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Taxing working memory reduces vividness and emotional intensity of images about the Queen's Day tragedy

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ABSTRACT

Eye movements during exposure to distressing mental images reduce their vividness and emotional intensity, which may be due to both tasks competing for working memory (WM) resources. WM theory predicts an inverted U-shaped relationship between degree of taxing and beneficial effects: greater taxing of WM will more greatly reduce vividness/emotionality, but extremely taxing tasks prevent holding the image in mind, thereby reducing benefits. This study examined whether mental arithmetic (subtraction) tasks during visual imagery reduce image vividness/emotionality ratings, and taxing WM and reduced vividness/emotionality show the predicted quadratic relationship. A non-clinical sample retrieved a distressing image of the Queen's Day tragedy (which occurred 1–3 months earlier in the Netherlands), and rated it for vividness and emotionality. Participants were assigned to one of four conditions: exposure alone or exposure with concurrent 'simple' subtraction, 'intermediate' subtraction, or 'complex' subtraction. Afterwards, vividness and emotionality were rated again. A reaction time task showed that the subtraction tasks increasingly taxed WM. Consistent with WM theory, exposure with subtraction reduced image vividness and emotionality compared to exposure alone. The expected inverse U-curve relationship was found for emotionality, but not for vividness: simple or intermediate subtraction had more beneficial effects than no dual-task or complex subtraction. Clinical implications are discussed.

1. Introduction

1.1. Vivid and distressing memories

Intrusive, distressing memories of negative past events are among the key symptoms of posttraumatic stress disorder (PTSD). These may involve all sensory modalities, but visual mental images of the event are common (e.g., Ehlers et al., 2002; Engelhard, van den Hout, Arntz, & McNally, 2002). Studies have shown that recurrent intrusive memories also occur in other disorders, including OCD, social phobia, panic disorder, depression, bulimia nervosa, and psychosis (Engelhard, Arntz, & van den Hout, 2007; Hackmann & Holmes, 2004), and thus appear to be a transdiagnostic phenomenon (Harvey, Watkins, Mansell, & Shafran, 2004). How can patients with such distressing memories be treated?

Effective treatments for PTSD include exposure techniques, which are used to confront patients with their distressing memories for prolonged periods of time to promote habituation and correct erroneous beliefs (e.g., Rothbaum, Meadows, Resick, & Foy, 2000). Eye movement desensitization and reprocessing (EMDR) is also effective (e.g., Bisson et al., 2007). Briefly, in the basic EMDR protocol (Shapiro, 2001), a client is asked to hold an unpleasant memory in mind, while a set of eye movements is elicited by having the client follow a repetitive side-to-side motion of the therapist's index finger. The client next reports current sensations, cognitions, and emotions. Sets are repeated until the client reports minimal distress related to the memory. Then the client is guided to replace a negative cognition related to the memory with a positive one.

There has been much debate about EMDR and theoretical weaknesses (e.g., Herbert et al., 2000; Muris & Merckelbach, 1999). Eye movements are thought to be a crucial therapeutic element but it has been unclear *how* they may cause benefits. Though it has been questioned whether the eye movement component of EMDR adds to the effects of the total EMDR package, a recent meta-analysis indicates that there is an additional benefit of eye movements (Lee & Cuijpers, 2010). The clinical findings are corroborated by analogue studies that consistently show that making eye movements during recall of an unpleasant autobiographical memory reduces its

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vividness and emotionality, relative to recall alone (Andrade, Kavanagh, & Baddeley, 1997; Barrowcliff, Gray, Freeman, & MacCulloch, 2004; Gunter & Bodner, 2008; Kavanagh, Freese, Andrade, & May, 2001; Kemps & Tiggemann, 2007; Maxfield, Melnyk, & Hayman, 2008; Van den Hout, Muris, Salemink, & Kindt, 2001). Findings from several research lines provide a fresh perspective on the effect of eye movements. This may explain mechanisms involved in EMDR, is clinically highly relevant, and is related to working memory.

1.2. Working memory account

The working memory (WM) account assumes that beneficial effects of eye movements occur because the two tasks (thinking of the memory and making eye movements) compete for limited-capacity WM resources (Andrade et al., 1997; Baddeley & Andrade, 2000; Gunter & Bodner, 2008). There are two version of the WM account. One version (e.g., Andrade et al., 1997) focuses on the fact that eye movements and visual imagery compete selectively for limited-capacity visuospatial WM resources. The other more general view (e.g., Gunter & Bodner, 2008) posits that central executive resources are important for vivid recollection and greater central executive loads will impair imagery more greatly, which implies that any task that taxes the central executive will have the same effects. These two accounts are not incompatible. For example, Baddeley and Andrade (2000) explain the role of the central executive in imagery, and report general task load effects on visual and auditory imagery across a series of experiments. Visual imagery is impaired more by visual dual-tasks than by an auditory or verbal dual-task, and the opposite has been found for auditory imagery (e.g., Kemps & Tiggemann, 2007).

Distracting tasks that tax visuospatial and central executive WM resources are effective, like drawing a complex figure (Gunter & Bodner, 2008), and playing the computer-game Tetris (Holmes, James, Coode-Bate, & Deeprose, 2009). Dual-tasks that do not appear to tax visuospatial WM resources, like articulatory suppression (Kemps & Tiggemann, 2007), auditory shadowing (Gunter & Bodner, 2008), and mental arithmetic (van den Hout, Engelhard, SmeetsHornsveld, Hoogeveen, & de Heer, 2010), are also effective (but see Lilley, Andrade, Turpin, Sabin-Farrell, & Holmes, 2009). Simple finger tapping is not effective (Van den Hout et al., 2001), while more *complex* tapping is (but less than eye movements effects; Andrade et al., 1997). Gunter and Bodner (2008) logically argue that the beneficial effects of complex tapping are due to greater taxing. Finally, EMDR has been advocated as a treatment of memories for traumatic events, but WM theory implies that eye movements also affect distressing images about future events ("flashforwards"). Experimental evidence confirms this (Engelhard, van den Hout, Janssen, & van der Beek, 2010).

1.3. Dose-response relationship

An important step in determining causality is determining a dose-response relationship between taxing WM during image retrieval and changes in image vividness/emotionality. The theory predicts that more taxing produces more reductions in vividness/adversity. Consistent with this prediction, the smaller individuals' WM span, the larger the effects of auditory shadowing on image vividness and emotionality ratings (Gunter & Bodner, 2008), and the more WM is taxed during mental arithmetic, the more vividness and emotionality are reduced (Van den Hout et al., 2010). Gunter and Bodner (2008) also found larger effects of copying a complex figure compared to eye movements, and attributed this to the copying task requiring more WM resources. However, they did not independently assess whether it is more demanding. In addition, it seems vital that WM is taxed *during* exposure to the image. Extremely taxing tasks may prevent holding an image in mind (Gunter & Bodner, 2008), thereby preventing a temporary weakening of the image and associated distress that allows the person to engage more fully in cognitive reprocessing (Andrade et al., 1997), and reducing benefits. Thus, too little or too much taxing may lead to lower drops in image vividness/emotionality. Accordingly, the WM theory asserts an inverted U-shaped function. Such a quadratic relationship can be assessed by first establishing different levels of taxing and then examining whether they are related to different outcomes.

Van den Hout et al. (2010) conducted such a study. A visuospatial reaction time (RT) task showed that mental arithmetic (subtraction) tasks require WM resources, and a more complex task (subtracting 7 from 450 downwards) is more demanding than a simple task (subtracting 2 from 450 downwards). Relative to exposure alone, exposure with concurrent mental arithmetic reduced vividness and emotionality during later recall of the image. However, the magnitude of the reduction did not differ between the two counting conditions. Van den Hout et al. (2010) suggested that the complex task may have been too taxing to produce extra benefits. This issue of an inverted U-shape can be empirically resolved by examining the effects of several levels of WM taxation, from weak to intermediate to strong.

1.4. This study

This study examined whether (1) mental arithmetic (subtraction) while holding a distressing mental image in mind reduces its vividness/emotionality (cf. Van den Hout et al., 2010), and (2) four levels of taxing WM and reduced vividness/emotionality show the predicted quadratic relationship, with stronger effects when taxing increases from absent to mild and moderate, and reduced effects for more extreme taxing. Initially, an RT task to visual cues was used to establish that the no dual-task and three subtraction tasks differ in degree of taxing (cf. Van den Hout et al., 2010). Then a memory experiment was conducted, in which participants were asked to hold a distressing visual image of the tragedy on "Queen's Day" (see 2.2) in mind, using one of four conditions: exposure alone or exposure with concurrent simple subtraction, intermediate subtraction, or complex subtraction. An advantage of images of this event is that they are rather homogenous in terms of content and time since the event. We predicted that (1) relative to exposure alone, exposure in conjunction with subtraction decreased vividness and emotionality ratings, and (2) no and extreme taxing would show less beneficial effects than mild and moderate taxing.

2. Method

2.1. Manipulation check: participants and procedure

Prior to the memory experiment, a manipulation check was carried out to assess whether the different task conditions tax WM in a dose-dependent way (cf. Van den Hout et al., 2010). A total of 15 undergraduate students (M age 22.8 years, $SD = 2.3$; 12 females) from UtrechtUniversity participated for financial compensation. Degree of taxing was assessed with a reaction times (RT) task to visual cues. Participants were asked to press the "Q" keyboard key as fast as possible when a green circle appeared on the screen and the "P" key if a yellow circle appeared. Circles were presented for 500 ms in random order with the restriction that no more than 4 of the same color were presented in a row. Participants started with 10 practice trials, and then carried out the RT task under 4 conditions of 3 min each: 1) single-task, 2) simple subtraction (1 from