The Virtual Episodic Memory Task: towards remediation in neuropsychiatric disorders.

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Abstract — **Impairment of cognitive functioning represents a characteristic manifestation in various neuropsychiatric disorders. Schizophrenia (SZ) is characterised by significant impairment of declarative memory and executive functioning. Remediation of these cognitive functions is therefore a crucial part of the long-term care in SZ. In two pilot studies we present two variants of the virtual Episodic Memory Task (vEMT) used to assess memory for 'what?'- 'when?'- and 'where?' happened during specific events. Pilot 1: The vEMT was designed in two complex virtual environments (VEs - an open space office and a family house) and applied in a working memory paradigm. Both variants were tested in several collecting trials with increasing level of difficulty (number of items). We demonstrated a crucial role of the VE structure in the memory for item-space associations, while the temporal associations were not affected. Pilot 2: The second variant was designed to test delayed recall of all three episodic-like memory components by including the item recognition. The task shows unbalanced performance measured for individual components. Both task variants are designed for cognitive remediation in ecologically valid episodic situations, affecting both short- and long-term memory. Presented findings will be used to control the difficulty of individual components by regulation of various task parameters in the remediation program.**

Keywords—episodic memory; working memory; schizophrenia

I. INTRODUCTION

Impairment of cognitive functioning represents a characteristic manifestation in various neurological and neuropsychiatric disorders, such as Alzheimer disease (AD) and schizophrenia that both share global cognitive impairment. In SZ, there is evidence for deficit in hippocampus-dependent declarative memory systems (semantic and episodic) [1] and in executive functions (EFs) associated with prefrontal cortex [2].

Episodic memory (EM) is a unique cognitive function, enabling us to recall past events with all contextual information. The episodic-like memory model represents a simplified memory for episodes characterized by three conditions: **'what'** occurred during a specific episode, **'where'** it took place, and **'when'** it happened [3]. According to contextual hypothesis, SZ patients are able to recall target information (what occurred), but they have difficulties remembering contextual (spatial, temporal, semantic and affective) information [4]. The EM impairment seems to be concentrated around the disruption of conscious recollection and it apparently results from the strategic processes failure [5]. This can be linked to EFs (e.g. planning, working memory) impairments, resulting in difficulties in retrieval initiation and organization of encoding material.

II. THE VIRTUAL EPISODIC MEMORY TASK

We propose a virtual task aimed at episodic memory and possible role of contextual information and executive strategies in recollection. The **virtual Episodic Memory Task (vEMT)** was designed in complex virtual environment (VE) to assess the what-where-when memory. The task requires the subject to collect objects in virtual space and remember their identity, position and temporal order. The 3D task was inspired by the original 2D test that demonstrated disrupted EM in elderly and AD [6] and using a working memory paradigm also in SZ [7].

Aims of the pilots are 1) to compare the effect of structure of the VE on the vEMT performance in a working memory paradigm; 2) to test the long-term memory performance in individual EM components (what, where, when) in order to set up the difficulty level appropriate for remediation.

A. Pilot study 1

vEMT-I. In order to test possible effect of the complexity of the VE, we designed the task in two different environments (see Fig. 1.): OFFICE - unstructured open space and a well-structured family HOUSE**.** In both environments participants performed a working memory paradigm – immediate recall of positions (*spatial component*) and order (*temporal component*) of collected items in 5 trials with increasing difficulty (3 for pre-training, 5, 7, 9 or 11 items). Each trial consisted of two phases (Fig.1. A, C): 1) *Acquisition phase* with consecutive collection of objects, and 2) immediate *Recall phase* (delay less than 1') - returning all items to their original positions in a correct (given) sequence. Error rates were calculated for both temporal order and spatial positions of individual items.

Study sample. Healthy subjects (age 18-40; high school or university degree) were tested in one of the environments: *OFFICE* (n= 41; 11 females; age_{avg} 26.9) or *HOUSE* (n= 31; 10 females; age_{avg} 26.5). In addition, the same paradigm was tested in two SZ patients (individual scores are represented by lines in Fig.2 A-B.): 29-year-old male with university degree, and 38-year-old female with high school education.

Results. ANOVA with repeated measures revealed that the number of both error types increased with growing task difficulty in both VEs (Trial effect $p<0.001$, Fig.2.). Participants showed superior ability to remember positions ($p<0.001$), but not item order ($p>0.05$) in HOUSE environment. An interaction between VE type and Trial was observed, post hoc test revealed significant VE effect only in final difficulty level (11items: $p<0.05$). The vEMT task performance was affected by age in order ($p<0.001$) more than in position ($p<0.05$), but not by gaming experience ($p>0.05$). The two case

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studies demonstrated impaired vEMT performance in SZ (see the line patterns in Figure 2.A).

B. Pilot study 2

vEMT-II. This variant was aimed at <u>long-term</u> episodic-like memory processes. In addition, the vEMT task was extended by **Item recognition phase**, testing the 3rd component of the EM – item identity (see Fig. 1). Based on previous results we chose to perform the vEMT in the HOUSE environment with only 4 consecutive trials (3 for pre-training, 5, 7, 9 items). We calculated the number of errors for all three components ('what', 'where', 'when'). Moreover, in order to identify the strategies used during vEMT, we performed a structured debriefing of the participants. **Study sample.** Healthy volunteers (n=28; 15 females; age_{avg}=27; University degree).

Fig. 1. Illustration of the vEMT procedure: (A) **Acquisition phase** - collection of objects from specific positions in order defined by an arrow guiding the subject to individual items. After adjustable **delay** the subject is teleported to the start position (entrance). (B) **Item recognition phase**- selection of the correct items from a bigger set (in vEMT-II). (C) The **Recall phase** - after re-shuffle of collected items participants are asked to return them to their original positions in the correct order.

Results. ANOVA with repeated measures in GLM model (component vs. trial) showed significant difference between performance (number of errors) in the 3 tested components (Fig. 2.B; $p<0.001$). Only non-significant interaction ($p=0.056$) was observed between the task difficulty (number of items) and tested component. These results are in agreement with the subjective reports of the participants during debriefing. In addition, the debriefing helped us to identify variable strategies used to solve the task, e.g. story creating, mental repeating of the order during items collection.

C. Remediation variants of the vEMT

Based on our findings we suggest several modifications applicable in future remediation paradigm, where the difficulty level can be addressed by means of the following adjustable parameters: 1) by the **length of the delay period** ranging from immediate to long-term memory; 2) the **number of items** that should be remembered (starting by 3 and increasing by 1 item after successful recall up to 11 or more items); 3) by incorporating the **'what' component** – requiring recognition of collected items by their active selection from a bigger set of additional items (either presented in previous trials or completely new items, the size of the set used to affect the difficulty level); 4) the difficulty of spatial context can be affected by the **complexity of the VE** ranging from simple virtual buildings (e.g. offices or houses) to large-scale environments such as small city; 5) the temporal context can be affected by more precise **temporal cues**, such as weather conditions and time of the day; and 6) by **addition of other contextual information** (such as avatars in social situations).

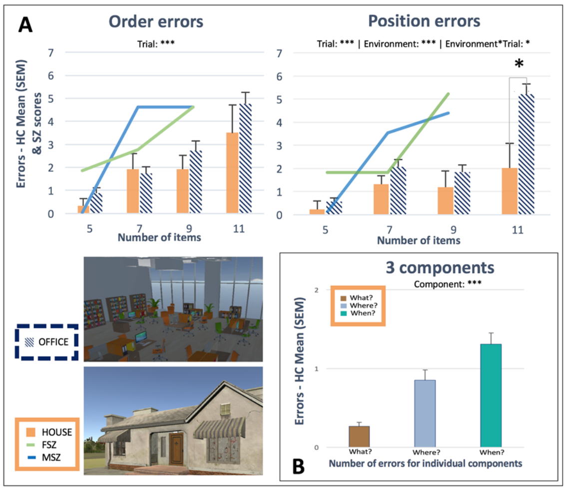

Fig. 2. (A). vEMT-I - Comparison of the VEs (structured House vs. unstructured Office) presented separately for order and position errors. The mean (SEM) values of control samples (HC) are presented in bars and the performance of the SZ subjects in line patterns (the last difficulty level was not tested in SZ). (B). Comparison of errors calculated for the 3 components ('what', 'where', 'when') in vEMT-II (avg+/-SEM).

III. CONCLUSIONS

The vEMT task showed performance dependent on several task parameters and demonstrated disturbed episodic memory in SZ (in case studies and [7]). Due to its contextual character it has the potential to remediate cognitive functions in ecologically valid situations. Suggested factors, such as the spatial complexity, adjustable delay and quantity of items can be used to control the task difficulty necessary for effective training. Variable VE designs including weather and daytime modifications could help us to prevent boredom and increase motivation. In addition, effective strategies observed in healthy subjects may be adopted by patients during the training process.

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