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VIRTUAL SUPERMARKET SHOPPING TASK FOR COGNITIVE REHABILITATION AND ASSESSMENT OF PSYCHIATRIC PATIENTS: VALIDATION IN CHRONIC SCHIZOPHRENIA

ADÉLA PLECHATÁ[1,2], LUKÁŠ HEJTMÁNEK[1,2], IVETA FAJNEROVÁ[1]

[1] National Institute of Mental Health, Klecany, Czechia
[2] Third Faculty of Medicine, Charles University, Prague, Czechia

ABSTRACT

Objectives. Schizophrenia has a debilitating impact on patient's cognitive functioning and everyday activities. As a part of the treatment, schizophrenia patients attend sessions of cognitive remediation to restore impaired cognitive abilities. To combine cognitive and real life training, this study presents a virtual task to use in cognitive rehabilitation and assessment. Virtual Supermarket Shopping Task (VSST) simulates a shopping activity, in which participants have to memorize and collect items from a virtual supermarket. The aim of this study is to establish its validity for use in clinical practice.

Sample and setting. Twenty patients suffering from chronic schizophrenia and twenty healthy controls were tested. Each participant completed the task and a battery of standard neuropsychological tests.

Statistical analyses. Groups' results were compared by Student's t-tests. Validity of VSST was examined using correlations with standard neuropsychological measures. Several VSST metrics, such as trial difficulty, distances and times, and the effect the extraneous variables have on VSST measures were investigated using analyses of variance and mixed effect models.

Results. The analyses demonstrate that patients perform worse in VSST than healthy controls and their performance corresponds to their mnemonic abilities measured by standard neuropsychological tests. VSST performance relates to the level of executive functioning only in patients. There was no effect of gaming experience on VSST performance. While potential gender effect has to be addressed in future studies, age seems to play a role in the additional VSST measures (trial time and distance).

Study limitations. Subjects were tested only once and therefore long term benefits of using VSST in rehabilitation could not be investigated. Only schizophrenia patients were included in the sample, which reduces generalizability of results to other psychiatric and neurologic conditions.

key words:
virtual reality,
memory deficit,
schizophrenia,
cognitive remediation,
validity

klíčová slova:
virtuální realita,
paměťový deficit,
schizofrenie,
kognitivní remediace,
validita

INTRODUCTION

Schizophrenia (SZ) is a disabling chronic psychiatric illness, which affects approximately 1% of the world population. Besides well-known positive (e.g. hallucinations and delusions) and negative symptoms (such as social withdrawal, abulia or apathy),

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Submitted: 26. 2. 2020; A. P., National Institute of Mental Health, Topolová 748, 250 67 Klecany; e-mail: adela.plechata@nudz.cz

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cognitive deficits represent an important part of schizophrenia psychopathology. The impairment is distributed across all cognitive domains, with the most profound deficit in processing speed, executive functioning and memory functions, especially in episodic memory (Dickinson et al., 2007; Fioravanti et al., 2012; Mesholam-Gately et al., 2009). Processing speed decline can further influence memory deficit through its impact on a rehearsal loop (Brébion et al., 2000).

Impairment in neurocognition and social cognition further aggravate SZ patients functioning and quality of life (Bowie et al., 2008; Green et al., 2004). The cognitive deficit in combination with negative symptomatology leads to difficulties in activities of daily living (ADL), e.g. food preparation, handling of finances or shopping (Samuel et al., 2018). Pharmacotherapy can significantly reduce positive symptomatology, but has only limited influence on cognitive abilities. So far pharmacotherapy for cognitive enhancement in SZ patients resulted mostly in rather weak effects (Harvey & Bowie, 2012; Sinkeviciute et al., 2018).

Currently, cognitive remediation is the method of choice for the cognitive deficit intervention. Computerized cognitive remediation in addition to paper-pencil approaches enables precise repetition of the stimuli, recording participant's performance and automatically adapting the task difficulty. Nevertheless, many computer tasks and paper-pencil methods used in cognitive assessment or rehabilitation predominantly focus on isolated cognitive domains, e.g. verbal working memory, attention shifting or inhibition in executive functions. This approach, although essential in diagnostics, can prevent patients from transferring the learned abilities into real-life (Karbach & Verhaeghen, 2014). Standard neuropsychological methods are therefore criticized for their low ecological validity (Neisser, 1978; Parsons, 2015) and their separation from real-life functioning.

Recently, virtual environment (VE) and virtual reality (VR) have found their place in cognitive neuroscience and psychiatry (Hejtmánek & Fajnerová, 2019; Parsons, 2015). VE enables recreating complex real-life situations while preserving laboratory conditions and control over presented stimuli (Parsons, 2015). Moreover, VE can be used as environment enrichment (Kempermann et al., 2002), which can increase cognitive enhancement effects (Clemenson & Stark, 2015; La Corte et al., 2019). VE enables patients to train everyday activities and improve their cognitive functions in a safe and controlled environment. According to previous studies, the opportunity to practice the cognitive skills learned during cognitive remediation enhances SZ patients' everyday functioning (Medalia & Saperstein, 2013). VE enables patients to practice their skills using ADL simulation in a safe environment and represent a suitable tool which can enhance the transfer of learned skills to real life (Rizzo et al., 2004).

Although immersive VR presented using head-mounted displays (HMD) is currently very popular in rehabilitation, it has a few drawbacks, such as cybersickness, challenging development or a high cost. Using immersive VR during patient's acute psychotic episodes could also be problematic and patients' safety should be always taken into consideration (Valmaggia, 2017). Moreover, the results from immersive VR can be influenced by sensory overload or increased cognitive load (Frederiksen et al., 2020; Makransky et al., 2019). In contrast, VE presented on a monitor screen with traditional controls (keyboard, mouse, potentially joystick or gamepad) allow us to simulate complex environments and tasks without the potential drawbacks of HMDs and seem more suitable for cognitive assessment and rehabilitation.

AIMS

The primary aim of this study is to validate a rehabilitation and assessment tool focused on cognitive deficits reported in SZ patients. We developed a task in which participants are asked to remember and later collect a list of items from a virtual supermarket (Virtual Supermarket Shopping Task, VSST). The task was inspired by standard neuropsychological tests assessing declarative memory using words list (e.g. Rey, 1964), and by the concept of the ADL demonstrated to be impaired in SZ patients (Samuel et al., 2018).

Based on previous research (Plechatá et al., 2017), we propose that VSST requires a multitude of cognitive skills - declarative and working memory to remember the items, executive functions and semantic memory for item categorization, and navigational and planning skills for route planning and self orientation. However, due to this complexity, the task is not aiming to address individual cognitive processes and is not meant to replace standard diagnostic methods.

To assess VSST's construct validity using convergent and divergent validity approach (Corriveau Lecavalier et al., 2018; Ouellet et al., 2018; Parsons & Rizzo, 2008), we administered it to schizophrenia patients and healthy participants along with a battery of standard neuropsychological tests.

We expect significantly lower VSST performance in SZ patients in comparison to healthy participants and the differences between the groups to be more pronounced with the task's increasing difficulty. We hypothesize that participant's VSST performance will correlate with their memory performance in standard cognitive tests, but due to its multifacetedness we also expect to find relationships with other cognitive measures.

MATERIALS AND METHODS

Participants

We tested a total of 40 participants, 20 patients suffering from chronic schizophrenia (F20.X), and 20 healthy participants paired to the experimental group according to their age, gender and education level. One patient was excluded because of an unfinished protocol. Our final sample had 15 female participants (8 healthy, 7 patients) and 24 male participants (12 healthy, 12 patients). Given the matched pairs design, there was no age difference between the groups ($M = 34.74$ ($SD = 10.23$), $t(36.97) = 0.19$, $p = .851$).

Sample inclusion criteria

All patients have been diagnosed with schizophrenia according to ICD-10 standard symptom criteria of F20.X (World Health Organization, 2004) and chronic schizophrenia was defined as lasting longer than 18 months (Ellison-Wright et al., 2008). We recruited patients from several institutions: NIMH Czech Republic, Psychiatric hospital Kosmonosy and Daily center for psychotic patients in Karvina.

Participants did not suffer from any other psychiatric disease, nor serious somatic or neurological disease which would prevent participation in the study, and they had no history of serious injury or head surgery. Participants had no prior knowledge of the cognitive tests used. Age range was 18-55 years. All participants signed an informed consent. The study was approved by the ethics committee of the NIMH in Klecany.

Study procedure

Prior to the experiment, we collected participants' basic demographic characteristics (age, education etc.) and inquired about their gaming experience (yes/no). All participants underwent clinical and cognitive evaluation and completed the experimental task (VSST).

Virtual Supermarket Shopping Task (VSST)

Task description

Virtual Supermarket Shopping task (VSST) is a simulation of a shopping activity which takes place in a small scale supermarket (29 x 50 meters) (for more details see Plechata et al., 2019). The supermarket layout is modeled so that products are placed as they would be in a real store, e.g. fruits and vegetables together, cleaning supplies together etc. (see Image 1). The task was developed using Unity3D game engine (Unity Technologies, n.d.).

Image 1 Part A (top). Overview of VSST environment layout. Part B (bottom). Participant`s first person view, while collecting an item. Please note that the name of the product is visible after pointing at it. The already collected (shopped) items are visible in the shopping bag in the right bottom corner. The images are in black and white due to the journal requirements.

VSST consists of several trials of increasing difficulty, with each trial having two phases: ***acquisition phase*** and a ***recall phase***.

During the ***acquisition phase***, the participant is moved to the supermarket lobby and is asked to remember a series of items (shopping list), which is presented as a written list on the monitor. The number of items varies based on trial difficulty and the learning time limit is set to 5 s per item (i.e., 15 s for three items; 25 s for five items; etc.). When the time runs out, the administrator can introduce a pause and assign a distractor activity. The idea is to simulate a real life situation of planning the shopping trip prior to the supermarket visit and allows for testing of a delayed, rather than immediate recall.

During the ***recall phase***, the participant walks around the virtual supermarket and collects items. Any items, not just those on the shopping list, can be collected and it is possible for an item to be collected multiple times. Items are visually recognizable and their names show up when directly looked at from a short distance to prevent potential confusion (e.g. cream vs mayonnaise, shampoo vs deodorant). The ***recall phase*** has no time limit and ends when the participant walks to the cashier and confirms the decision to finish.

After completing the ***recall phase***, the participant is shown his or her results (number of errors, trial time, and trial distance) and proceeds to the next trial's ***acquisition phase***. For more details on VSST task see (Plechatá et al., 2017; Plechatá et al., 2019).

VSST procedure

VSST was administered on a 17" laptop. Participants controlled the task with mouse and keyboard. The movement velocity was constant. Before the test started, each participant explored the VE until they became familiar with its control system and the supermarket's spatial layout (maximum of 240 s). Participants then completed 4 consecutive trials of VSST with increasing difficulty (three, five, seven, and nine items on the shopping list). Participants were instructed to try to solve the trials as fast (short trial time) and as effectively as possible (low trial distance). Between the ***acquisition*** and the ***recall phases***, participants were administered cognitive tests and questionnaires for approximately three minutes as a distraction task.

VSST Measures

VSST has multiple measures of performance:

- number of correctly collected items (or inversely missing items);
- number of *extra items* (items which participant collected but which were not on a list);
- trial time (how long did the participant take to finish the trial);
- trial distance (how long was the distance the participant walked during the trial).

As the number of items to be collected is related to the number of potential mistakes (e.g. forgetting one item out of three is arguably a worse mistake than one out of nine), we decided to evaluate trial's *item performance* as the ratio between the number of items which were correctly collected and the number of items which should have been collected (3, 5, 7 or 9). This measure was used as a primary parameter addressing recall accuracy in the task, while the other less specific variables were analysed as additional measures.

VSST task variants

To allow for repeated assessment in clinical practice, we created two shopping list variants (A and B list) for each difficulty level. Each participant completed only a single randomly assigned VSST variant (healthy subjects 12A, 8B; patients 12A, 7B). We compared the metrics of interest in both variants using two tailed t-tests and found no significant difference in *item performance* ($t(127.38) = -0.78$, $p = .440$), trial time ($t(128.11) = 0.00$, $p > .999$), or trial distance ($t(148.82) = 1.70$, $p = .091$). We therefore analysed both variants together.

Cognitive evaluation

All participants were evaluated with standard neuropsychological measures to assess their declarative memory, learning abilities, sustained attention, psychomotor speed and executive control.

Rey Auditory Verbal Learning Test (RAVLT) is a standard measure of episodic memory and verbal learning. The participant is asked to remember and recall a list of 15 words which is repeated five times. Delayed recall (RAVLT delayed) is performed after 20-30 minutes (Preiss, 1999; Rey, 1964). RAVLT is a test which has similar rationale as VSST and was chosen as the gold standard for the convergent validity of VSST.

Logical Memory I, II (LM) is a subtest of Wechsler Memory Scale III for episodic memory assessment (Wechsler, 2002). The participant is asked to remember a story, recall it immediately and again after 30 minutes (LM delayed). LM test in contrast to RAVLT measures the ability to remember logically organized material that is repeated once (story A) or twice (story B).

Trail Making Test (TMT) is used to measure psychomotor speed, attention and mental flexibility (Preiss & Preiss, 2006; Reitan & Wolfson, 1985). The level of psychomotor speed (TMT A) can influence the performance in VSST as the higher psychomotor speed can result in more repetitions during the ***acquisition phase*** list reading. The derived difference score (the difference B-A) indicates the level of executive control (Sánchez-Cubillo et al., 2009)

PEBL Continuous performance task (PCPT) is a vigilance test from PEBL test battery (Mueller & Piper, 2014). The PCPT allows us to assess participant's sustained attention. Moreover, the *detectability* measure, indicating the ability to differentiate between signal and noise, was used for divergent validity as it has no direct relationship to performance measured in VSST.

Clinical rating scales

We evaluated the patient's severity of symptoms to address the influence of their mental state on cognitive functioning. While patients with SZ can be in a stabilized state during the remission phase, their cognitive performance can be altered during the relapse episodes (Brissos et al., 2011; Stratta & Rossi, 2013) therefore their symptomatology needs to be evaluated. Moreover, the level of negative symptomatology (e.g. abulia) can play a critical role in cognitive performance (Bezdicek et al., 2020; Ventura et al., 2009).

Positive and Negative Syndrome Scale (PANSS) is a standardized interview to assess positive and negative symptoms and general psychopathology in SZ patients (Kay et al., 1987). PANSS was administered only to the SZ patients.

Beck Depression Inventory (BDI-II) is a self-report questionnaire measuring the severity of depression (Beck et al., 1961).

Beck Anxiety Inventory (BAI) is a self-report questionnaire measuring the severity of anxiety (Beck et al., 1988).

Global Assessment of Functioning (GAF) is a 100-point scale measuring illness severity of daily life functioning (Hall, 1995).

RESULTS

The statistical analysis was performed using statistical software R version 3.6.0 (R Core Team, 2017). We used *ggplot2* package for graphs (Wickham, 2009) and *lmerTest* (Kuznetsova et al., 2017) package for mixed effect modeling. Pearson correlation coefficients with standard neuropsychological measures were used to assess convergent and divergent validity (Corriveau Lecavalier et al., 2018; Nir-Hadad et al., 2017; Ouellet et al., 2018; Parsons & Rizzo, 2008).

Outlier removal

Four trials (in three participants) which did not record properly and one outlier trial which took more than 10 minutes to finish (average time of trials was M = 173.79 (SD = 106.92) seconds) were removed, leading to 151 trials in total.

Evaluation of VSST measures and group comparisons

Our first aim was to evaluate the VSST measures and their alterations in the SZ group to select task difficulties to focus on. As we expected, the *item performance* differences between groups became more apparent with increasing difficulty. Mixed effect model with group and difficulty as fixed factors and participant as a random factor showed that the task difficulty had an impact on *item performance* ($b = -0.07$, 95% CI [-0.09, -0.05], $t(92.1) = -7.35$, $p < .001$), as well as did the interaction between the experimental group and the trial difficulty (steeper performance decline in patients, $b = -0.04$, 95% CI [-0.07, -0.02], $t(92.77) = -3.21$, $p = 0.002$, see Figure 1). This suggests that what best differentiates healthy participants from patients is the rate of *item performance* decline with the increasing difficulty, rather than overall performance. We found no difference in VSST measures between patients and healthy subjects in

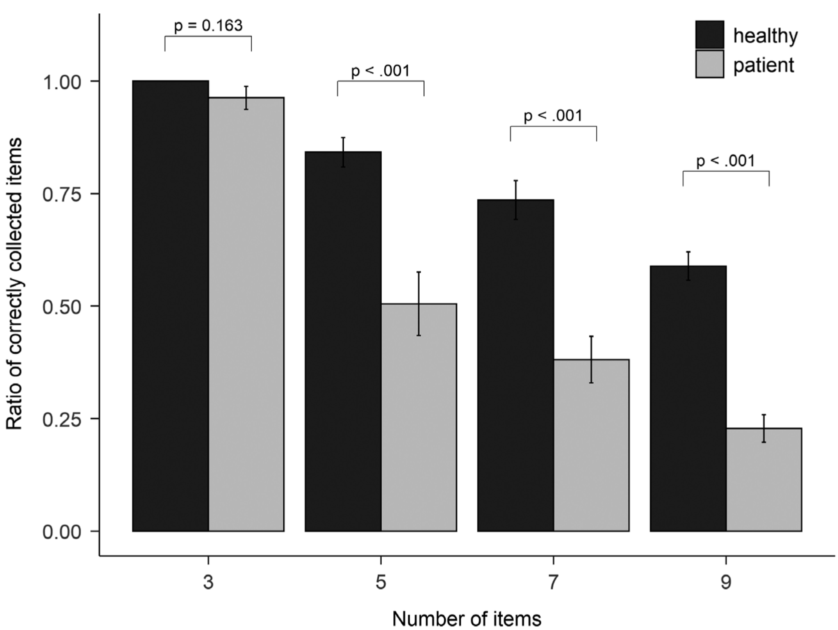

Figure 1 Average item performance (ratio of correctly collected items) with SEM error bars for all VSST trials at increasing difficulties (number of items) split by group. Groups were compared at each difficulty using two-sample t-tests.

the lowest difficulty (3 items). At this difficulty level, groups didn't differ in the number of correctly collected items (t(17) = 1.46, p = .163), extra items collected (t(34.76) = −0.04, p = .970), nor trial distance (t(28.82) = −0.56, p = .578), although they differed in trial time (t(22.75) = −2.59, p = .016).

Running the same mixed model but predicting the *extra items,* we have found an increased number of *extra items* being picked up with increasing difficulty (b = 0.19, 95% CI [0.09, 0.29], t(93.22) = 3.69, p < .001), but no group by difficulty interaction (b = 0.07, 95% CI [-0.08, 0.22], t(93.72) = 0.94, p = 0.35).

To study the effects of difficulty on item collection more closely, we fitted a linear regression separately for patients and controls to model the total number of collected items (correct items + *extra items*) as a function of difficulty. We observed a significant increase of number of items collected in healthy controls (b = 0.55, 95% CI [0.46, 0.65], t(76)=11.70, p < .001) but not in SZ patients (b = 0.12, 95% CI [−0.03, 0.27], t(71) = 1.64, p = .105). This suggests that patients were collecting approximately 3 items in each trial regardless of difficulty (i.e. number of items on the list) (see Figure 2).

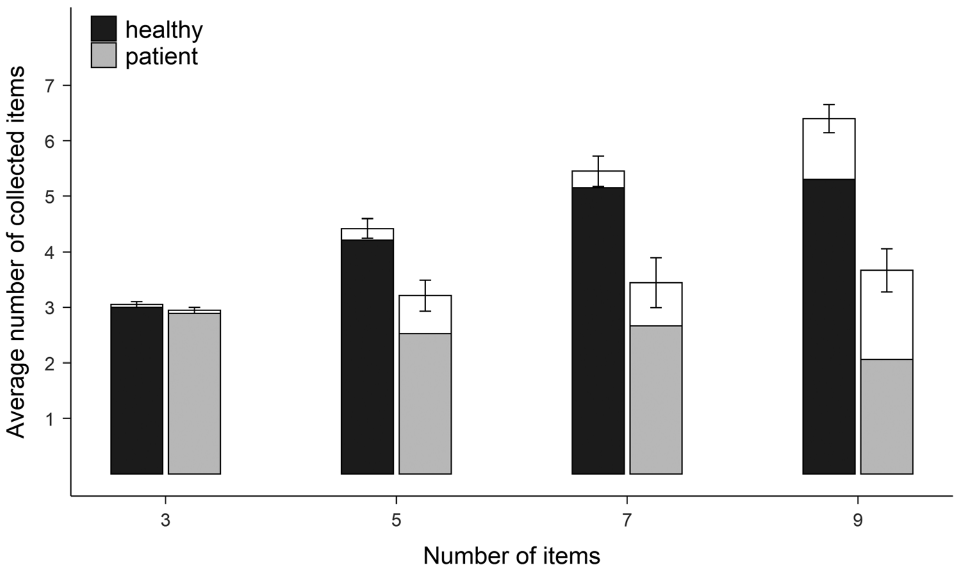

Figure 2 Average number of all collected items (correct + extra) separated by groups and shaded by the item type. The darker section on the bottom represents correct items and the lighter section on top represents extra items. Error bars represent SEM of the total.

VSST distance and time

Using a mixed effect models we modelled the trial distance as a function of a task difficulty and group as fixed effects and participant as a random effect and found a significant effect of task difficulty (b = 17.54, 95% CI [8.76, 26.31], t(92.97) = 3.92, p < .001) and the interaction between task difficulty and group (b = -14.51, 95% CI [-27.45, -1.57], t(93.39) = -2.2, p = 0.03), suggesting increase of travelled distances with increasing number of items. But comparing trial distances between groups at each difficulty using t-tests, we found no differences except at the highest difficulty (t(29.74) = 3.20, p = .003).

Modelling the distance as a function of time and group with participant as a random effect, we found a significant effect of time (b = 1.06, 95% CI [0.83, 1.29], t(104.23) =

= 9.13, $p < .001$) and group by time interaction ($b = −0.71$, 95% CI [-0.99, -0.44], $t(109.75) = −5.07$, $p < .001$), but no group effect ($b = 60.7$, 95% CI [-9.46, 130.86], $t(69.83) = 1.7$, $p = 0.094$). In other terms, for healthy subjects the distance increased more steeply as a function of time than for patients, as can be seen in Figure 3. Note that patients overall walked shorter distances and spent less time shopping, although only trial distance significantly differed from healthy controls (see Table 1).

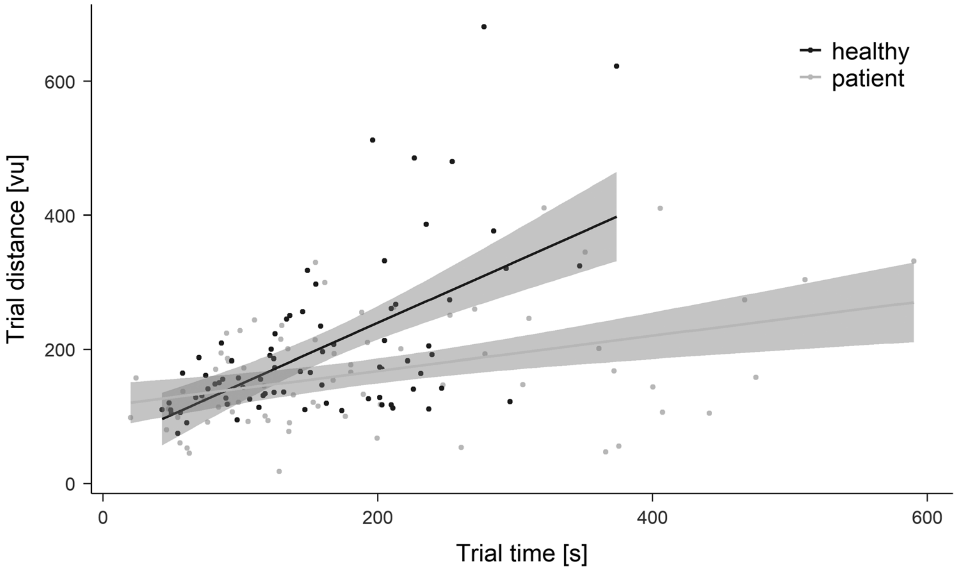

Figure 3 Scatter plot of trial distance (in virtual units) and trial time (in seconds) split by group. Grey areas represent 95% confidence interval of fitted linear regression slope.

Neuropsychological evaluation

The results of neuropsychological tests can be found in Table 1. As expected, groups differed in all analysed cognitive measures and clinical scales.

VSST convergent and divergent validity

As VSST differentiates groups better with increasing difficulty, and groups' performance often did not differ in lower difficulties, we decided to focus solely on the performance from the two most difficult trials (7 and 9 items) to reduce the possibility of false negatives. Although other metrics also demonstrate differences between the groups, we decided to further discuss and analyse the *item performance* as the best and most consistent measure of participant's performance.

We assessed the convergent and divergent validity of VSST *item performance* by obtaining Pearson correlation coefficient against neuropsychological measures. We did so for the average of the two most difficult trials (e.g. 7 and 9 items). The correlation coefficients can be found in Table 2.

We can pinpoint several important findings. Firstly, the moderate correlations with both standard memory tests for both patients and healthy controls indicate that VSST performance is representative of mnemonic functions in both groups. TMT difference score, evaluating executive control and mental flexibility, correlates moderately with

Table 1 Descriptive data of neuropsychological assessment, psychiatric scales and VSST assessment (reported for the two most difficult trials) and group comparisons

	Measure	Healthy group mean (SD)	Patient group mean (SD)	t.value	p.value	cohen.d
VSST measures	Item performance	0.66(0.18)	0.31(0.19)	8.274	< .001	1.907
	Trial time	189.47(73.90)	171.84(118.14)	0.769	0.445	0.181
	Trial distance	224.68(116.76)	160.57(77.02)	2.851	0.006	0.641
Neuropsychological measures	RAVLT delayed	9.95(2.63)	5.42(3.01)	5.001	< .001	1.608
	BAI	5.60(5.27)	12.21(8.30)	-2.949	0.006	-0.955
	BDI	3.00(2.56)	9.58(6.54)	-4.101	< .001	-1.339
	GAF	100.00(0)	66.84(17.97)	8.044	< .001	2.646
	PANSS positive scale	_	11.78(3.52)	_	_	_
	PANSS negative scale	_	16.06(6.67)	_	_	_
	PANSS general psychopathology	_	29.33(6.15)	_	_	_
	LM delayed	27.75(7.21)	15.16(8.18)	5.089	< .001	1.636
	PCPT Detectability d’	2.35(0.72)	0.65(2.34)	2.868	0.01	0.984
	TMT A time	24.20(7.31)	52.26(26.01)	-4.535	< .001	-1.486
	TMT difference score	48.60(28.04)	100.39(64.32)	-3.229	0.004	-1.053

The reported VSST measures were calculated as an average performance in the two most difficult trials (7 and 9 items to remember).

Legend: RAVLT (Rey Auditory Verbal Learning Test) delayed recall, LM (Logical Memory) delayed recall, PCPT – PEBL Continuous Performance Task, TMT (Trail Making Test) difference – TMT B and TMT A time difference, BDI – Beck Depression Inventory, BAI – Beck Anxiety Inventory, GAF – Global Assessment of Functioning.

VSST performance only in the patient group, but the p-value was not sufficient after correction for multiple comparisons.

The PCPT Detectability d’ evaluates the subject’s ability to discriminate visual stimuli (target vs. non-target). Although we observed differences between the groups (see Table 1), there was no association with VSST performance.

We didn’t observe any significant correlations of VSST performance and measures of mental state. Neither PANSS subscale scores, nor GAF correlate significantly with the *item performance*. However, correlations with PANSS negative scale and GAF score are moderate and we address them more in the Discussion.

Gender, age and gaming experience

We investigated the effect of gender and group and their interaction on average *item performance* in the two most difficult trials using ANOVA and found a significant effect of gender ($F(1,35) = 6.91$, $MSE = 0.02$, $p = .013$, $\eta^2G = .165$), with female participant performing better ($M = 0.57$, $SD = 0.27$) then male participants ($M = 0.44$, $SD = 0.24$). No gender by group interaction ($F(1, 35) = 0.04$, $MSE = 0.02$, $p = .834$, $\eta^2G = .001$) was identified. We address this later in the Discussion.

Table 2 Correlation of VSST item performance (average for 7 and 9 items) and neuropsychological measures split by group

test/correlation	healthy	patient
Convergent validity		
RAVLT delayed	r = 0.63, p = 0.003*	r = 0.61, p = 0.005*
LM delayed	r = 0.48, p = 0.031	r = 0.74, p < .001*
TMT A time	r = − 0.12, p = 0.617	r = − 0.11, p = 0.667
TMT difference score (B-A)	r = − 0.16, p = 0.489	r = − 0.46, p = 0.046
Divergent validity		
PCPT Detectability d’	r = 0.08, p = 0.768	r = 0.11, p = 0.18
Mental status		
PANSS negative scale	–	r = − 0.41, p = 0.088
PANSS positive scale	–	r = − 0.09, p = 0.732
PANSS general psychopathology	–	r = - 0.23, p = 0.367
GAF	–	r = 0.42, p = 0.077

Legend: RAVLT (Rey Auditory Verbal Learning Test) delayed recall, LM (Logical Memory) delayed recall, PEBL CPT - PEBL Continuous Performance Task, TMT (Trail Making Test) difference B-A - TMT B and TMT A time difference, PANSS - Positive and Negative Syndrome Scale, GAF - Global Assessment of Functioning. After applying Bonferroni correction on multiple comparisons in each section we set the alpha to 0.0125. Asterisk symbol marks statistically significant correlations at this level.

We then used ANOVA to compare *item performance* as a function of gaming experience and group. We didn’t observe any effect of gaming experience ($F(1,35) = 1.07$, $MSE = 0.03$, $p = .308$, $\eta^2G = .030$) nor group by gaming experience interaction ($F(1,35) = 0.27$, $MSE = 0.03$, $p = .608$, $\eta^2G = .008$).

Using a linear regression to model *item performance* as function of age, we didn’t find any effect ($b = 0.00$, 95% CI [−0.01, 0.01], $t(37) = −0.39$, $p = .698$), although we did find an effect of age on trial time ($b = 3.94$, 95% CI [1.42, 6.47], $t(37) = 3.16$, $p = .003$) and marginally on trial distance ($b = −2.67$, 95% CI [−5.29, −0.05], $t(37) = −2.07$, $p = .046$).

DISCUSSION

Our goal was to validate a novel method for cognitive rehabilitation and/or additional assessment of cognitive deficit in psychiatric patients. For this purpose we administered VSST and a battery of standard neuropsychological tests to a group of chronic schizophrenia (SZ) patients and healthy volunteers. We used the *item performance* - calculated as the ratio of number of correctly collected items and number of items on a list for the given trial - as the primary VSST performance measure.

The groups differed significantly in their VSST performance. As hypothesized, SZ patients performed significantly worse than the healthy controls in all, but the easiest trials. Further analyses confirmed that the deterioration in the VSST performance as a function of the task difficulty is more pronounced in SZ patients, although this effect might be solely driven by no significant difference between the groups at the easiest difficulty and a large difference at the highest difficulty.

Groups also differed in the total number of collected items. In each trial, SZ patients collected approximately three items, regardless of their correctness or number of items presented during encoding. Besides presumed inferior ability to encode the items, and therefore impaired ability to collect the correct ones, we assume that the patients' performance could be influenced by the motivational deficits which are commonly described in SZ (Fervaha et al., 2015).

Our analyses also revealed that what differentiates patients from healthy participants is the relationship between their trial times and distances. In comparison to healthy participants, SZ patients walked shorter distances in longer times. As the movement velocity was constant, this could be the result of longer and more frequent pauses. Trial times and distances could be beneficial variables during repeated clinical examination or intervention, addressing patients' planning and navigation abilities and could offer additional information about their psychomotor speed. However, participants were neither penalized nor rewarded for slow times or optimal trajectories, therefore their performance in these parameters could be influenced by other factors, such as perseverance or impaired attention. These metrics and their association with standard cognitive and clinical measures therefore need to be studied in more detail.

VSST construct validity

Our goal was to determine the construct validity of the VSST using convergent and divergent validity approaches used previously (Corriveau Lecavalier et al., 2018; Nir-Hadad et al., 2017; Ouellet et al., 2018; Parsons & Rizzo, 2008). The convergent validity estimates the relationship with a well-established neuropsychological measure of the cognitive domain targeted by the developed method. Conversely, the divergent validity investigates the correlation with a standard method measuring different concepts.

As expected, we have found correlation between VSST *item performance* and the two standard memory measures of delayed recall - Rey Auditory Verbal Learning Task and Logical Memory. In SZ patients *item performance* correlated strongly with RAVLT delayed recall (r = 0.61) and LM delayed recall (r = 0.74). We also found moderate to strong correlations in healthy controls with RAVLT delayed recall (r = 0.63) and LM delayed recall (r = 0.48), although the LM did not correlate after correction for multiple comparisons. We believe that this result supports the construct validity of the VSST as a memory task.

During the VSST ***acquisition phase***, participants read the shopping list by themselves and the number of repeated readings might be dependent on their processing speed. Due to the processing speed deficit in SZ patients (Brébion et al., 2000), illustrated by longer TMT A time in our sample, we expected that patients might fail to read the list multiple times and their VSST performance can be affected. The missing association between VSST performance and TMT A, however, does not support this assumption.

In the patients' group we have also found a moderate correlation between the *item performance* and the TMT difference score (r = -0.46), although it was not found after the multiple comparison correction. Given the strength of the correlation, we believe that this might be only due to a relatively small sample. TMT difference score reflects patient‘s level of executive control (Sánchez-Cubillo et al., 2009). The deficit in executive functioning is common in SZ patients (Green et al., 2004) and it could inhibit their ability to organize encoded information and prevent them from compensating their memory impairment with a mnemonic strategy. Missing association of the TMT difference score and VSST in healthy subjects suggests that the average level of executive functioning in healthy controls might be sufficient for successful VSST completion and does not relate directly to the VSST performance. But this assumption should be investigated in future studies.

The *item performance* did not correlate with the Continuous performance task Detectability d' measure assessing sustained attention and impulsivity. This missing association of the VSST performance with specific attentional processes (not addressed by the task) is in line with our hypothesis and supports the divergent construct validity of the task.

Mental status and cognitive performance

It was proposed that the severity of SZ positive symptomatology does not affect cognitive processing (Bezdicek et al., 2020), while some studies demonstrated relationships with negative symptoms (Bezdicek et al., 2020; Ventura et al., 2009). Although we have not found a significant association between negative SZ symptomatology and patient's performance, the observed correlation between PANSS negative scale with *item performance* ($r = -0.41$) does not seem circumstantial, as a weaker correlation was reported ($r = -0.24$) in the meta-analysis by Ventura et al. (2009). Similarly, although GAF correlated significantly with cognitive measures in previous studies (Torio et al., 2014), correlation of GAF with *item performance* in our sample ($r = 0.42$) was not significant. Given that the observed correlations were moderate and in the expected direction (negative for PANSS and positive for GAF), we assume that the correlation coefficients did not reach significance as a result of relatively small sample size (19 patients). These associations should therefore be investigated in future studies.

Gender, age and gaming experience

Interestingly, female participants performed overall better in VSST than male subjects, but we found no interaction between group and gender suggesting the illness affects both genders equally. Previous studies suggest a more profound memory deficit in male patients in comparison to females (Bozikas et al., 2010; Han et al., 2012). This could be however due to high variability and a small sample size and it should be addressed in future studies. Importantly, our analyses showed no effect of gaming experience on VSST performance. Regarding age related effects, previous studies using VSST in healthy volunteers (comparing young and elderly) showed evidence of age-related performance (Plechatá et al., 2019), and although in our sample age had no significant impact on *item performance*, we found an effect of age on trial time and distance. We therefore suggest that when using these VSST metrics to track a patient's progress or performance, their age should be considered.

Implications for clinical purposes

The main potential of VSST is in its multifacetedness and resemblance to a real life activity. Our data indicate that the task might rely on more cognitive facets than just mnemonic abilities and the performance can be potentially related to executive functions, such as mental flexibility, planning and organisation. This suggests that VSST may be beneficial for multi-domain cognitive rehabilitation. Still, the main targeted domain of the VSST is memory, which was, together with processing speed and executive functions, repeatedly reported as the most impaired cognitive function in SZ (Fioravanti et al., 2012; Kraguljac et al., 2013).

Moreover, we suggest that simulating grocery shopping allows patients to train shopping skills to reduce anxiety or fear associated with this ADL. This might present a benefit for patients' everyday life if resulting in increased internal motivation to continue with rehabilitation sessions. In repeated assessment and combined with standard neurocognitive methods, VSST could provide additional information about patients' everyday performance and functioning.

Importantly, the possible effect of negative and general symptomatology, such as avolition, apathy or disorganized thinking, should be carefully considered in interpretation of the measured performance in neuropsychiatric patients.

Limitations

Previous study with a similar design confirmed that virtual shopping tasks predict real life performance more accurately than standard cognitive measures (Greenwood et al., 2016). At the moment, we cannot confirm the exact relationship between patients' real life functioning and VSST performance as we did not test the performance in real-life situations.

Our sample might be too small for some trending relationships to manifest themselves clearly. We also recruited only chronic schizophrenia patients. It would be interesting to investigate VSST on a larger sample, potentially covering a wider variety of psychiatric or neurological conditions - e.g. mild cognitive impairment, Alzheimer dementia, multiple sclerosis or attention deficit hyperactivity disorder. It is also necessary to confirm some of the observed correlations, particularly the missing association with negative symptomatology.

To address the rehabilitation purpose of the task, it is crucial to conduct repeated assessments and observe its long term impact on cognitive functions. In this study we provide support for our task to be a good indicator of a patient‘s cognitive state, but long term research is necessary to validate its impact on patients' cognitive abilities and benefits for their wellbeing.

Although the task offers many parameters to be set individually, such as acquisition time, task difficulty, delay time, number of repetitions etc., in this study we have tested only a single setting and a limited number of shopping items. Nevertheless, our results suggest that the difference between groups in their *item performance* and other parameters becomes more pronounced as the task's difficulty increases. While deliberate, slow increase of difficulty is crucial for rehabilitation purposes, in case of cognitive assessment, it can be beneficial to focus solely on the more challenging trials and to use the lowest trial as training.

Finally, VSST does not allow us to assess isolated cognitive functions, as they cannot be entirely separated. For example, the *item performance* can be related to participants' spatial orientation and ability to localize the recalled items in the virtual environment. Moreover, the visual recognition of shopping items cannot be addressed and the task thus differs from free recall tasks. The possible solution would be to ask participants to verbally recall encoded items prior to entering the VE, but we believe this would disrupt the task's resemblance to ADL and real-life shopping. As the encoding and recall in VSST are predominantly visual (e.g. items visual recognition during recall), it would be beneficial to investigate the relationship between VSST performance and visual memory tests, e.g. Brief Visuospatial Memory Test (Benedict et al., 1996) or written alternative of Rey Auditory Verbal Learning Test (Frydrychová et al., 2018).

CONCLUSION

We developed a method for cognitive remediation and repeated assessment in neuropsychiatric patients, which simulates a real life shopping activity. VSST offers an engaging and stimulating task in which patients can learn and practice valuable skills to use in everyday life and possibly improve their cognitive state. The task offers global evaluation of cognitive abilities through several metrics of patient's performance. VSST performance is indicative of patients' current cognitive state in mnemonic abilities, and, to a certain degree, executive functions and their level of general functioning. We therefore believe that VSST offers a valuable and an approachable tool for psychiatric practitioners to consider.

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SOUHRN

Úloha nákupu ve virtuálním supermarketu pro kognitivní rehabilitaci a vyšetření psychiatrických pacientů: Validace u pacientů s chronickou schizofrenií

Cíle. Schizofrenie je onemocnění výrazně omezující kognitivní schopnosti člověka a jeho každodenní fungování. Pacienti se schizofrenií v rámci léčby podstupují kognitivní remediaci za účelem zlepšení svých kognitivních schopností. Virtuální úloha určená ke kognitivní rehabilitaci a vyšetření kognitivních funkcí byla vytvořena s cílem propojení kognitivního tréninku s tréninkem v reálných životních podmínkách. Úloha nákupu ve virtuálním supermarketu (ÚNVS) simuluje proces nákupu, při kterém si jedinec musí zapamatovat a posbírat produkty ve virtuálním supermarketu. Cílem této studie je stanovit validitu úlohy pro její využití v klinické praxi.
Soubor a procedura. V rámci studie bylo otestováno dvacet pacientů trpících chronickou schizofrenií a dvacet zdravých dobrovolníků. Každý respondent absolvoval úlohu společně s baterií standardních neuropsychologických testů.
Statistická analýza. Výsledky skupin byly porovnány pomocí t-testu. Validita ÚNVS byla stanovena na základě Pearsonovy korelace se standardními neuropsychologickými testy. Pomocí lineární regrese a lineárních smíšených modelů byly podrobně prozkoumány jednotlivé proměnné, jako je obtížnost úlohy, ušlá vzdálenost či čas. Ověřen byl i vliv vnějších proměnných na výsledky v testu.
Výsledky. Analýza prokázala, že výkon SZ pacientů v ÚNVS je horší oproti výkonu zdravých dobrovolníků a tento výkon odpovídá úrovni jejich paměťových schopností zachycené standardními neuropsychologickými testy. Pouze ve skupině SZ pacientů byl zjištěn vztah mezi výkonem v ÚNVS a exekutivními funkcemi. Analýza neodhalila žádný efekt zkušenosti s hraním počítačových her na výkon v ÚNVS. Zatímco efekt pohlaví musí být ověřen v následujících studiích, výsledky studie naznačují, že věk respondenta může mít vliv na vybrané proměnné ÚNVS (ušlá vzdálenost a čas řešení úlohy).
Omezení studie. Participanti absolvovali úlohu pouze jednou, a proto nemohl být ověřen dlouhodobý přínos ÚNVS v rehabilitaci. Výzkumný soubor byl tvořen pouze pacienty se schizofrenií, což omezuje možnost zobecnění výsledků na jiná psychiatrická a neurologická onemocnění.