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Deficits in cue detection underlie event-based prospective memory impairment in major depression: an eye tracking study

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ABSTRACT

This study examined the cue detection in the non-focal event-based prospective memory (PM) of individuals with and without a major depressive disorder using behavioural and eye tracking assessments. The participants were instructed to search on each trial for a different target stimulus that could be present or absent and to make prospective responses to the cue object. PM tasks included cue only and target plus cue, whereas ongoing tasks included target only and distracter only. The results showed that a) participants with depression performed more poorly than those without depression in PM; b) participants with depression showed more fixations and longer total and average fixation durations in both ongoing and PM conditions; c) participants with depression had lower scores on accuracy in target-plus-cue trials than in cue-only trials and had a higher gaze rate of targets on hits and misses in target-plus-cue trials than did those without depression. The results indicate that the state of depression may impair top-down cognitive control function, which in turn results in particular deficits in the engagement of monitoring for PM cues.

1. Introduction

Depression is associated with mild-to-moderate impairment in several cognitive domains, including attention, memory and executive functioning (Beats et al., 1996; Elliott et al., 1996; Purcell et al., 1997; Veiel, 1997; Den Hartog et al., 2003; Hammar et al., 2003). Studies examining the impact of depression on memory functioning have focussed on retrospective memory (i.e., the ability to remember past events), whereas little is understood about the influence of depression on prospective memory (PM) (i.e., 'remembering to remember'). PM refers to the formation, maintenance and execution of future intentions (Kvavilashvili and Ellis, 1996), involving the function of retrospective memory, working memory and executive functions (Burgess and Shallice, 1997; Martin et al., 2003), but separable from these related constructs. There are two categories of PM: event-based (e.g., remembering to turn off the stove after cooking) and time-based (e.g., remembering to take medicine after 15 min) (Einstein and McDaniel, 1996). PM pervades our everyday lives, with an apparent clinical relevance.

To our knowledge, the performance of patients with depression on objective time-based and event-based PM tests has been assessed in three previous studies. Rude and his colleagues (1999) reported that major depression resulted in the impairment of tasks that required a high degree of controlled, self-initiated processing, such as time-based PM tasks. Lee et al. (2010) studied participants with bipolar disorder and discovered that increased age and disease severity contributed to deficits in time-based PM (Lee et al., 2010). The single evidence of impairment on measures of event-based PM provided by Altgassen et al. (2009) revealed that the non-depressed group outperformed the individuals with depression in the non-focal condition, but not in the focal condition. Focality describes the similarity of the cognitive processes needed for performing the ongoing task and detecting the prospective cue (McDaniel and Einstein, 2000). For example, if both the ongoing task and the prospective cues demand perceptual processing, the cue is focal to the processes involved in the ongoing activity. However, if the ongoing task needs perceptual processing, but the prospective cues demand semantic processing, the cue is non-focal to the ongoing processes. Relative to the focal condition that involves the same type of processing in retrieving the planned action on the task, a non-focal condition

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that involves different types of processing demands more effort and resources to engage in strategic processes to detect the cue and retrieve the associated intention (McDaniel and Einstein, 2000).

Together, these findings suggest that depression may negatively impact time-based PM, but the deficit in event-based PM in depression needs more consideration. According to Altgassen et al. (2009), it is important to take into account the conditions in which significant attentional capacity is (or is not) required to notice the cue as relevant to an intention. Therefore, we conducted the present study focussing directly on the issue about cue detection, and, more specifically, the links between depression and event-based PM as well as the mechanisms that might underlie these links among major depressive disorder and matched participants without depression in an eye tracking study.

In the laboratory-based measures of event-based PM tasks, cues are embedded in an ongoing activity and participants must execute dual-task processing, which requires detecting the cue while performing the ongoing task and shifting attention from the ongoing to the PM task. For example, on a lexical decision task, participants are instructed to remember to perform a specific action (e.g., 'hit the Z key') in response to the cue, such as the appearance of a special word (or items from the 'animal' category) on the computer screen. There is a dual-task trade-off between the effort and the attention placed on the ongoing versus prospective tasks (Marsh and Hicks, 1998; Smith and Bayen, 2004; Marsh et al., 2005). In the process, cue detection may be mediated by where the attention resources are focussed on at the time in which a cue occurs in the environment (Marsh et al., 2003; West et al., 2005). If individuals cannot effectively distribute attention resource respectively to perform the ongoing task and monitor the cue, or if attention is withdrawn from the entire task set, the PM is likely to fail.

It is believed that neuropsychological malfunctions in depression are based on pathological projections from the amygdala to the anterior cingulate cortex (ACC) and the prefrontal cortex (PFC) (Elliott et al., 1997; Davidson et al., 2002), which are implicated in PM (Burgess et al., 2001). Since these areas of the brain are part of widely distributed networks of attention and executive function (Cabeza and Nyberg, 2000), the detected effects of depression on PM may be mediated by the top-down cognitive control function. Consistently, Ellis and Ashbrook's (1988) resource allocation model indicates that a depressive mood leads to reduced overall cognitive capacity during the performance of cognitive tasks by deflecting some amount of attentional resources to intrusive, task-irrelevant or depression-related thoughts (see also Ellis, 1991; cf. Hartlage et al., 1993; Kliegel et al., 2005; Kliegel and Jäger, 2006).

To examine the cognitive control effect of depression on detecting the cue, we used the non-focal condition in our experiment to simulate the environment that demands the processes to strategically monitor the environment for the presence of the cue. We also used a target-searching task as the ongoing task in which individuals searched for a different target stimulus (i.e., an image object), which could be present or absent, and made prospective responses to objects from the specific category (i.e., fruit objects). We manipulated the interference to the cue by making the cue co-exist with the target object or appear without the target object. Thus, the stimuli included 1) only targets, 2) only prospective cues, 3) target plus cues and 4) distracters (neither targets nor cues). The poorer performance of participants with depression on target-plus-cue trials than cue-only trials compared with participants without depression would provide evidence suggesting that individuals with depression might have deficits in shifting attention from ongoing trials to prospective trials.

We combined behavioural measures and eye tracking methodology to examine the attention processing of individuals with and without depression. Examining the visual processing of prospective cues can determine the amount of attentional resources that participants may devote to processing cue recognition and to intention retrieval (West et al., 2007). PM processing of patients and the non-depressed group measured by eye tracking was compared on four indices: fixations, total fixation duration, average fixation duration and gaze rate. The number of fixations was the total number of times a certain area was fixed, measuring whether stimuli fell on the fovea of the retina. The total fixation duration was the total time of all fixations within a given region, including both consecutive fixations within a region (gaze duration) and refixations on the region (fixations initiated from outside the region). Total fixation duration provided an index of the entire processing of stimuli on the fovea. The average fixation duration was defined as the mean of all individual fixation durations on a particular area. Finally, the gaze rate was the ratio of gaze time divided by total time of stimuli presentation.

Concerning the profile and neural substrates of depression-associated cognitive deficits, we hypothesised that compared with their non-depressed counterparts individuals with depression would require more attentional effort to complete the task and engage in compensation processing, as indicated by greater numbers of fixations and longer total and average fixation durations. Moreover, the probability of gazing at the prospective cue or target on target-plus-cue trials would provide evidence indicating whether interference was inhibited and attention was correctly shifted from ongoing trials to prospective trials.

2. Methods

2.1. Participants

Participants with depression ($N=19$; right-handed) were recruited from the Medical Psychology Division of a General Hospital. All the participants with depression were categorised according to *Diagnostic and Statistical Manual of Mental Disorders*, fourth edition (DSM-IV; American Psychiatric Association, 1994; First et al., 2002) criteria for unipolar major depression. No participant was taking antidepressant medication at the time of participating in this study. They came to seek treatment when they did not have any antidepressant medication. After communicating with the doctor, they participated in this study, and then they began the antidepressant medication. These participants were tested on 17-item Hamilton Depression Rating Scale (Ham-D 17; Hamilton, 1967) and 21-item Beck Depression Inventory-II (BDI-II; Beck et al., 1996) to ensure that they were over the cut-off score on the severity of depression. All the participants scored at least 17 on Ham-D 17 and 20 on BDI-II. Participants in the non-depressed group ($N=19$; right-handed) were recruited from a university in the same city. Exclusion criteria were based on clinical laboratory tests such as the mini-mental state examination (MMSE; Folstein et al., 1975), comprehensive demographic and clinical information including family history, psychiatric and medical history and medication history. All participants scored 27 or higher on the MMSE. Individuals were excluded from the groups if they had diagnoses of lifetime or current bipolar I or II disorder, primary diagnosis of another Axis I or II disorder, schizophrenia, delusional disorder and organic brain disorder. Other exclusion criteria included substance abuse or dependence in the last 6 months, imminent suicide risk, current use of medications and pregnancy. Written informed consent was obtained from the participants before the study began.

2.2. Materials and equipment

The stimuli were 128 black-and-white line drawings of common objects, taken from Snodgrass and Vanderwart (1980). Before the experiment, the participants were asked to name the objects to avoid confusion during the experiment. The 128 objects were combined into 128 search displays, each containing four semantically unrelated objects on a white background. These displays appeared after the target word (black) presented at the centre of the screen. The display was divided into four areas, equivalent to the four quadrants in which an object could occur. Each object subtended approximately 2° of visual angle both horizontally and vertically and there were approximately 4.5° of visual angle between the centres of any two adjacent objects. The cues were the fruit objects (e.g., apple). The experiment included 64 trials with targets (target-present) and 64 without (target-absent). Within the 64 target-present trials, there were 60 target-only trials and 4 target-plus-cue trials. For these trials, the target appeared 16 times and the cue appeared one time at each of the four positions. Within the 64 target-absent trials, there