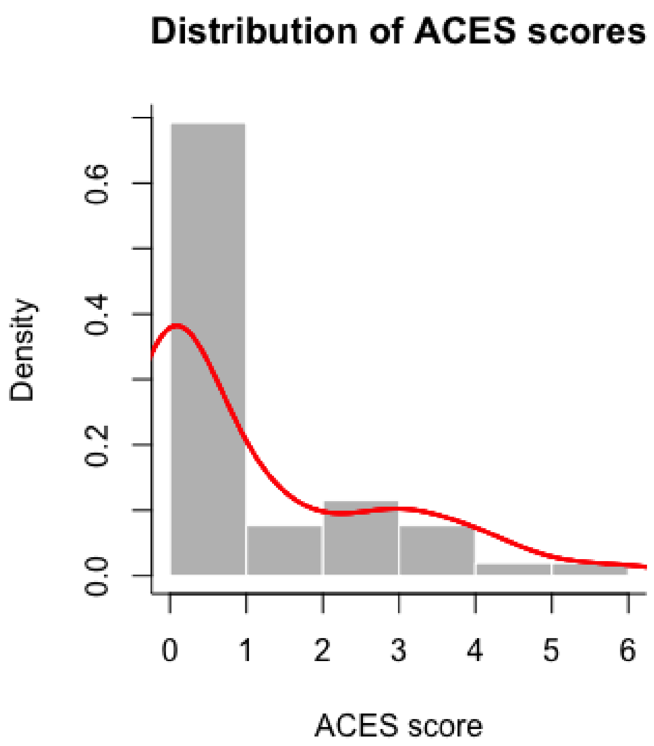
Equivalence testing shows that effects of both response bias $p = 0.26$ and false alarm rate $p = 0.14$ are not equal to zero within the range of moderate effect size. However, significant p-value $p = 0.03$ was observed in the perceptual sensitivity; thus, observed correlation practically equals to zero within the bounds of r = -0.3 – 0.3.

However, LSHS-E did not correlate with any of the measure: false alarms $r_s = -0.008$, $p = 0.52$, response bias $r_s = -0.02$, $p = 0.44$, perceptual sensitivity $r_s = 0.03$, $p = 0.59$.

13.6 Hypothesis 5: Hallucination proneness and traumatic experiences

No participant decided to skip Adverse Childhood Experiences Scale and thus N = 52 were included in the analysis. CAPS positively correlated with ACE score $r_s = 0.30$, $p = 0.01$, showing one of the largest correlations out of all measures. Moreover, equivalence testing rejected the null hypothesis $p = 0.50$ and thus suggested that an effect within the bounds of moderate effect size exists. Moreover, a positive correlation has been between LSHS-E and ACE scores $r_s = 0.23$, $p = 0.05$.

Figure 3: Distribution of scores on ACES



Participants reported on average M = 1.17 score on ACES with SD = 1.61. ACES distribution was highly positively skewed (*skewness* = 1.24) with a median of M*nd* = 0. Furthermore, distribution is leptokurtic (*kurtosis* = 0.58) with a small second peak around score 3.2 (*range* = 0 – 6; maximal possible score = 17). This suggests that a large number of participants did not experience any early adverse experiences. However, a lower proportion of participants experienced a small number of adverse or traumatic experiences; these participants formed a small but visible peak in the ACES score distribution. Lastly, a fraction of the participants reported a moderate level of early adverse and traumatic experiences.

13.7 Comparing results with the ICHR study

The empirical section of this thesis describes results from a laboratory study conducted in the Czech environment. However, as mentioned earlier, this study was conducted on a larger, international scale with additional online data collection. The main ICHR study confirmed two hypotheses. First, hallucination proneness was associated with performance on the SDT, which showed increased false alarm rate and decreased response bias. Second, proneness to hallucinations was associated with an increased number of early traumatic experiences. Both hypotheses were also observed in the present study. Moreover, the ICHR study and the present study failed to link a higher number of imagine-to-hear errors in the SMT to hallucination proneness. Similarly, no correlation was observed between performance on the SDT task, which suggests no perceptual deficits.

However, the present study differs in the performance in the dichotic listening task when compared to the ICHR study. Particularly, a moderate negative correlation was observed between performance in the forced-left condition and the main measure of hallucination proneness; this association indicates that the student population might have more profound impairment in top-down processing as compared to the general population. Additionally, in the non-forced condition moderate correlation was observed between a number of correct right ear responses and hallucination proneness; this finding is contrary to the previous evidence in hallucination research. Ordinarily, a negative correlation is observed between the number of correct right ear responses and hallucination proneness. Furthermore, present correlation also differs from the findings from the ICHR study which found no correlation between the two measures.

Lastly, in the present study, a weak positive correlation was observed between working memory and proneness to hallucinatory experiences. Again, this is contradictory to the expected negative correlation. Moreover, the ICHR study failed to measure any correlation between working memory performance and hallucination proneness.

Table 2: Spearman's correlations between task performance and CAPS

Hypothesis	*Spearman's rho – CAPS Czechia*	*Spearman's rho - CAPS ICHR*
H1: Source monitoring	r_s = -0.03	r_s = 0.02
H2: Dichotic listening H2.1: REA H2.2: FL	 r_s = 0.24 r_s = -0.27	 r_s = 0.006 r_s = 0.02
H3: Working memory	r_s = 0.12	r_s = -0.02
H4: Signal detection False alarm rate Response bias Perceptual sensitivity	 r_s = 0.15 r_s = -0.21 r_s = -0.03	 r_s = 0.14 r_s = -0.17 r_s = -0.05
H5: ACES	r_s = 0.30	r_s = 0.24

Table 3: Spearman's correlations between task performance and LSHS-E

Hypothesis	*Spearman's rho - LSHS-E Czechia*	*Spearman's rho - LSHS-E ICHR*
H1: Source monitoring	r_s = 0.03	r_s = -0.005
H2: Dichotic listening H2.1: REA H2.2: FL	 r_s = 0.33 r_s = -0.15	 r_s = < 0.19 r_s = < 0.19
H3: Working memory	r_s = -0.05	r_s = -0.06
H4: Signal detection False alarm rate Response bias Perceptual sensitivity	 r_s = -0.008 r_s = -0.02 r_s = 0.03	 r_s = 0.12 r_s = -0.12 r_s = -0.10
H5: ACES	r_s = 0.23	r_s = 0.24

14. Exploratory analysis

Collected dataset can be explored beyond the scope of the preregistered analysis plan. In the theoretical section, a few alternative viewpoints have been presented to otherwise 'traditional' understanding of the tasks used in hallucination and psychosis research and in the present thesis.

14.1 Signal detection and perceptual hypervigilance

Dodgson and Gordon (2009) hypothesized that another theoretical explanation might describe the performance of hallucinators and hallucination prone individuals on SDT. Authors emphasize the role of hypervigilance associated with increased levels of anxiety might lead to false perceptions. Authors propose that heightened anxiety leads to a tendency to falsely perceive ambiguous stimuli as present. Thus, DASS anxiety scale was correlated with SDT performance, due to non-normal distribution Spearman's correlation was used. Anxiety is indeed linked to increased false alarms $r_s = 0.24$, $p = 0.04$ and response bias $r_s = -0.32$, $p = 0.01$. Interestingly, a set of traits closely related to schizophrenia – schizotypy did follow the general effect, however, correlations differed in size FA $r_s = 0.06$, $p = 0.32$, SPQ and response bias $r_s = -0.11$, $p = 0.23$. Therefore, increased anxiety might contribute to a pattern of responses that are associated with proneness to hallucinations to a larger extent than other traits traditionally associated with schizotypy and hallucinations. Also, observed correlation was higher than the main primary measure of hallucination proneness.

14.2 Source memory task and signal detection

Source monitoring approaches to AVHs collected some evidence suggesting that performance on the source memory task and on the signal detection task ought to be interconnected as they assess the same underlying mechanisms with different experimental paradigms. However, when comparing participants' performance on the both tasks only a weak correlation was observed $r_s = 0.10$, $p = 0.24$, which might suggest that these mechanisms might not be measuring a unitary construct.

Discussion

Present thesis conducted a laboratory study which examined cognitive processes associated with proneness to auditory hallucinations. Five hypotheses were formulated to test some of the prominent approaches in hallucination research. Namely, cognitive mechanisms that might have a significant influence over proneness to hallucinatory experience in non-clinical populations. The laboratory study conducted as a part of the present thesis supported three out of five hypotheses. However, associated international research supported only two hypotheses. Together, both results provide evidence in support of the involvement of top-down processing and cognitive inhibition in the hallucination proneness. On the other hand, tasks assessing bottom-up and perceptual processes failed to show any meaningful interconnection with hallucination proneness. Furthermore, both the Czech and the international (ICHR) studies found an association between early traumatic experiences and elevated hallucination proneness. The following paragraphs discuss findings from the present study, compare them to results from the international study as well as put them into a broader context of the previous scientific findings from the field. Finally, the results are further discussed in the context of psychosis continuum models and reproducibility of hallucination research.

Two results from the present thesis contribute to evidence linking hallucination proneness to impaired top-down processing. First, individuals prone to hallucinatory experiences exhibited an increased number of false perceptions on the auditory signal detection task. Similarly, their performance on the SDT was associated with a lowered threshold for decision criteria involved in the source monitoring; these decision criteria represent top-down processing within source monitoring. Thus, observed results support previous evidence documenting bias in source monitoring (Barkus et al., 2007, 2011; Bentall and Slade, 1985; Bentall et al., 1991). Second, individuals with increased hallucination proneness performed worse on the forced-left condition in the dichotic listening task; this condition was operationalized to elicit top-down inhibitory control. Therefore, worse performance on the FL condition in the DL further supports findings that showed impaired top-down control in hallucination prone individuals. In general, observed results in this thesis contribute to previous evidence on the involvement of top-down cognitive processing in hallucinatory experiences (de Boer et al., 2019; Powers et al., 2016). Furthermore, this thesis contributes to the research literature linking dichotic listening and hallucinatory experiences in non-clinical populations (Hugdahl, 2009; Hugdahl et al., 2009; Badcock and Hugdahl, 2014).

Finally, observing a significant association between an increased number of traumatic experiences and hallucination proneness might further contribute to the body of evidence connecting top-down processing and hallucinations as traumatic experiences have been proposed to influence hallucinations and hallucination proneness via top-down processing, mainly through cognitive inhibition (Varese et al., 2012a). Besides the effects of top-down processing, traumatic experiences showed one of the largest correlations in both national and international study. This is consistent with the previous findings described in the theoretical section. The association between hallucination proneness and traumatic experiences represents an important avenue to a better understanding of the aetiology underlying hallucinatory experiences. This comes largely due to the fact that the association is not only well established in the clinical samples, but also in the non-clinical samples.

Even though both the present study and the ICHR study confirmed some of the findings relating to the role of top-down processing, both studies failed to observe any association between aberrant bottom-up processing and hallucination proneness. First, dichotic listening failed to show any association between decreased right ear advantage and hallucination proneness. Generally, a decrease in the number of right ear responses indicates an impairment in bottom-up processing and atypical language lateralization (Hugdahl, 2009). Furthermore, decreased right ear advantage has been observed in clinical samples, particularly in schizophrenia patients as well as in healthy parents of patients with schizophrenia (Sommer et al., 2001). Nonetheless, contrary to meta-analytical evidence (Ocklenburg et al., 2013) no impairment in the right ear advantage was observed in the ICHR study. Moreover, in the present study, a moderate positive correlation was observed between the number of correct right ear responses and hallucination proneness. This is unanticipated finding contradicting prior research on the topic. This might be caused by an absence of standardized stimuli (consonant-vowel syllables recordings) for the dichotic listening task in the Czech Republic; to authors' best knowledge, no such standardization exists. Therefore, a few different syllable stimuli were tested. Although the default stimuli were standardized in the anglophone countries the English version proved to be hardly recognizable in the Czech context due to different pronunciation of syllables. After additional testing French stimuli were used, which sounded closest to the Czech pronunciation. This might have confounded the present study and led to an unexpected finding which shows a positive correlation between hallucination proneness and correct number of right ear responses in spite of existing research literature documenting exactly the opposite effect.

Additionally, bottom-up processing was assessed by a perceptual sensitivity parameter on the signal detection task. Both the present laboratory study and the main ICHR study observed no effect between perceptual sensitivity and hallucination proneness. Moreover, equivalence testing failed to distinguish observed correlation from zero in the bounds of moderate effect size. In all, the present findings offer additional evidence from the non-clinical student population for approaches which emphasize the role of perceptual deficits and impairments in the bottom-up processing in the origin of hallucinations.

Next, the present study addressed source monitoring in relation to hallucination proneness. Previous studies linked source monitoring deficits to auditory hallucinations in clinical and non-clinical groups (Larøi et al., 2004b; Woodward et al., 2007). However, the present study and the ICHR study both failed to observe any association between performance on the source memory task and hallucination proneness. These results are in line with some of the recent findings by Alderson-Day et al. (2019) or Garrison et al. (2017) who failed to document source monitoring impairments in non-clinical samples. Moreover, source monitoring has been theorized to account for performance on the source memory task and on the signal detection task as they are supposed to share the same underlying mechanism. Notwithstanding, a weak correlation was observed between performance on the source memory task and signal detection task. This might suggest that the two tasks, in fact, might not share the same mechanism. Alternatively, performance on both tasks might be correlated in the clinical sample, and uncorrelated in the non-clinical sample as the independence of the two measures might vary with the severity of hallucinations. Regardless, no association between the source monitoring deficits in a large international study and no interconnection between the two measures in the present study might prompt a reexamination of the paradigm that conceptualizes and operationalizes source monitoring, especially because deficits in source monitoring have been previously confirmed by meta-analysis (Brookwell et al., 2013).

Lastly, this thesis examined the role of working memory on hallucination proneness. In the main ICHR study, no correlation between working memory and hallucination proneness was found. However, the present study documented a weak positive correlation indicating that hallucination proneness might be associated with better working memory performance. This finding has no support in the existing literature. Considering that the ICHR study with a larger sample better approximating the general population observed no effect, this might suggest that the weak positive relationship might be due to the characteristics of the student sample used in the present study. It stands to reason that student populations might have increased working memory performance as compared to the general population and therefore introduce an artefact into the measurement. Similarly, positive correlation was observed between hallucination proneness and better performance on a non-verbal reasoning task. Therefore, students likely represent a specific group on the continuum model of voice-hearing which might present with increased levels of working memory when compared to other groups who might hear voices or have other hallucinatory experiences. Arguably, these differences might highlight the importance of the studies examining various non-clinical groups of voice-hearers.

To extend on the differences in non-clinical voice-hearers, the present study suggests that hallucination proneness in the student population might be associated with further decreased top-down inhibitory control. When compared to the ICHR study, students showed a more profound impairment in top-down processing as the present study observed a negative correlation between performance on forced-left condition in dichotic listening and the ICHR study did not. This might be due to a larger prevalence of hallucinatory experiences in student samples which have been recorded to be double that of the general population. Moreover, the ICHR study observed association only between traumatic experiences and performance on the SDT, therefore, other effects examined by the study like impaired working memory or reduced right ear advantage as well as deficits in source monitoring measured by the SMT might be a clinically relevant sign of hallucinatory experiences. Consequently, these processes would not show any atypical changes in the general population. Moreover, these differences between student sub-population and the general population provide some evidence for the continual models of psychosis.

Nonetheless, the variability in the experimental findings might not only be seen as evidence for continuum models of hallucinations. Alternatively, present findings might indicate a problem in the reproducibility of hallucination research as all five hypotheses have been previously linked to hallucination proneness in non-clinical samples. Subsequently, studies previously documenting deficits in source memory, working memory and reduced right ear advantage might be poorly reproducible. The present research and particularly the international study by ICHR addressed possible reproducibility issues in hallucination research by conducting a large scale international study as well as preregistering all analysis plans and exclusion criteria to avoid questionable research practices.

Finally, limitations of this thesis need to be addressed. First, hallucination proneness was assessed by scales which include multiple modalities. Even though hallucinations have been reported across different sensory modalities in non-clinical hallucinators, this experimental procedure constructed a test battery that primarily examined the auditory domain of hallucinatory experiences. Furthermore, the LSHS-E subscale assessing both visual and auditory hallucinations together showed lowest internal consistency between items. This might also be a reason as to why the two measures of hallucination proneness yielded somewhat inconsistent results. Also, in the present sample LSHS-E measured some hallucinatory experiences in every participant. This was not the case with CAPS, which had highly positively skewed distribution of scores suggesting that most participants had no hallucinatory experiences. This might be due to translations or due to differences between dichotomous and Likert-type responses. Alternatively, differences in both measures might be due to fatigue as LSHS-E was second after CAPS, which might have 'primed' the participants for more positive responses. In fact, participants might have been depleted prior to questionnaire section, since by that time they, on average, had to complete approximately 50 minutes of experimental tasks. Hence the temporal order of the questionnaires could have interfered with participant's answers.

Another possible limitation of the present study is the lack of the standardization of different experimental tasks used in the study. Even though the tasks were carefully tested and translated to fit the Czech environment the collected data on the dichotic listening task suggests that there were limitations present. Lastly, the present study had limited demographic information. Due to the extensive experimental manipulation, not many demographic questions were included. Limiting nature of this decision became more apparent after data collection. Demographic data were mostly centered around standard variables that might affect hallucination proneness such as low socioeconomic status, cannabis or alcohol use. However, more detailed questions could have been added. For example, it would be interesting to compare students with different levels of finished education.

Conclusion

The present thesis set out to examine various mechanisms that have been theorized to play a significant role in hallucination proneness in non-clinical populations. To address methodological variability in hallucination research, the present thesis adapted a unified testing battery comprising of established and standardized methods. This novel approach aimed to shed light on the previous body of evidence that has been burdened by inconsistent results. In addition, this thesis was conducted as a part of a large international collaboration. This allowed to not only to provide novel findings, but also to further the field for a better, reproducible science rooted in good research practices.

Unique contribution of the thesis is documentation of differences between different sub-groups of non-clinical hallucinators. However, data from the present thesis convey much more information in addition to data collected on 11 different sites across the world. In this manner, present thesis contributed to addressing the variability in findings in the field of hallucination research. On the international scale, only two out of five hypotheses were supported, this might serve as an insight to reexamine the way hallucinations and hallucination proneness are operationalized, studied and ultimately conceptualized.

Furthermore, this thesis contributes to hallucination research in the Czech Republic as the methods adapted for the present thesis follow some of the most influential experimental paradigms. Moreover, present work might be elaborated on. Particularly, questionnaire measures and their double-translations ought to be further tested and more data needs to be collected to possibly standardize these measures in the national settings.

Lastly, the present thesis and other quantitative design studies might serve as empirical basis for qualitative studies examining differences in phenomenological characteristics between different groups of hallucinators in both clinical and non-clinical populations. Qualitative studies exploring phenomenology of hallucinations are relatively scarce and much needed. Lack of phenomenological accounts was beyond the scope of the present thesis, but better understandings of experiences in different groups might provide great insight into the hallucination field.

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