Using a virtual supermarket as a tool for training executive functions in people with mild cognitive impairment

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ABSTRACT

Cognitive and executive functions (EF) intervention programs for people with mild cognitive impairment (MCI) has not been studied enough, especially with the use of virtual reality. The purpose of the current study was to examine the effectiveness of using the Virtual Action Planning – Supermarket (VAP-S) to improve performance of a shopping task and EF among people with MCI. Seven participants with non-amnestic or multi-domain amnestic MCI completed the study protocol which followed an ABA single subject design. The outcome measures included the Multiple Errands Test (MET) to assess EF while performing a shopping task and the WebNeuro to assess EF impairments. Results showed that 4 participants improved their EF as assessed by the WebNeuro and 4 improved their performance of the shopping task in the MET. It seems that in some cases a learning effect occurred which explains why some of the participants did not improve. The results point to the potential of using the VAP-S as an intervention tool for training EF in people with MCI.

1. INTRODUCTION

Mild Cognitive Impairment (MCI) is considered as the early phase of cognitive decline in older adults (Werner and Korczyn, 2008) and incorporates observed clinical heterogeneity, with various subtypes: amnestic (memory impairments) or non-amnestic and either multi-domain (impairment in additional cognitive areas) or single-domain (Winblad et al, 2004). Executive functions (EF), defined as higher-order cognitive functions needed for performing complex tasks (Godefroy, 2003) have been shown to be impaired among persons with MCI (Nelson and O’Connor, 2008) especially in the areas of response inhibition, cognitive flexibility, attentional switching (Traykov et al, 2007), and planning (Zhang et al, 2007).

Intervention approaches for treating cognitive deficits in people with MCI focus mainly on memory disabilities and may include: physical exercise (Erickson and Kramer, 2009), medications (Jelic and Winblad, 2003) and cognitive group therapy (Kurz et al, 2009). There is some evidence for the effectiveness of these interventions, however, the evidence is not strong and the treatments usually did not address executive dysfunction and the impact on performance of Instrumental Activities of Daily Living (IADL).

Virtual Reality (VR) technologies which have been used as an assessment and treatment tool in cognitive and EF rehabilitation (Kizony et al, 2008; Klinger et al, 2010; Kizony, 2011), have advantages in providing an ecological–valid environment for treatment, which is considered to be more useful in EF rehabilitation. These environments may be used to train meta-cognitive strategies to enable a better transfer of skills to real life according to Toglia’s dynamic interactional model which is widely used in cognitive rehabilitation (Toglia, 2011).

The Virtual Action Planning- Supermarket (VAP-S) (Marié et al, 2003; Klinger et al, 2004) is a virtual supermarket that was found to be an ecologically valid tool for the assessment of EF in people with Stroke...
(Josman et al., 2006), Schizophrenia (Josman et al., 2009), Parkinson Disease (Klinger et al., 2006) and MCI (Werner et al., 2009).

Intervention studies for the treatment of cognition and EF showed some evidence for the use of VR. Rand et al. reported substantial improvements in the Multiple Errands Test (MET) - Hospital Version in 4 post-stroke participants when they received 10 treatment sessions in the Virtual Mall (VMall), a video-capture VR system using a single-subject design (SSD) (Rand et al., 2009). Yip and Man showed that 3 out of 4 participants with Acquired Brain Injury were able to transfer memory skills to a real-world environment after 10 training sessions in environments that simulated the use of public transportation and shopping (Yip and Man, 2009).

Despite the growing evidence of using VR for rehabilitation of EF deficits, the emphasis has been more on the assessment of EF deficits rather than on their treatment benefits (Kizony, 2011), with no studies in persons with MCI.

The objectives of this study were: 1. To examine the effectiveness of using the VAP-S to improve EF in people with MCI and 2. To examine the VAP-S effectiveness in improving performance of a shopping task in real world.

2. METHODS

2.1 Participants

Four women and 3 men who were diagnosed with non-amnestic or multi-domain amnestic (mixed) MCI were included in the study, using a Single Subject Design method. Their ages ranged between 65 and 89 years and all were living at home (See Table 1). Diagnosis of MCI was done by an expert physician using a comprehensive cognitive tests battery.

2.2 Outcome measures

Multiple Errands Test - Simplified Version (MET-SV) (Knight et al., 2002), a validated test for a variety of populations (Alderman et al., 2003) is an assessment designed to examine EFs in a real mall environment. An adapted version of the assessment was formulated for the current study to be used in a large supermarket. The scoring was based on Rand et al., (Rand et al., 2009). The final score of performance in the MET-SV, ranging between 0-133, was determined by the total number of mistakes made by the participant; therefore, the lower the score, the better the performance was.

WebNeuro battery (Brain Resource Company) (Silverstein et al., 2007) is a reliable and valid accessible web-based cognitive test battery that takes 30 minutes to administer. The battery contains subtests in few cognitive domains such as memory, attention, psychomotor functioning and especially executive functions. It includes few Hebrew versions for repeated measures.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Type of MCI</th>
<th>Gender</th>
<th>Age</th>
<th>Family status</th>
<th>Education (years)</th>
<th>Shopping frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mixed</td>
<td>M</td>
<td>65</td>
<td>Married</td>
<td>17</td>
<td>Once a week</td>
</tr>
<tr>
<td>2</td>
<td>Non amnestic</td>
<td>F</td>
<td>85</td>
<td>Widow</td>
<td>12</td>
<td>Once a week</td>
</tr>
<tr>
<td>3</td>
<td>Non amnestic</td>
<td>M</td>
<td>76</td>
<td>Married</td>
<td>8</td>
<td>Few times a week</td>
</tr>
<tr>
<td>4</td>
<td>Mixed</td>
<td>F</td>
<td>65</td>
<td>Married</td>
<td>16</td>
<td>Sometimes</td>
</tr>
<tr>
<td>5</td>
<td>Mixed</td>
<td>F</td>
<td>69</td>
<td>Married</td>
<td>12</td>
<td>Once a week</td>
</tr>
<tr>
<td>6</td>
<td>Mixed</td>
<td>M</td>
<td>89</td>
<td>Widow</td>
<td>36</td>
<td>Once a week</td>
</tr>
<tr>
<td>7</td>
<td>Non amnestic</td>
<td>F</td>
<td>74</td>
<td>Married</td>
<td>12</td>
<td>Sometimes</td>
</tr>
</tbody>
</table>

2.3 Intervention tool

The VAP-S Virtual Environment (Klinger et al, 2004) simulates a fully textured, medium-sized supermarket (Fig. 1). Users enter the supermarket behind a cart, as if they are pushing it, and can navigate freely within the VAP-S via the keyboard arrow keys. They experience the environment from a first person perspective. A list of items appears on the screen and the user is asked to shop for those items, go to the cashier, pay and exit the supermarket. Prior to the beginning of this study, the VAP-S was modified by Klinger to enable the use....
of the VAP-S as a training tool. The modifications include the ability to grade the level difficulty of the shopping tasks.

**Figure 1. The Virtual Action Planning- Supermarket- VAP-S (Klinger et al., 2004).**

2.4 Procedure

After signing an informed consent form, each subject underwent the following protocol which followed an ABA single subject design (See Fig. 2): Initially, a baseline evaluation with the MET-SV and the WebNeuro battery and after 3-4 weeks a second evaluation (with a different version of the battery) was performed. This was followed by 10 treatment sessions over 5 weeks which were performed by a therapist blinded to the assessments’ results. The treatment protocol was tailored to each subject and was based on Toglia’s model (Toglia, 2011) focusing on training of meta-cognitive strategies within the VAP-S. After completing the training a third evaluation with another version of the above tests was performed and finally, a fourth evaluation was performed 3-4 weeks after completing the training.

![Illustration of study design](image)

**Figure 2. Illustration of study design.**

3. RESULTS

Data was analyzed descriptively as appropriate in a single subject design. Results showed that 4 subjects improved in their EF as assessed by the WebNeuro (Fig.3) and 4 subjects showed some improvement in their total MET-SV (Fig.4). Two of those showed improvement in both assessments. Median scores of EF as assessed by the WebNeuro increased between the first 3 evaluations and then remain unchanged on the 4th evaluation (See Fig. 5). Similar tendency was seen in the median scores of the Total MET-SV (See Fig. 6).

From a qualitative point of view subjects enjoyed the treatment and compliance was good. In addition four of them indicated that the treatments sessions helped them in improving their strategies during performance of other everyday activities.

4. DISCUSSION AND CONCLUSIONS

The findings of the current study point to the potential of using the VAP-S as an intervention tool within a meta-cognitive model for training of EF in people with MCI. The between and within subjects’ variability was high which might point to the heterogeneity of deficits in this population and thus indicate that single subject design method as was used in this study, is the appropriate design for this population.

Four participants showed an improvement in their total scores of the MET-SV suggesting the transfer of strategies trained during the intervention, into a real life situation. This is considered to be an intermediate
transfer according to (Toglia, 2011) since performance in real world was assessed in a supermarket and training was performed in a virtual supermarket. However, it seems that in some participants skills were transferred to other activities as well. For example, this is a quote from one of the participants: “now I’m more organized and I learned various strategies that will help me in the performance of daily activities, not only during shopping, but also while performing other tasks.”

Figure 3. Results of EF domain from the WebNeuro Battery in 4 evaluations (note that 2 subjects were not able to complete the EF domain of the battery at the first evaluation and one also in the second and one subject was not able to complete this domain in all 4 evaluations).

Figure 4. Total scores of MET-SV in 4 evaluations (low scores indicate better performance).

Figure 5. Medians of EF domain from the WebNeuro Battery in 4 evaluations (n=7).
There are few explanations why some of the participants did not show improvement of EF or performance of the shopping task post intervention. Analysis of the results revealed that there was a learning effect from the first evaluation to the second. This can be seen in Figures 5 & 6 in the median scores as well as in the individual participants in Figures 3 & 4. The learning effect might be due to two main reasons; learning of the tasks within the assessments, and familiarity with the task in WebNeuro or with the testing environment (i.e. the supermarket) in the MET.

Rand et al., (Rand et al, 2009) reported an improvement in total scores of the MET post intervention, in all 4 participants in their study. However, the participants were only assessed twice; pre and post intervention, thus learning effect was not controlled. In the current study, when looking only at two evaluations as in Rand et al., study, most participants showed an improvement in the MET (n=7) and the EF domain of the WebNeuro (n=6).

Another explanation why some of the participants did not improve post intervention is their level of awareness to their deficits that might impede transfer of skills to other situations. In addition, emotional state like anxiety or depression might affect the ability to learn and use efficient strategies for daily life activities (Toglia, 2011). These functions were not measured in the current study.

A tendency of decline in performance in the 4th evaluation was observed in the WebNeuro (1 participant) and in the MET-SV (3 participants) and is also apparent in the group’s medians. This might be explained by a change in the level of motivation of the participants once the intervention was over and there was nothing to look forward to in the future, in terms of the research.

The limitations of this study are mainly the small sample size and the lack of a control group. In addition, intervention was limited to one VE, a supermarket, which does not reflect the complexity of everyday life.

In conclusion, although the results should be interpret cautiously, the protocol developed in this study using the VAP-S, may help improve EF and shopping task in people with MCI. Further studies should be carried out in a larger sample of participants with MCI as well as other clinical populations.

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