Routledge
Taylor & Francis Group

The Quarterly Journal of Experimental Psychology

ISSN: 1747-0218 (Print) 1747-0226 (Online) Journal homepage: http://www.tandfonline.com/loi/pqje20

Effects of Valent Image-Based Secondary Tasks on Verbal Working Memory

Phillip L. Morgan, Craig Williams, Fay M. Ings & Nia C. Hughes

To cite this article: Phillip L. Morgan, Craig Williams, Fay M. Ings & Nia C. Hughes (2017): Effects of Valent Image-Based Secondary Tasks on Verbal Working Memory, The Quarterly Journal of Experimental Psychology, DOI: 10.1080/17470218.2017.1329324

To link to this article: http://dx.doi.org/10.1080/17470218.2017.1329324

Publisher: Taylor & Francis & The Experimental Psychology Society

Journal: *The Quarterly Journal of Experimental Psychology*

DOI: 10.1080/17470218.2017.1329324

Effects of Valent Image-Based Secondary Tasks on Verbal Working Memory

Phillip L. Morgan[1], Craig Williams[1], Fay M. Ings[2], and Nia C. Hughes[1]

[1]Psychological Sciences Research Group, Department of Health and Social Sciences, University of the West of England (UWE) - Bristol, Frenchay Campus, Bristol, UK

[2] School of Psychology, Education, Early Years, and Therapeutic Studies, University of South Wales, Pontypridd, UK

Word Count:

Abstract: 194

Text (excluding abstract, keywords, references, tables and figure captions): 11, 041

Correspondence concerning this article should be addressed to: Phillip L. Morgan, Psychological Sciences Research Group, Department of Health and Social Sciences, University of the West of England - Bristol, Frenchay Campus, Coldharbour Lane, Bristol, UK, BS16 1QY, UK. Contact: Tel: (+44) 1173 283515, Email: phil.morgan@uwe.ac.uk. From September 2017, Phillip L. Morgan will be at the School of Psychology, Cardiff University, Park Place, Cardiff, UK. Email: morganphil@cardiff.ac.uk.

Abstract

Two experiments examined if exposure to emotionally valent image-based secondary tasks introduced at different points of a free recall working memory (WM) task impair memory performance. Images from the International Affective Picture System (IAPS: Lang, Bradley, & Cuthbert, 2008) varied in the degree of negative or positive valance (mild, moderate, strong) and were positioned at low, moderate, and high WM load points with participants rating them based upon perceived valence. As predicted, and based on previous research and theory, the higher the degree of negative (Experiment 1) and positive (Experiment 2) valence and the higher the WM load when a secondary task was introduced, the greater the impairment to recall. Secondary task images with strong negative valance were more disruptive than negative images with lower valence at moderate and high WM load task points involving encoding and/or rehearsal of primary task words (Experiment 1). This was not the case for secondary tasks involving positive images (Experiment 2), although participant valence ratings for positive IAPS images classified as moderate and strong were in fact very similar. Implications are discussed in relation to research and theory on task interruption and attentional narrowing and literature concerning the effects of emotive stimuli on cognition.

Keywords: Emotion, valence, working memory, secondary tasks, interruption

Effects of Valent Image-Based Interruptions on Verbal Working Memory

Working memory (WM) involves internal encoding and maintenance of phonological and visuo-spatial information over brief time periods (Baddeley, 2003, 2007). The effectiveness of these processes depends upon successful storage and rehearsal of information (Miyake & Shah, 1999) as well as controlling and inhibiting interference from competing stimuli (Sakai, Rowe, & Passingham, 2002). A key challenge is to avoid getting embroiled in processing information from secondary tasks that may interfere with WM processes (Conway & Engle, 1994) and possibly lead to the forgetting of encoded information within a primary task (Hasher & Zacks, 1988). However, secondary tasks such as interruptions are commonplace and difficult to avoid. A task interruption (e.g., a nurse talking to a drop-in visitor) diverts attention away from a primary task (e.g., monitoring a critically ill patient) and can cause forgetting of information (Altmann, Trafton, & Hambrick, 2014; Morgan, Patrick, Waldron, King, & Patrick, 2009). Features of interrupting tasks such as complexity (Monk, Trafton, & Boehm-Davis, 2008) are known to exacerbate the degree of disruption. To our knowledge, none have examined whether emotive interruptions – that are common in some workplace situations (e.g., hospitals, emergency services, military) – are also disruptive and if so to what extent. Some have investigated effects of exposure to emotive images prior to (Pereira et al., 2006) and following a task (Erk, Kleczar, & Walter, 2007) and found impairments to reaction times but not performance accuracy. Others have manipulated emotive images as background (to-be-ignored) *distractions* and also reported slower reaction times but not impairments to WM (Wessa, Heissler, Schönflder, & Kanske, 2013). The current paper examines whether emotive valent images operationalized as secondary *tasks* (like interruptions and not distractions) impair performance on a primary WM task. We also explore effects of the type of emotivity (negative or positive valence), the degree of emotivity (valence strength), and possible interactions with WM load at the point in which secondary tasks are introduced.

Task Interruption: Background and Theory

Having to switch to a secondary task interrupts performance of a primary task. Being interrupted by a secondary task causes suspension of a primary task that usually has to be resumed at some future point. This will often involve having to retrieve previously encoded information from WM in order to efficiently resume and continue with the primary task. Interruptions are usually disruptive (e.g., McFarlane, 2002), irrespective of the nature of the primary task (e.g., involving memory, planning, problem solving) and testing context (e.g., laboratory: Trafton & Monk, 2008; healthcare: Chisholm, Dornfeld, Nelson, & Cordell, 2001; aviation: Damos & Tabachnick, 2001). Effects include delays in resuming the primary task (a *resumption lag*: e.g., Altmann & Trafton, 2007; Hodgetts & Jones, 2006; Hodgetts, Vachon, & Tremblay, 2014) and forgetting previously encoded information (Altmann et al., 2014; Morgan & Patrick, 2013; Morgan, Patrick, & Tiley, 2013; Morgan et al., 2009). Other effects include increased primary task completion times (e.g., Cutrell, Czerwinski, & Horvitz, 2001) and elevated stress (e.g., Zijlstra, Roe, Leonora & Krediet, 1999).

Many studies have examined interruption effects, with primary tasks that involve executing actions in a particular order for successful completion (e.g., Hodgetts & Jones, 2006; Trafton, Altmann, Brock, & Mintz, 2003), often with resumption lag taken as a key criterion of the disruptiveness of interruptions sometimes together with other measures such as deviation from optimal solution sequences (e.g., Altmann et al., 2014). The current study employs a more traditional free recall verbal WM task that does not involve trying to follow a particular procedure, but where variations in WM load at the point in which a secondary task occurs are easy to manipulate. Free recall might be particularly sensitive to interference and decay effects demonstrated by impaired memory recall on trials where emotive image-based secondary tasks occur and interrupt the primary task. In fact, investigating the effects of emotive secondary tasks on static as well procedural and even dynamic tasks (e.g., Hodgetts, Temblay, Vallières, & Vachon, 2015) is important given that not all tasks prone to being interrupted are procedural and/or dynamic (e.g., Morgan et al., 2009, 2013). Take the example of a nurse taking readings from a drug infusion pump (primary task) and having to turn his/her attention to an emotive emergency situation (interrupting secondary task). He/she may still have to try and remember previously encoded information (drug infusion pump readings) to efficiently resume and continue with the primary task and this will not always require procedural memory.

It is important to consider our research questions in terms of relevant theory. Many accept that secondary task interruptions are disruptive because primary task information encoded in memory prior to being interrupted decays during the secondary task, and, information encoded from the secondary interrupting task interferes with decaying primary task memory traces (Altmann & Trafton, 2002; Hodgetts & Jones, 2006; Trafton et al., 2003). Decay and interference are central components of a leading task interruption model: the *Memory for Goals* (MfG) model (Altmann & Trafton, 2002, 2007). According to MfG, encoded items from a suspended primary task decay unless regularly and opportunistically rehearsed (*strengthened*) during the secondary interrupting task period. An *interference threshold* determined by the level of activation of encoded primary task and secondary task memory traces will determine which items (if any) are active enough to be retrieved when memory is queried following interruption. Previously encoded items that fall below this threshold will require an activation boost from a primed retrieval cue. *Priming* takes time and if the relevant cue is not available following interruption, then encoded items risk being forgotten.

Studies have tested these MfG constraints and shown, for example, that demanding interrupting tasks that limit further rehearsal of encoded primary task information are more disruptive than less demanding tasks (Hodgetts & Jones 2006; Monk et al., 2008); a point echoed in classic memory disruption studies (Kroll & Kellicutt, 1972; Posner & Konick, 1966). Within the current paper, we explore whether opportunistic rehearsal of encoded primary task information can be compromised by the emotive content of secondary tasks and therefore not just due to the cognitive demands associated with completing them. The MfG model might support such an effect if elements of more meaningful emotive secondary tasks are encoded to a deeper level and receive higher activation than those that are less emotive. Other factors exacerbate the magnitude of interruption effects such as when a secondary interrupting task takes more than a few seconds to complete (Hodgetts & Jones 2006; Monk et al., 2008) and when cognitive load is high at the point of interruption (e.g., Bailey & Iqbal, 2008). For example, Monk et al. (2004) found longer resumption delays when a VCR programing task was interrupted during programming of event-sequences (high load) than before planning and execution of sequences (low load). Such effects are also accounted for by MfG model predictions according to differential encoding costs at the point in which an interruption occurs (Monk et al., 2004, p. 653). Thus, emotive secondary interrupting tasks introduced at task points associated with a high WM should be more disruptive than when introduced at lower WM load points; especially if the secondary tasks inhibit opportunistic rehearsal of encoded primary task items and retrieval cues. This should especially be the case when interrupted at the end of an encoding period as TBR items are no longer available within the task environment compared to interruption during an encoding period.

It is important to note that whilst the MfG (Altmann & Trafton, 2002, 2007) seems to support the above novel predictions, such effects tend to be examined using procedural primary tasks with goals or steps and through investigation of resumption lags. The current study employs a non-procedural or goal-directed memory-based primary task and examines memory for previously encoded *items* rather than time taken to resume the task through e.g., executing a suspended goal. Thus, predictions within the current paper based upon parameters of the MfG should be considered as tentative, yet, potentially important with future scope to test similar variables with different types of tasks and measures.

Given the amount of research concerning features such as interruption task demands (Hodgetts & Jones, 2006; Monk et al., 2008), cognitive demands at the point of interruption (e.g., Bailey & Iqbal, 2008; Monk, Boehm-Davies, & Trafton, 2004), similarity between interruption and primary tasks (Gillie & Broadbent, 1989; Ledoux & Gordon, 2006), and interruption duration (e.g., Monk et al., 2008, Hodgetts & Jones, 2006), it seems surprising that none have yet considered the effects of emotive interruption secondary tasks on primary task performance. There are numerous safety-critical examples of emotive secondary task situations such as a soldier suspending a map reading task to tend to an injured colleague, or a fire chief receiving an urgent update regarding a forest fire when trying to encode details relating to a current emergency situation. In each case, it is vital to accurately remember encoded information from the suspended primary task after returning from the emotive secondary task given that memory errors could be costly. Such secondary tasks are likely to capture attention, cause interference, limit rehearsal of encoded primary task information, and lead to decay and forgetting. Thus investigating and establishing their effects is important not only in terms of theory but also in terms of possible practical implications.

Next we consider what makes a secondary task emotive and whether there are reasons to suspect that different features of such tasks including type of emotivity (negative or positive valence) and degree of emotivity (valence strength) might cause different degrees of disruption to a memory-based primary task.

Emotive Secondary Tasks

Definitions of what constitutes an emotional stimulus have long been debated (see Barrett, 2012). It is generally accepted that a central feature is whether they involve positive (e.g., happy, excitement) or negative (e.g., sad, angry) reactions or feelings often referred to as valence (e.g., Bradley & Lang, 1999; Lang, Bradley, & Cuthbert, 2008) and that the degree of positive and negative valence can vary (Kensinger, 2004). For example, the magnitude of the emotional reaction to an image of a devastating earthquake (high negative valence) is likely to be stronger than that of an image of a dental examination (lower negative valence). Also, positive and negative valent emotive stimuli will often differ in arousal; relating to how calming or exciting they are (Kensinger, 2004). For example, one highly valent negative image may not be as arousing as another equally valent image. Valance (negative and positive) and degree of valance (i.e., ranging from mild to strong) are features of images used as secondary task interruptions within the current study. Image arousal is controlled for but not manipulated.

Unlike when distracted, to be interrupted assumes at least some engagement with a secondary task as well as an attentional shift from a primary task. Emotional stimuli tend to be engaging and often cause physiological reactions, variations to activity in particular brain regions, and behavioural changes. Physiological and behavioural reactions amongst normal functioning individuals include fluctuations in heart rate, respiration and flushed skin (Lane, Bucknall, Davis, & Beedie, 2012). Furthermore, outwardly expressed reactions to emotive stimuli can be characterised by behaviour (e.g., attention drawn to it), body language (e.g., withdraw from it), and facial expressions (e.g., disgust or like for it) (Schindler, van Gool, & De Gelder, 2008). The current study focusses more on the cognitive effects of emotive secondary task interruptions. There is evidence that emotional material is processed to a deeper level and remembered for longer and more vividly than non-emotional material (Dolcos, LaBar, & Cabeza, 2005; Kern, Libkuman, & Otani, 2005; Talmi, Schimmack, Paterson, & Moscovitch, 2007) particularly when negative (e.g. Kensinger, Garoff-Eaton, & Schacter, 2007a; Ochsner, 2000). These effects are often attributed to attentional narrowing (Easterbrook, 1959), especially when trying to explain enhanced memory for negative versus positive emotive stimuli (Chipchase & Chapman, 2013; Kensinger, Garoff-Eaton, & Schacter, 2006; Kensinger, Garoff-Eaton, & Schacter, 2007b; Loftus, Loftus, & Messo, 1987; Nobata, Hakoda, & Ninose, 2010).

Easterbrook's (1959) *cue utilization theory* asserts that emotional stimuli increase arousal and limit the range of available task-related cues (i.e., cause attentional narrowing). If over aroused – such as when already performing a demanding task – emotive stimuli can disrupt task performance. They reduce cue utilization by prioritizing task-relevant cues over task irrelevant cues. Thus, it can be posited that emotive secondary interrupting tasks will cause a narrowing of attention and reduce the processing of task irrelevant cues. Given that we are operationalizing them as secondary tasks, then the primary task becomes less relevant and cues processed from it suppressed in order to focus on cues relevant to the secondary and most currently focal task. Performance should therefore suffer when returning to the primary task as relevant cues will have decayed and thus may need to be reactivated. This account is fitting with some aspects of the MfG model (Altmann & Trafton, 2002, 2007); in particular the idea that decaying representations of items encoded prior to switching to an interrupting task may need reactivating and that such reactivation is dependent upon the availability of priming cues. If such cues have been suppressed (mental cues) and/or are no longer available within the task environment (environmental cues), then it is likely that primary task performance will suffer. That is, we would expect forgetting of previously encoded primary task information in conditions involving emotive secondary tasks; perhaps especially when such secondary tasks are high in emotivity.

Some have explored the effects of emotive stimuli not operationalized as secondary task interruptions on performance with mixed findings. For example, Wessa et al. (2013) found that highly arousing positive and negative images (from the International Affective Picture System/IAPS: Lang et al., 2008) presented as background distractions (not interruptions) during arithmetic problems increased solution times compared with neutral distractors, but did not increase performance errors. Together with fMRI data, solution time decrements were interpreted as adaptation to additional activation demands caused by the mere presence of the emotive distractions and extra activity in brain areas responsible for processing arithmetic tasks. In a simulated driving study, Chan and Singhal (2013) found that participants drove slower than advised when billboards placed throughout a scenario contained positive (e.g., glory) or negative (e.g., reject) valent words versus neutral (e.g., foot) distracting words, and this effect persisted for longer following positive valent words. However, and fitting with other literature (e.g. Kensinger et al., 2007a), more negative distractor words were recalled during surprise recall tests suggesting that they were encoded to a deeper level.

Others have examined the effects of exposure to emotive images before performing a task and immediately after encoding items within a task. Pereira et al. (2006) reported reduced reaction times in a detection task performed after exposure to blocks of highly negative valent IAPS images, although reaction times were faster following blocks of highly positive valent IAPS images. Findings were interpreted as carryover effects from a defensive attentional focus on negative stimuli and an appetitive motivational response to positive stimuli.

With some similarity to the current study, Erk et al. (2007) examined if WM is susceptible to interference from what they regarded as emotional image-based *distracting* stimuli and possible interactions with task load. They employed an item-recognition primary task, varied memory load (1 or 6 letters), and introduced IAPS images during a retention interval, i.e., after participants had encoded primary task information and were likely rehearsing it. They found *improved* hit-rates/false-alarms in the high WM load condition following exposure to positive and negative valent images compared with neutral. fMRI data revealed no increased WM related brain activity when emotive images were presented during high load trials. Like Wessa et al. (2013), effects were attributed to functional attenuation of visuo-spatial emotive distractor stimuli in order to free-up activation and provide an arousal boost for verbal to-be-remembered (TBR) information, especially under high WM load (see also Shakman et al., 2006).

At first glance, the Erk et al. (2007) findings suggest that emotive images introduced at a task point where participants should be rehearsing encoded task information (i.e., high WM load) were less disruptive than neutral images. However, they found comparable reaction times following positive, negative, and neutral images in the high load condition. But, reaction times were longer in the high compared to the low load condition and longer on positive and negative emotive image trials compared with no image trials in the low load condition. Thus the idea that resources are deployed to free-up activation may only apply when the ability to process primary task information becomes compromised due to high WM load. However, the primary task encoding phase lasted on 1.5-seconds, involved encoding very simple letter stimuli, and emotive images were presented relatively briefly (e.g., 4-seconds vs 7-seconds in Wessa et al., 2013). Within an interruption study, Hodgetts and Jones (2006) found that shorter secondary interrupting tasks (6-seconds) were less disruptive than longer tasks (18-seconds). Thus, it may be that the images were not presented for long enough to markedly disrupt WM within the Erk et al. (2007) study and that the encoding a retention periods were too short to have resulted in significant decay of primary task information. The current study involved more TBR items (16 words vs 6 letters in Erk et al., 2007), a longer encoding period (30-seconds) and secondary task images were displayed for 10-seconds with participants having to engage with them by rating valence.

Taken together, these findings suggest that performance measures other than response times are largely spared from disruption by emotive stimuli that would be expected to compete for cognitive resources. This is surprising given evidence concerning how emotive stimuli can commandeer cognition and cause powerful effects such as attentional narrowing (e.g., Easterbrook, 1959). Maybe then, other tasks and paradigms need to be employed to further try and tease apart possible effects on for example, memory. The current study adopts a free recall primary task where WM load can be even higher than in tasks used in other studies (e.g., Erk et al. 2007) and a secondary task interruption paradigm where participants have to engage with emotive images by rating how valent they are.

It remains to ask whether valance type (negative vs positive) and strength (e.g., mild to strong) of a secondary task might mediate the disruptive effects of emotive interrupting secondary tasks on a WM primary task. Baumeister, Bratslavsky, Finkenauer, & Vohs (2001) stress that negative emotions, emotional memories, and emotive events dominate thoughts and behaviour more than positive equivalents. As noted earlier, Pereira et al. (2006) found images high in negative valence (e.g., mutilated bodies) increased reaction times in subsequent tasks compared with positive valent images (e.g., babies). In contrast, there was a non-significant trend for negative images to invoke longer reaction times than positive images in the low load condition of the Erk et al. (2007) study. When viewing faces, attention is drawn more towards those conveying negative than positive emotion (e.g., Feldmann-Wüstefeld, Schmidt-Daffy, & Schubö, 2011). Also, it has been shown that strong unpleasant stimuli produce greater interference than milder and moderate stimuli (Mogg, McNamara, Powys, Rawlinson, Seiffer, & Bradley, 2000; Schimmack, 2005). In general then, attention seems biased more towards negative than positive emotive stimuli; especially when such stimuli contain stronger emotive content.

Predictions

Information encoded in WM at the time of experiencing a secondary interrupting task is vulnerable to being forgotten due to decay and interference effects (Altmann & Trafton, 2002, 2007). Emotive interrupting tasks should be no exception although may have differential disruptive effects depending upon their type (negative or positive) and degree of valence. The cue utilization account (Easterbrook, 1959) suggests that attention will narrow in on emotive stimuli within secondary interrupting tasks that will then receive more activation at the cost of maintaining activation of cues encoded from primary tasks. The MfG model posits that primed primary task cues are essential in order to retrieve previously encoded suspended items (Altmann & Trafton, 2002, 2007). Given that emotive secondary tasks are likely to impair such processing and hinder opportunistic rehearsal of encoded primary task information, a key prediction linking elements of both theoretical frameworks is that emotive interruptions will impair memory recall and that the degree of secondary task valence will increase the disruption caused and subsequent forgetting (e.g., Mogg et al., 2000; Schimmack, 2005). A second prediction is that disruption will be greater when emotive secondary tasks occur at higher WM load task points (Bailey & Iqbal, 2008; Monk et al., 2004). Emotive secondary tasks will occur at three task points: before, during and after encoding of primary task information and a negative linear trend in subsequent memory recall is expected. Memory recall will be worse when interrupted at the end of an encoding period as TBR items are no longer available within the task environment compared to interruption during an encoding period. Finally, negative emotive stimuli are often more attention grabbing and memorable than positive emotive stimuli (Kensinger et al., 2006; 2007a, 2007b; Nobata et al., 2010), especially when high in valence (Feldmann-Wüstefeld et al., 2011; Schimmack, 2005; Vuilleumier, 2005). Thus, negative valent secondary tasks should be more disruptive to processes of maintaining encoded information in WM than positive valent image-based secondary tasks, especially when higher in negative valence.

Experiment 1

The main aim of Experiment 1 is to establish whether image-based secondary tasks that disrupt the flow of a WM task and vary in the degree of negative valence impair memory performance. Only negative valent images are used in Experiment 1 to rule-out possible asymmetric transfer effects (Poulton, 1982) that could occur if including both negative and positive valent images within the same repeated measures design. Images were from the IAPS (Lang et al., 2008) that has been widely used by those studying effects of emotive image-based stimuli on task performance (e.g., Erk et al., 2007; Pereira et al., 2006; Wessa et al., 2013). IAPS images vary in terms of valence (e.g., lower ratings indicating greater negativity) as well as arousal (e.g., higher ratings indicating greater arousal). This enabled three negative valence conditions to be created with each clearly differentiated by degree of valence (referred to as mild, moderate, and strong hereafter) yet all with comparative levels of arousal. Neutral non-emotive TBR words were sourced from the standardized Affective Norms for English Words database (ANEW: Bradley & Lang, 1999). Secondary task images occurred at different points during the primary task: pre-encoding (lowest WM load), during-encoding (moderate WM load), and post-encoding (highest WM load). The during-encoding condition is most like a task interruption according to a strict definition of something that takes attention away from a primary task, although the post-encoding condition also takes attention away from rehearsing information and cues already encoded and thus is also interrupting. The pre-encoding condition whist not really interrupting encoding or rehearsal of information nevertheless may cause retroactive interference as suggested by Pereira et al. (2006). It also serves as a baseline condition to compare against the other interruption points.

To encourage engagement with secondary task emotive images, participants rated their valence.

It is predicted that secondary tasks involving negative emotive images will disrupt the ability and opportunity to maintain active representations of encoded words and retrieval cues in WM (Altmann & Trafton, 2002, 2007; Easterbrook, 1959) and result in diminished free recall performance. Linear trends are predicted with memory recall decreasing as negative valence of secondary task images increases (Kensinger & Corkin, 2003) and when WM load is higher at the point in which a secondary task occurs (Bailey & Iqbal, 2008; Monk et al., 2004) with differences in cue availability post-interruption. Moreover, if the degree of negative valence plays a key role in determining the ability to maintain encoded items and retrieval cues in memory *as well as* WM load at the point when the secondary task occurs, an interaction should occur. That is, strong negative valent images should be more disruptive than mild negative images when positioned at higher WM load task points.

Method

Participants. Thirty-two undergraduate students from the University of the West of England (UWE) – Bristol, UK participated as part of a course requirement. This was adequate to detect a medium effect size (Cohen's *f* = .25) with power of .8 (determined using G*Power 3.1.7 software: Faul et al., 2007). Ages ranged from 18 to 30 years of age *(M* = 21.32, *SD* = 2.78), and 23 were women. None reported having current/past emotional, anxiety or behavioural disorders or having experienced a significant emotional life event (e.g., death/major illness of a loved one, major breakdown in a relationship, major personal injury/illness, pregnancy, victim of a crime, serious financial problems) within 12-months of taking part. None were color blind.

Materials. The Experiment was run on Dell© Core™i3 PCs connected to 1920x1080 Dell© 54.61cm flat-panel monitors. The first few screens were controlled by pressing the spacebar, and contained basic task instructions. A screen displaying two high negative valence IAPS images (not used after) was included so participants could judge whether they were comfortable participating. Forty-five experimental trials contained sets of 15 English words selected from the ANEW database (Bradley and Lang, 1999) simultaneously presented in a black Arial font size 48 on a white background in 5 rows x 3 columns. Bradley and Lang (1999) posit that words with valence ratings closest to the middle of the scale (i.e., rating of 5.0 out of 1.0-9.0) are neutral in terms of valence and neither positive nor negative. There are only 17 words within ANEW with valence ratings of 5.0. Thus the 675 words needed for the current experiment (i.e., 45 sets of 15 words) were chosen as follows: 17 words had valence ratings of 5.0, 329 had ratings between 4.12 and 4.98, and, 329 had valence ratings between 5.02 and 5.55. Example words include: ‘stove’ (valence = 4.98), ‘foot’ (valence = 5.02), ‘listless’ (valence = 4.12), and ‘name’ (valence = 5.55). Words were randomly distributed to trials although after this, attention was given to not having words within a trial that sound the same (e.g., rock, clock) or are semantically similar (e.g., wine, glass). It was also ensured that trials contained similar numbers of low-frequency (e.g., pamphlet) and high frequency (e.g., bone) words (British National Corpus: http://www.natcorp.ox.ac.uk/). During each trial, words were presented simultaneously for 30-seconds without a retention interval. When disappeared, and unless a secondary task occurred in between, participants had 30-seconds to write down as many words as they could remember in any order within an answer booklet.

Thirty-six trials contained secondary tasks (one per trial) with images that covered the entire screen for 10-seconds. When a secondary task occurred, the trial timer froze and restarted after the image disappeared. Nine trials contained secondary tasks with neutral images consisting of a black and white fixation cross in the middle of a white screen. A fixation cross was used to encourage participants to focus on the otherwise blank computer screen, and, to not invoke a positive or negative emotional reaction. All other secondary task trials contained negative valent images from IAPS (Lang et al., 2008) with valance ratings in the bottom 30% of IAPS rated images (Table 1). Nine were from the lowest 5% of IAPs valance ratings (*M* valence = 1.63, *M* arousal = 6.55) and assigned to a strong negative valent image category. Nine were from the lowest 12.5%-17.5% of IAPs valence ratings (*M* valence = 2.76, *M* arousal = 6.11) and assigned to a moderate negative valent category. Nine were from the lowest 25%-30% of IAPs valence ratings (*M* valence = 3.83, *M* arousal = 6.08) and assigned to a mild negative valent category. A one-way ANOVA confirmed a significant difference between average valence ratings for these three categories, *F*(2, 24) = 761.87, *MSE* = .014, *p* < .001 with each category significantly differing (*ps* < .001). There was no difference in arousal ratings between valence categories, *F*(2, 24) = 2.05, *MSE* = .30, *p* = .15.

Design. A repeated measures design was adopted. Valence of negative secondary task images was manipulated as one independent variable (IV) with four levels: neutral/control; mild negative valence; moderate negative valence; and, strong negative valence. Secondary tasks occurred at three different points during memory recall trials (the second IV): immediately before words were presented (pre-encoding/lowest WM load); 15-seconds after words appeared (during-encoding/moderate WM load) with words presented for a further 15-seconds after an image had disappeared; and, immediately after words disappeared (post-encoding/highest WM load). Nine trials did not contain secondary tasks in order to provide baseline recall data and to reduce the predictability of trials containing secondary tasks. These always remained in the same trial positions (1, 7, 15, 17, 20, 23, 30, 37, and 43). Eight randomly generated trial sequences of secondary task valence x secondary task treatment combinations were generated with 4 participants completing each version. The dependent variable was the number of words correctly recalled (maximum = 15 per trial).

Procedure. Up to 10 participants were tested simultaneously in silent separated laboratory booths and each was seated 60cm from the centre of computer screens. They were given instructions and a booklet to write down words during recall periods and to rate the valence of secondary task images. An experimenter was present at all times to ensure participants did not attempt to write words until the recall instruction appeared. Participants were told that an image would occur during some trials and that they needed to rate each image in terms of its valence using a Likert scale ranging from 1 (highly negative) – 9 (highly positive). They had to write a valence rating next to the trial number in the answer booklet whilst the image was displayed. They were instructed to 'think about the images that may appear during some of the memory recall trials' and to only make a valence rating when confident that it reflected how they felt about the image. They were also encouraged to look back at the image and continue thinking about it even if a valance rating was made before the image disappeared. A practice phase involved a control memory recall trial (no secondary task) and then exposure to two strong valent negative images (both for 10-seconds). These allowed participants to judge whether they were willing to be exposed to such images during the experiment and to practice recording a valence rating during the 10-second period. Five participants failed to record a rating for the first image before it disappeared although all rated the second image. The experimental trials started after pressing a key. In multiple testing situations all participants pressed the key at the same time. Participants were debriefed and listened to an up-tempo music track before leaving the laboratory. The experiment lasted 70 minutes.

Results and Discussion

All tests are two-tailed with alpha levels of .05. Effect sizes were determined using Cohen's *d* for t-tests (with .2, .5 and .8 indicating small, medium and large effect sizes respectively) and Cohen's *f* for F tests (with .1, .25 and .4 indicating small, medium and large effect sizes) (Cohen, 1988). First, it was important to determine whether secondary task images, irrespective of content and position, had a detrimental effect on memory recall (Figure 1). Mean recall was significantly higher on control (*M* = 7.04, *SD* = 1.26) than secondary task trials (*M* = 6.50, *SD* = .94), *t*(31) = 5.53, *p* < .001, *d* = 1.99, although interestingly was significantly higher for secondary task trials that contained neutral images (*M* = 7.21, *SD* = .1.32) than for control trials, *t*(31) = 2.51, *p* = .018, *d* = .90. The latter finding indicates a facilitation rather than inhibitory effect of being exposed to and having to think about a *meaningless* image involving a black fixation cross on a white background. Whilst this might not appear surprising given that this condition possibly afforded a period (after making a valence rating) to further strengthen items already encoded in memory more so than in the mild-strong valent image conditions, it was still a secondary task that took attention away from the primary task. Nevertheless, participants may have been able to strategically use some of this period (and more so than when valent images were used) to further strengthen representations of encoded items in memory; increasing the chances of successfully retrieving them at recall. However, and if this were the case, we would expect memory recall to be higher within this condition when neutral secondary tasks occurred during- and post-encoding as no words were available to rehearse when such tasks occurred pre-encoding.

We also examined whether there were differences in participant (note not IAPS) valence ratings for the different images across the four valence categories (neutral, mild, moderate, strong). A repeated measures ANOVA confirmed a difference, *F*(3, 24) = 101.95, *MSE* = .15, *p* < .001, *f* = 3.56, with a higher rating for neutral (*M* = 5.10, *SD* = .19) versus mild (*M* = 3.96, *SD* = .17), moderate (*M* = 2.95, *SD* = .50) and strong (*M* = 2.14, *SD* = .42) negative valence images (*ps* < .001). Ratings for strong negative valent images were also significantly lower than mild negative valent images (*p* < .001) and whilst lower than moderate negative valent images, were not significantly different (*p* = .09). Moderate valent images did receive significant lower valence ratings than mild images (*p* = .005). No image within a category had a mean valence rating higher than the mean rating for the next highest valence rating category. The highest mean rating for an image in the strong valence category was 2.91 whilst the mean for the moderate category was 2.95, and the highest mean rating for an image in the moderate valence category was 3.66 whilst the mean for the mild category was 3.96. The lowest rating for a fixation cross control-neutral image was 4.84 and thus markedly higher than any image within the mild negative valence category. Therefore, we are confident that the neutral secondary task condition served as an effective control in terms of being treated as having neutral valence. A black fixation cross on a white background was rated as neither negative nor positive (noting that an absolute neutral rating would be 5.0).

Next we consider secondary task conditions only. Figure 1 illustrates that recall was highest in the neutral condition and reduced as the negative valence of images increased from mild to strong. Also, the number of words correctly recalled decreased across WM load positions. A factorial 4 x 3 repeated measures ANOVA revealed significant main effects of image valence (with a Huynh-Feldt correction due to a violation of sphericity, $p < .001$), $F(2.18, 64.23) = 27.03$, $MSE = 1.50$, $p < .001$, $f = .93$, and image position, $F(2, 62) = 23.45$, $MSE = .49$, $p < .001$, $f = .87$. As predicted, there was also a significant linear trend for image valance, $F(1, 31) = 48.22$, $MSE = 1.78$, $p < .001$, $f = .125$. As negative valence strength increased, recall decreased proportionally. Also, and as predicted, there was a significant linear trend for image position $F(1, 31) = 43.99$, $MSE = .52$, $p < .001$, $f = 1.19$. As WM load at the point in which a secondary task occurred increased, recall decreased proportionally.

The interaction was also significant, $F(6, 186) = 5.64$, $MSE = .49$, $p < .001$, $f = .43$. Bonferroni post-hoc tests revealed that the number of words correctly recalled did not differ across positions during neutral image trials (all $ps \geq .69$). In the strong negative valence condition, significantly fewer words were recalled when images occurred post-encoding than pre-encoding or during-encoding ($ps < .001$ and .004 respectively) and when they occurred during-encoding compared with pre-encoding ($p = .031$). A similar pattern was found in the moderate negative valence condition with significantly fewer words recalled when images occurred post-encoding than pre-encoding or during-encoding (*ps* = .001 and .038 respectively) and when they occurred during-encoding compared with pre-encoding (*p* = .027). Thus, whilst it is clear that exposure to moderate-strong negative valent images during secondary tasks impaired the ability to maintain encoded representations of words and possibly retrieval cues within WM, the level of disruption was intensified due to a higher WM load at the point in which an emotive secondary task occurred. In the mild negative valence condition, significantly fewer words were recalled when images occurred post-encoding than pre-encoding (*p* < .001) and during-encoding than pre-encoding (*p* = .036) but there was no difference between during-encoding and post-encoding positions (*p* = .56).

Furthermore, when secondary tasks occurred post-encoding, those involving strong negative valent images were more disruptive than neutral, mild negative and moderate negative valent images (*ps* < .001, = .001, and .048 respectively). At this position, moderate and mild negative valent images were also more disruptive than neutral images (*ps* < .001 and = .001 respectively) but recall on moderate and mild negative trials did not differ (*p* = .71). When secondary tasks occurred during-encoding, images with strong negative valence were again more disruptive than neutral and mild negative valence images (*ps* < .001 and = .001 respectively) but were not more disruptive than moderate negative valent images (*p* = .44). Also at this position, moderate and mild negative valent images were more disruptive than neutral images (*ps* < .001 and = .001 respectively), but, there was no difference between moderate and mild trials (*p* = 1). This latter finding illustrates that moderate and strong valent images were equally disruptive at a task point where participants were still able to encode and/or further strengthen representations of already encoded words after completion of the secondary task. Finally, when secondary tasks occurred pre-encoding, only images with strong negative valence were more disruptive than neutral and mild negative valence images (*ps* = .003 and .01 respectively). This is interesting as it suggests a carryover disruptive effect of exposure to highly valent negative images prior to any TBR words being presented (similar to Pereira et al. 2006 and possibly due to attentional narrowing: Easterbrook, 1959). There were no other significant differences.

Even though valence is the main dimension of emotive images that we are concerned with in this paper, it is still important to check whether arousal ratings contributed in any way to the memory recall findings. The mean number of correctly recalled words for each of the negative valance images used were calculated and tabulated with IAPS arousal rating for each image (Table 2). Pearson’s correlations revealed non-significant relationships in memory recall and arousal for mild negative valent images, $r(9) = .00$, $p = 1$, moderate negative valent images, $r(9) = -.52$, $p = .16$, and strong negative valent images, $r(9) = -.21$, $p = .59$. Thus we can tentatively rule out a contributory effect of the arousal of negative secondary task images on memory recall findings in Experiment 1.

In support of our predictions, the findings suggest that secondary tasks containing negative valent images disrupt WM, especially when high or moderately high in valence (e.g., Kensinger & Corkin, 2003) and when positioned at primary task points associated with a high WM load (e.g., Bailey & Iqbal, 2008; Monk et al., 2004). Secondary task images with mild negative valence were also disruptive, but only when positioned at task points with a high encoding or encoding/rehearsal load. Thus, participants did not seem to be able to inhibit negative valent images other than when they were mild or moderate and positioned at a task point associated with a low WM load. Overall, the processes involved in dealing with negative valent image-based secondary tasks such as attentional narrowing (Easterbrook, 1959) and encoding (e.g., Chipchase & Chapman, 2013; Kensinger et al. 2006; Loftus et al., 1987) were cognitively pressing enough to disrupt the maintenance of representations of primary task words in WM (so also linked with some MfG predictions: Altmann & Trafton, 2002, 2007). Furthermore, these effects occurred independently of even minor differences in the emotive arousal associated with the images used.

Now that we have established the effects of secondary tasks involving negative valent images experienced at different points of a free recall WM task, it is also important to consider the effects of positive valent images. This forms the main aim of Experiment 2.

Experiment 2

In Experiment 2 we examine the effects of secondary tasks involving positive themed images with IAPS valence levels comparable to those used in Experiment 1. As in Experiment 1, it is predicted that secondary tasks involving positive valent images will be more disruptive to memory recall compared to those involving neutral images. Also, a linear trend is predicted with memory recall decreasing as the positive valence of images increases. Based upon variety of studies that find positive stimuli tend to be less attention grabbing than negative stimuli (e.g., Feldmann-Wustefeld et al. 2011; Kensinger et al., 2006, 2007b) and are less likely to cause attentional narrowing (Easterbrook, 1959) and exclusion of (primary) task irrelevant cues, a valence and WM load interaction is not expected.

It is also worth highlighting again why the negative and positive valence conditions in Experiments 1 and 2 were not combined within the same Experiment. This is because our main aims relate to the valence strength of emotive images rather than factors such as arousal. Also, whilst it is possible to find IAPS images with comparative levels of negative and positive valence in terms of the average distance from a neutral 5.0 valence rating, it is difficult to also calibrate suitable positive and negative images in terms of arousal. Strong negative valent IAPS images (e.g., scenes of death, mutilation, etc.) often have higher arousal ratings than highly positive IAPS images (e.g., scenes of puppies, beaches, etc.). Nevertheless, general comparisons between positive and negative valent images will be considered within the General Discussion, although these must be treated with caution given the above points.

Method

Participants. Forty undergraduate UWE – Bristol students participated. This was slightly more than enough to detect a medium effect size (Cohen's *f* = .25) with power of .8. Ages ranged from 18 to 29 years of age (*M* = 20.85, *SD* = 2.74), and 27 were women. Everything else was the same as in Experiment 1.

Materials. Twenty-seven trials contained secondary tasks with positive valent images and ratings within the highest 30% of all IAPS images (Table 3). Nine were selected from the highest 5% of IAPs valence ratings (*M* valence = 8.07, *M* arousal = 4.94) for the strong valent category, nine from the highest 12.5%-17.5% of IAPs ratings (*M* valence = 7.0, *M* arousal = 5.08) for the moderate category, and nine from the highest 25%-30% of IAPs ratings (*M* valence = 6.36, *M* arousal = 4.78) for the mild category. A one-way ANOVA confirmed a significant difference between average valence ratings for these categories, *F*(2, 24) = 447.59, *MSE* = .015, *p* < .001, with each category significantly differing (*ps* < .001). Mean arousal ratings for each category did not differ, *F*(2, 24) < 1, *p* = .72. Average valance ratings for positive images were as equally distant from the middle of the valance scale (i.e., a 5.0 rating) as the negative images used in Experiment 1 (i.e., *M* = 2.74 in Experiment 1 and 8.34 in Experiment 2), *t*(52) = .53, *p* = .60. Everything else was the same as in Experiment 1.

Design. Everything was the same as in Experiment 1 except that positive mild, moderate and strong positive valent images replaced images within secondary tasks. Also, it was no surprise to find a significant difference in arousal ratings between positive valent images used in Experiment 2 (*M* = 4.93, *SD* = .77) and negative valent images used in Experiment 1 (*M* = 6.24, *SD* = .58), *F*(1, 52) = 50.15, *p* < .001. As noted earlier, this is one reason why Experiments 1 and 2 are treated separately.

Procedure. The same as in Experiment 1 except that two IAPS positive themed images were used during the practice phase of Experiment 2.

Results and Discussion

As in Experiment 1, mean recall was significantly higher for trials involving secondary tasks (*M* = 7.18, *SD* = 1.04) than control trials (*M* = 6.78, *SD* = .79), *t*(39) = 4.74, *p* < .001, *d* = 1.52, Figure 2. Unlike Experiment 1, memory recall was not significantly higher on secondary task trials involving neutral images (*M* = 7.30, *SD* = .1.08) than on control trials, *t*(31) = 1.58, *p* = .12, Figure 2. We also examined whether there were differences in participant valence ratings for images across the four valence categories (neutral, mild, moderate, strong). A repeated measures ANOVA confirmed a difference, *F*(3, 24) = 52.33, *MSE* = .10, *p* < .001, *f* = 2.55, with a lower rating for neutral (*M* = 5.21, *SD* = .18) versus mild (*M* = 6.14, *SD* = .31), moderate (*M* = 6.62, *SD* = .26) and strong (*M* = 6.91, *SD* = .35) positive valent images (*ps* < .001). Participant ratings for strong positive valent images were also significantly higher (i.e., more positive) than mild positive valent images (*p* < .001) *but* did not differ from moderate positive valent images. Moderate positive valent images were rated significantly higher than mild positive images (*p* < .001.). The lowest mean rating for an image in the strong valence category was 6.45 (sea) whilst the mean for the moderate category was slightly higher at 6.62, and only one other image in the strong valance category had a rating lower than this mean (6.58, beach). The lowest mean rating for an image in the moderate valence category was 6.18 whilst the mean for the mild category was 6.14. The lowest rating for a fixation cross neutral image was 4.93 and was markedly higher than the mean for the mild positive category as well as any individual image within that category (lowest rated image = 5.63, clowns). The highest rating for a fixation cross neutral image was 5.5 and lower than any image within the mild positive category. Thus, and as in Experiment 1, we can be confident that the neutral condition served as an effective control for the positive valent conditions in Experiment 2. It is worth noting that participant mean valence ratings for the positive images were lower than IAPs valence ratings (mild category *M* = 6.14, IAPs = 6.36; moderate category *M* = 6.62, IAPS = 7.0; strong category *M* = 6.91, IAPs = 8.07).

Next we consider memory recall for secondary task conditions. Figure 2 illustrates that recall was highest in the neutral image condition and increased as the positive valence of secondary task images decreased from strong to moderate and mild (*M* = 6.87, 6.45, and 6.49 respectively) although was almost identical for strong and moderate valence conditions. Also, noticeably fewer words were correctly recalled when secondary tasks occurred during-encoding (*M* = 6.70) and post-encoding (*M* = 6.60) than pre-encoding (*M* = 7.04). A factorial 4 x 3 repeated measures ANOVA revealed significant main effects of image valence (with a Huynh-Feldt correction due to a violation of sphericity, *p* = .02), *F*(2.68, 104.47) = 20.46, *MSE* = 1.04, *p* < .001, *f* = .72, and image position, *F*(2, 78) = 13.27, *MSE* = .66, *p* < .001, *f* = .58. As in Experiment 1, there was a significant linear trend for image valance, *F*(1, 39) = 35.20, *MSE* = 1.40, *p* < .001, *f* = .95, indicating that as positive valence strength increased, memory recall decreased proportionally. There was also a significant linear trend for image position *F*(1, 39) = 21.23, *MSE* = .75, *p* < .001, *f* = .74, indicating that as WM load at the point of in which an image occurred increased, memory recall again decreased proportionally. However, and as predicted, there was a non-significant interaction, *F*(6, 234) = 1.50, *MSE* = .47, *p* = .18 indicating that unlike Experiment 1 with negative images, the degree of impairment to recall caused by secondary tasks involving the rating of positive images was not dependent upon WM load at the point in which the secondary task occurred.

The mean number of correctly recalled words for each positive image together with its IAPS arousal rating were collated (Table 4). Pearson’s correlations revealed non-significant relationships in the mild, *r*(9) = .12, *p* = .76, moderate, *r*(9) = .51, *p* = .16, and strong negative valent conditions, *r*(9) = .21, *p* = 58, allowing us to tentatively rule out a contributory effect image arousal on memory recall performance; as was the case in Experiment 1.

As in Experiment 1 with negative valent images, positive valent images also seem to impair the ability to maintain active representations of encoded primary task words and associated retrieval cues in memory. Also, positive valent images are disruptive when positioned at higher WM load task points. Unlike Experiment 1, the degree of valance associated with positive images and WM load at the point in which a secondary task occurred did not exacerbate the level of disruption and this is possibly due to weaker attentional narrowing effects (Easterbrook. 1959) and subsequently less suppression of primary task cues that might help to improve memory recall when returning to the suspended primary task.

General Discussion

Two novel experiments were conducted to explore whether secondary tasks involving rating emotive images interfered with WM processes during performance of a free recall verbal memory task. As predicted, memory recall was impaired on trials involving both negative (Experiment 1) and positive (Experiment 2) valent image-based secondary tasks with both effects qualified by significant linear trends. Specifically, memory recall decreased as valence strength increased fitting with an attentional narrowing and cue utlilization theoretical account (Easterbrook, 1959). Also, and again as predicted, memory recall decreased when WM load was higher at the point in which secondary tasks occurred, particularly when interrupted after encoding of primary task information. This finding is supported by MfG model predictions (Altmann & Trafton, 2002, 2007) based upon the lack of environmental retrieval cues post-interruption in the after-encoding compared to the during-encoding condition. This was the case in both Experiment 1 involving negative valent images and Experiment 2 involving positive valent images. There was also a significant interaction between the degree of negative valance and the position of secondary tasks within in

Experiment 1. Secondary tasks involving rating images with moderate and strong negative valance were more disruptive than those involving mild negative valance images when positioned at high WM load task points (i.e., during-encoding and post-encoding). This was predicted by drawing upon parameters of the attentional narrowing and cue utlilization framework (Easterbrook, 1959) and the MfG model (Altmann & Trafon, 2002, 2007); specifically in relation to the suppression of primary task items and cues and giving more priority to cues within the current interrupting secondary task. Interestingly, strong negative valent images were more disruptive than neutral and mild-negative valent images when positioned at a task point where WM load should be lowest (pre-encoding), suggesting a carryover effect of exposure to such images even before primary task words were available to encode (see also Pereira et al. 2006 using a different paradigm).

In Experiment 2, positive image valance strength and secondary task position did not interact. At first glance, this suggests that negative valent images (Experiment 1) are more disruptive than positive valent images (Experiment 2) when WM load is high at the point in which a secondary task occurs. However, such an interpretation needs to be treated with caution as participants within Experiment 2 gave similar valence ratings to images within moderate and strong valence categories even though they were initially categorised (and were significantly different) based upon IAPS valence ratings (Lang et al., 2008). There are a number of reasons why valance ratings of positive moderate and strong images were not similar to those in the original IAPS study. It could have been that some positive emotive IAPS images differentiated by valence are perceived to be similar when experienced as secondary or interrupting tasks using the paradigm adopted within the current experiment. However, we should have expected a similar pattern for negative images in Experiment 1, which was not the case. It is possible that the similar positive valance ratings were due to individual differences in affect and/or emotional regulation that were not controlled for in the current experiments. Specifically, participants in Experiment 2 may have had lower positive affect and/or suppressed their positive emotions more than would be expected amongst a random sample of undergraduate psychology students. There may also be possible cultural differences in positive valance between the UK participants that took part in the current study and the North American participants that rated the IAPS images in the Lang et al (2008) study (e.g., Lasaitis, Ribeiro, & Bueno, 2008; Lohani, Gupta & Srinivasan, 2013; Ramirez, Hernandez, Sanchez, Fernandez, Vila, Pastor, et al., 1998; Verschuere, Crombez, G., & Koster, 2001). These are all areas that warrant future investigation; especially in terms of studies concerning the effects of emotive secondary tasks on performance of a primary task.

The significant interaction in Experiment 1 can be explained by negative images with a high degree of valance causing more attentional narrowing and suppression of suspended primary task cues (e.g., Easterbrook, 1959) as well elements of the images undergoing deeper processing and encoding (Chipchase & Chapman, 2013; Kensinger et al. 2006, 2007b; Loftus et al., 1987; Nobata et al., 2010). These effects were strong enough to disrupt the ability to maintain active representations of encoded information and possibly retrieval/priming cues in WM (e.g., Altmann & Trafton, 2002, 2007), especially at task points associated with a moderate to high WM load (Bailey & Iqbal, 2008; Monk et al., 2004). Like Experiment 1, the results of Experiment 2 suggest that secondary tasks involving positive valent images also cause attentional narrowing and primary task cue suppression and those with a higher degree of valance undergo deeper processing and encoding. However, in contrast to Experiment 1, the severity of the disruption caused by positive valent IAPS images did not seem to depend upon WM load at the point of in which a secondary task occurs if we are willing to accept original IAPS valance ratings in terms of differentiating valence strength categories within the current Experiment 2. It is also important to note that the interaction in Experiment 2 was not marginally non-significant (*p* = .20) Also, power was higher than in Experiment 1 with 40 participants. In Experiment 1, the significant interaction was found with 20% fewer participants and had a large effect size. Future studies should further investigate the effects of emotive secondary task interrupting images on performance of a primary task to try and replicate and extend the current findings. For example, using different sets of existing emotive image-based stimuli (e.g., Geneva Affective Picture Database/GAPED: Dan-Glauser & Scherer, 2011) and emotive images directly related to the lives and occupations of participants (e.g., Military Affective Picture System/MAPS: Goodman, Katz, & Dretsch, 2016) or even using new sets of emotive images.

Recall on negative valance trials in Experiment 1 (*M* = 6.26) was lower than positive valence trials in Experiment 2 (*M* = 6.60) with the biggest difference between the strong valence negative and positive conditions (*M* = 5.88 and 6.48 respectively). However, these trends can only be treated as indications that negative valent images were more disruptive than positive valent images given that the average IAPS arousal ratings were lower for positive than negative images (*M* = 4.93 versus 6.24). Indeed, and as discussed earlier in the current paper, calibrating both valance and arousal of IAPS images for a design like the one we employed is incredibly difficult and would have resulted in fewer repeats of treatment combinations and reduced power. Nevertheless, our recall data seemed to be unaffected by even minor differences in arousal associated with the images used given that there were no relationships between the number of words correctly recalled and arousal level (based upon IAPS ratings) in Experiments 1 and 2.

Another important point is that the ‘during-encoding’ and ‘post-encoding’ points were most akin to our earlier definition of being interrupted (i.e., taking attention away from encoding and rehearsing items within a primary task and engaging with a secondary task); especially the during encoding condition. The ‘pre-encoding’ condition (similar to that used in Pereira et al., 2006) was less like an interruption in that there were no items within the primary task or residing in memory to disrupt. Nevertheless, and as with the other secondary task conditions, participants had to think about and rate images that varied in terms valence. The fact that memory recall was impaired on trials involving secondary tasks with strong negative valent images is testimony to the possibility that engaging with such stimuli prior to performing a free recall memory task can have negative consequences. It is therefore not only response times that are impaired by some types of valent images experienced prior to performing a task (Pereira et al., 2006).

Taken together, the current findings suggest that emotive visuo-spatial secondary tasks, operationalised as task interruptions, *can* impair WM performance within a verbal primary task; adding to literature involving different paradigms that have tended to report effects only on primary task performance speed and/or reaction times (often disruptive: e.g., Wessa et al., 2013; Pereira et al., 2006; sometimes beneficial: Erk et al., 2007). For example, Erk et al. (2007) found that verbal WM was not susceptible to interference from pictorial visuo-spatial distractor information in a high WM load condition; fitting with the idea that there might be limited competition for similar attention resources (see also Shackman, Sarinopoulos, Maxwell, Pizzagalli, Lavric, & Davidson, 2006). They also found in some cases WM was enhanced in the presence of positive and negative valent distractors and posited this might have been due to an arousal boost and/or an effect of processing spatial information indirectly enhancing verbal WM performance. This could not however explain why performance was better in the neutral and no distractor picture condition; unless the neutral condition had an attenuating effect due to having lower arousal properties. Erk et al. (2007, p. 629) noted that these possible explanations for effects were tentative with more research required. However, there are key differences between our tasks and paradigm to that used by Erk et al. (2007). Images were only presented for 4-seconds in the Erk et al. (2007) study versus 10-seconds in the current study. It could be that images were not presented for long enough to markedly disrupt WM in the high load condition within the Erk et al. (2007) study. Also, participants had to engage with secondary tasks in the current study. Additionally, WM load within the primary task used for the current study (16 words per trial) was higher than in the Erk et al. (2007) study (up to 6 letters) with a much longer encoding phase (30-seconds vs 1500-ms). We suggest that all of these differences might explain why our study revealed not only significantly impaired primary task WM performance due to emotive secondary tasks but also differences with large effect sizes.

Overall, these novel findings contribute to evidence concerning effects of secondary interrupting tasks on performance particularly in relation to the forgetting of encoded information (e.g., Altmann et al., 2014; Morgan & Patrick, 2013; Morgan et al., 2009, 2013). They reveal for the first time that secondary interrupting tasks with negative (Experiment 1) and positive (Experiment 2) emotive valence properties impair memory recall. This is important for the interruption literature in terms of conditions that involved disrupting WM during-encoding and post-encoding as these conditions were most like task interruptions and can tentatively be explained by activation and priming cue parameters of the MfG model (Altmann & Trafton, 2002, 2007). The findings also provide additional support to the view that cognitive load (in this case WM load) at the point in which a negative valent secondary task occurs can intensify the degree of disruption caused which is also fitting with predictions of the MfG model (e.g., Altmann & Trafton, 2002, 2007; Monk et al., 2004).

It is also important to note that unlike some other studies involving interruption (e.g., Altmann & Trafton, 2007; Monk et al. 2004) and distraction (e.g., Wessa et al. 2013) we were not able to explore reaction/resumption times in a meaningful manner. This was not an appropriate measure for three reasons. First, two of the three secondary task points (pre-encoding and during-encoding) did not involve participants having to record a response when returning to the primary task in order to continue with that task. Second, whilst we could have recorded the time to start recalling words following post-encoding secondary tasks, this would have been confounded given the exact number of words recalled will have differed across trials and between participants. That is, there was not just one important action to perform after returning from a secondary task, as is the case in some task interruption studies involving procedural memory. Third, it has recently been highlighted that there can be a trade-off between resumption speed and behavior where participants take more time to resume a task to avoid making errors following an interruption (Brumby, Cox, Back, & Gould, 2013). Overall, our memory recall measure was strong and robust in terms of demonstrating that secondary tasks involving rating the valence of images impairs the ability to maintain the activation of encoded representations of words and possibly retrieval/priming cues in WM. We are confident in this assertion given that fairly small differences in the degree of valance of negative and positive images were enough to identify differences in memory recall performance between these conditions.

There are some other limitations to the current study. First, apart from rating the valence of images during secondary tasks, participants were only required to focus on and think deeply about the images. The extent to which they did this was not controlled apart from by an experimenter who monitored participants at all times to ensure that they were not writing words in answer booklets other than times when recall was permitted. Measuring gaze activity when images are presented would have allowed measurement not only of the time spent fixating on images but also when and where gaze was focussed the most (Chipchase & Chapman, 2013). Second, whilst we were able to make strong inferences about WM load at the point in which a secondary task occurred (i.e., our pre-encoding, during-encoding, and end-encoding conditions) based upon definitions from previous studies (e.g., Bailey & Iqbal, 2008), further explorations of workload variations within a primary task are needed. Third, we deliberately used a fairly static non-procedural primary task (see

Introduction) akin to many real life tasks (e.g., a nurse trying to remember a number of different drugs). Future studies should consider examining effects of emotive secondary tasks using more procedural-based tasks involving recall of steps within a sequence (e.g., Brumby et al., 2013) and even within dynamic evolving tasks (e.g., Hodgetts et al., 2014) that would allow further investigation of effects of emotive interruptions based upon parameters of the MfG model (Altmann & Trafon, 2002, 2007) and measurement of effects on e.g., resumption speed as well as memory. Fourth, we used image-based secondary tasks and it would be worthwhile to explore the effects of types of stimuli such as text. Fifth, our valent images were different on every trial and thus a degree of the disruption caused could be due to the attention grabbing and narrowing nature of novel images. Future studies should seek to address whether novelty plays a part in the degree of disruption caused by emotive secondary tasks.

One other limitation concerns the neutral secondary task used in both of the current Experiments. Some might associate a black cross in the middle of white screen with an image of a gun sights and this may invoke a negative emotive response. Whilst we cannot determine what participants imagined when thinking about this fixation cross, we do know that it was rated as neutral (i.e., very close to 5.0) on a 1 (highly negative) to 9 (highly positive) valence scale in both Experiments 1 and 2. We had originally thought about including IAPS images with valence ratings close to 5.0 for the neutral valent secondary task. However, other studies within our laboratory have demonstrated that some IAPS neutral images do not reliably produce valance ratings that are similar to those reported within IAPS (Lang et al. 2008). For example, we found that some IAPS images with valance ratings of or close to 5.0 are rated 4.0 – 5.0 (sometimes lower, sometimes higher) and others are rated 5.0 – 6.0 (sometimes higher, sometimes lower). These ratings are too close to the ratings of some of the mild negative and mild positive images selected for the current study and is was crucial to avoid using any images that might ‘blur the boundaries’ between valence strength conditions.

In conclusion, the present study provides novel evidence concerning the disruptive effects of secondary and interrupting tasks involving valent images on recall performance within a verbal WM task. Both negative and positive valent image-based secondary tasks disrupted the ability to maintain encoded verbal items and possibly associated retrieval cues in WM. However, negative images (Experiment 1) seemed to be more disruptive than positive images (Experiment 2) when WM load at the point in which the secondary task occurred was high. Like secondary tasks involving negative images, those involving positive images were also disruptive, although WM load did not intensify their disruptive effect. Taken together, the findings are of theoretical importance as they suggest that emotive secondary tasks are powerful enough to capture and narrow attention, draw upon limited activation resources, and disrupt rehearsal of items and cues encoded within a primary task. These effects are predicted by two different theories: one concerning emotional processing and arousal (Easterbrook, 1959), and the other focussed on task interruption effects from the perspective of goal suspension and resumption (Altmann & Trafton, 2002, 2007). Drawing upon parameters of both frameworks offers great potential for future theoretically informed research concerning the effects of emotive interruptions on primary task performance. The findings also have implications for many every day and workplace settings. For example, those working within safety-critical settings such as nurses, physicians, military personnel, and firefighters prone to having to switch to emotive visual secondary tasks, They should be extra vigilant if such tasks occur during memory-based tasks, especially when memory recall is a key criterion of task performance. For now, we would suggest avoiding such situations wherever possible, especially when the secondary tasks are irrelevant.

Acknowledgments

We thank Greg Trafton and two anonymous reviewers for their comments on earlier drafts of this article.

References

Altmann, E. M., & Trafton, J. G. (2002). Memory for goals: An activation-based model. *Cognitive Science, 26*(1), 39-83.

Altmann, E. M., & Trafton, J. G. (2007). Timecourse of recovery from task interruption: Data and a model. *Psychonomic Bulletin & Review, 14*(6), 1079-1084.

Altmann, E. M., Trafton, J. G., & Hambrick, D. Z. (2014). Momentary interruptions can derail the train of thought. *Journal of Experimental Psychology: General, 143*(1), 215-226.

Baddeley, A.D. (2003) Working Memory: Looking back and looking forward. *Nature Reviews Neuroscience, 4 (10),* 829-839.

Baddeley, A. D. (2007). *Working memory, thought and action*. Oxford: Oxford University Press.

Bailey, B. P., & Iqbal, S. T. (2008). Understanding changes in mental workload during execution of goal-directed tasks and its application for interruption management. *ACM Transactions on Computer–Human Interaction, 14(4),* 1–28.

Barrett, L. F. (2012). Emotions are real. *Emotion, 12*(3), 413-429.

Baumeister, R. F., Bratslavsky, E., Finkenauer, C., & Vohs, K. D. (2001). Bad is stronger than good. *Review of General Psychology, 5*(4), 323-370.

Bradley, M. M., & Lang, P. J. (1999). Affective Norms for English Words (ANEW): Stimuli, instruction manual, and affective ratings *(Tech. Report C-1).* Gainesville: University of Florida, Center for Research in Psychophysiology.

Chan, M., & Singhal, A. (2013). The emotional side of cognitive distraction: Implications for road safety. *Accident Analysis & Prevention, 50*, 147-154.

Chipchase, S. Y., & Chapman, P. (2013). Trade-offs in visual attention and the enhancement of memory specificity for positive and negative emotional stimuli. *Quarterly Journal of Experimental Psychology, 6(2),* 277-298.

Chisholm, C. D., Dornfeld, A. M., Nelson, D. R., & Cordell, W. H. (2001). Work interrupted: A comparison of workplace interruptions in emergency departments and primary care offices. *Annals of Emergency Medicine, 38*(2), 146-151.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Conway, A. R. A., & Engle, R. W. (1994). Working memory and retrieval: A resource-dependent inhibition model. *Journal of Experimental Psychology: General, 123,* 354-373.

Cutrell, E., Czerwinski, M., & Horvitz, E. (2001). Notification, disruption and memory: Effects of messaging interruptions on memory and performance. In: M. Hirose (Ed.) Human–computer interaction — *INTERACT 2001* (pp. 263–269). IFIP: IOS Press.

Damos D. L., & Tabachnick B. G. (2001). The effect of interruptions on flight crew performance: *ASRS Reports,* Los Angeles: Damos Research Associates.

Dan-Glauser, E. S., & Scherer, K. R. (2011). The Geneva affective picture database (GAPED): a new 730-picture database focusing on valence and normative significance. *Behavior Research Methods, 43(2),* 468-477.

Dolcos, F., LaBar, K. S., & Cabeza, R. (2005). Remembering one year later: Role of the amygdala and the medial temporal lobe memory system in retrieving emotional memories. *Proceedings of the National Academy of Sciences, USA, 102(7),* 2626–2631.

Easterbrook, J. A. (1959). The effect of emotion on cue utilization and the organization of behavior. *Psychological Review, 66(3),* 183–201.

Erk, S., Kleczar, A., & Walter, H. (2007). Valence-specific regulation effects in a working memory task with emotional context. *Neuroimage, 37*(2), 623-632.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175-191.

Feldmann-Wüstefeld, T., Schmidt-Daffy, M., & Schubö, A. (2011). Neural evidence for the threat detection advantage: Differential attention allocation to angry and happy faces. *Psychophysiology, 48*(5), 697-707.

Goodman, A. M., Katz, J. S., Dretsch, M. N. (2016). Military Affective Picture System (MAPS): A new emotion-based stimuli set for assessing emotional processing in military populations. *Journal of Behavior Therapy and Experimental Psychiatry, 50,* 152-161.

Gillie, T., & Broadbent, D. (1989). What makes interruptions disruptive? A study of length, similarity, and complexity. *Psychological Research, 50*, 243–250.

Hasher, L., & Zacks, R. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 22, pp. 193–226). New York: Academic Press.

Hodgetts, H. M., & Jones, D. M. (2006). Interruption of the tower of London task: Support for a goal-activation approach. *Journal of Experimental Psychology: General, 135*(1), 103-115.

Hodgetts, H. M., Vachon, F., & Tremblay, S. (2014). Background sound impairs interruption recovery in dynamic task situations: Procedural conflict? *Applied Cognitive Psychology, 28*(1), 10-21.

Hodgetts H. M., Tremblay S., Vallières B. R., & Vachon F. (2015). Decision support and vulnerability to interruption in a dynamic multitasking environment, *International Journal of Human-Computer Studies, 79,* 106-117.

Kensinger, E. A. (2004). Remembering emotional experiences: The contribution of valence and arousal. *Reviews in the Neurosciences, 15,* 241–252.

Kensinger, E. A., & Corkin, S. (2003). Memory enhancement for emotional words: Are emotional words more vividly remembered than neutral words? *Memory & Cognition, 31*(8), 1169-1180.

Kensinger, E. A., Garoff-Eaton, R. J., & Schacter, D. L. (2006). Memory for specific visual details can be enhanced by negative arousing content. *Journal of Memory and Language, 54(1),* 99–112.

Kensinger, E. A., Garoff-Eaton, R. J., & Schacter, D. L. (2007a). Effects of emotion on memory specificity in young and older adults. *Journals of Gerontology, Series B: Psychological Sciences and Social Sciences, 62(4),* P208–P215.

Kensinger, E. A., Garoff-Eaton, R. J., & Schacter, D. L. (2007b). Effects of emotion on memory specificity: Memory trade-offs elicited by negative visually arousing stimuli. *Journal of Memory and Language, 56(4),* 575–591.

Kern, R. P., Libkuman, T. A., & Otani, H. (2005). Emotional stimuli, divided attention, and memory. *Emotion, 5(4),* 408–417.

Kroll, N. E. A., & Kellicutt, M. H. (1972). Short-term recall as a function of covert rehearsal and of intervening task. *Journal of Verbal Learning and Verbal Behavior, 11,* 196 – 204.

Lane, A. M., Bucknall, G., Davis, P. A., & Beedie, C. J. (2012). Emotions and emotion regulation among novice military parachutists. *Military Psychology, 24*(3), 331-345.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). International affective picture system (IAPS): Affective ratings of pictures and instruction manual. *Technical Report A-8.* University of Florida, Gainesville, FL.

Lasaitis, C., Ribeiro, R. L., & Bueno, O. F. A. (2008). Brazilian norms for the International Affective Picture System (IAPS)-comparison of the affective ratings for new stimuli between Brazilian and North-American subjects. *Journal Brasileiro de Psiquiatria, 57,* 270–275.

Ledoux K., Gordon P. C. (2006) Interruption-similarity effects during discourse processing, *Memory*, *14 (7)*, 789-803

Loftus, E. F., Loftus, G. R., & Messo, J. (1987). Some facts about weapon focus. *Law and Human Behavior, 11(1),* 55–62.

Lohani, M., Gupta, R., & Srinivasan, N. (2013). Cross-cultural evaluation of the International Affective Picture System on an Indian sample. *Psychological Studies, 58(3),* 233–241.

McFarlane, D. C. (2002). Comparison of four primary methods for coordinating the interruption of people in human-computer interaction. *Human-Computer Interaction, 17,* 63–139.

Miyake, A., & Shah, P. (1999). Toward unified theories of working memory: Emerging general consensus, unresolved theoretical issues, and future research directions. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control.* Cambridge, UK: Cambridge University Press.

Mogg, K., McNamara, J., Powys, M., Rawlinson, H., Seiffer, A., & Bradley, B. P. (2000). Selective attention to threat: A test of two cognitive models of anxiety. *Cognition & Emotion, 14,* 375–399.

Monk, C. A., Boehm-Davis, D. A., & Trafton, J. G. (2004). Recovering from interruptions: Implications for driver distraction research. *Human Factors, 46*(4), 650-663.

Monk, C. A., Trafton, J. G., & Boehm-Davis, D. A. (2008). The effect of interruption duration and demand on resuming suspended goals. *Journal of Experimental Psychology: Applied, 14,* 299-313.

Morgan, P. L., & Patrick, J. (2013). Paying the price works: Increasing goal access cost improves problem solving and mitigates the effect of interruption. *Quarterly Journal of Experimental Psychology. 66(1),* 160-178.

Morgan, P. L., Patrick, J., & Tiley, L. (2013). Improving the effectiveness of an interruption lag by inducing a memory-based strategy. *Acta Psychologica*, *142*(1), 87-95.

Morgan, P. L., Patrick, J., Waldron, S. M., King, S. L., & Patrick, T. (2009). Improving memory after interruption: Exploiting soft constraints and manipulating information access cost. *Journal of Experimental Psychology: Applied*, *15*(4), 291-306.

Nobata, T., Hakoda, Y., & Ninose, Y. (2010). The functional field of view becomes narrower while viewing negative emotional stimuli. *Cognition & Emotion, 24(5),* 886–891.

Ochsner, K. N. (2000). Are affective events richly recollected or simply familiar? The experience and process of recognizing feelings past. *Journal of Experimental Psychology: General, 129(2),* 242–261.

Pereira, M. G., Volchan, E., de Souza, Gabriela Guerra Leal, Oliveira, L., Campagnoli, R. R., Pinheiro, W. M., & Pessoa, L. (2006). Sustained and transient modulation of performance induced by emotional picture viewing. *Emotion, 6*(4), 622-634.

Posner, M. I., & Konick, A. W. (1966). On the role of interference in short-term retention. *Journal of Experimental Psychology, 72,* 221–231.

Ramirez, I., Hernandez, M. A., Sanchez, M., Fernandez, M. C., Vila, J., Pastor, M. C., et al. (1998). Spanish norms of the International Affective Picture System. *Journal of Psychophysiology, 12,* 312–313.

Sakai, K., Rowe, J. B., & Passingham, R. E. (2002). Active maintenance in prefrontal area 46 creates distractor-resistant memory. *Nature Neuroscience, 5,* 479-484.

Shackman, A.J., Sarinopoulos, I., Maxwell, J.S., Pizzagalli, D.A., Lavric, A., Davidson, R.J., 2006. Anxiety selectively disrupts visuospatial working memory. *Emotion 6,* 40–61.

Schimmack, U. (2005). Response latencies of pleasure and displeasure ratings: Further evidence for mixed feelings. *Cognition & Emotion, 19*(5), 671-691.

Schindler, K., Van Gool, L., & de Gelder, B. (2008). Recognizing emotions expressed by body pose: A biologically inspired neural model. *Neural Networks, 21*(9), 1238-1246.

Shackman, A. J., Sarinopoulos, I., Maxwell, J. S., Pizzagalli, D. A., Lavric, A., & Davidson, R. J. (2006). Anxiety selectively disrupts visuospatial working memory. *Emotion 6,* 40–61.

Talmi, D., Schimmack, U., Paterson, T., & Moscovitch, M. (2007). The role of attention and relatedness in emotionally enhanced memory. *Emotion, 7(1),* 89–102.

Trafton, J. G., Altmann, E. M., Brock, D. P., & Mintz, F. E. (2003). Preparing to resume an interrupted task: Effects of prospective goal encoding and retrospective rehearsal. *International Journal of Human-Computer Studies, 58,* 583-603.

Trafton, J. G., & Monk, C. M. (2008). Task interruptions. In D. A. Boehm-Davis (Ed.), *Reviews of Human Factors and Ergonomics, Vol. 3.* (pp. 111–126): Human Factors & Ergonomics Society.

Verschuere, B., Crombez, G., & Koster, E. (2001). The international affective picture system: a Flemish validation study. *Psychologica Belgica, 41,* 205–217.

Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *Trends in Cognitive Sciences, 9*(12), 585-594.

Wessa, M., Heissler, J., Schonfelder, S., & Kanske, P. (2013). Goal-directed behavior under emotional distraction is preserved by enhanced task-specific activation. *Social Cognitive and Affective Neuroscience, 8*(3), 305-312.

Zijlstra, F. R., Roe, R. A., Leonora, A. B., & Krediet, I. (1999). Temporal factors in mental work: Effects of interrupted activities. *Journal of Occupational and Organizational Psychology, 72*(2), 163-185.

Figure Captions

Figure 1. Effect of the image valence (negative) and secondary task position on number of words recalled (Experiment 1). Error bars show standard error of mean.

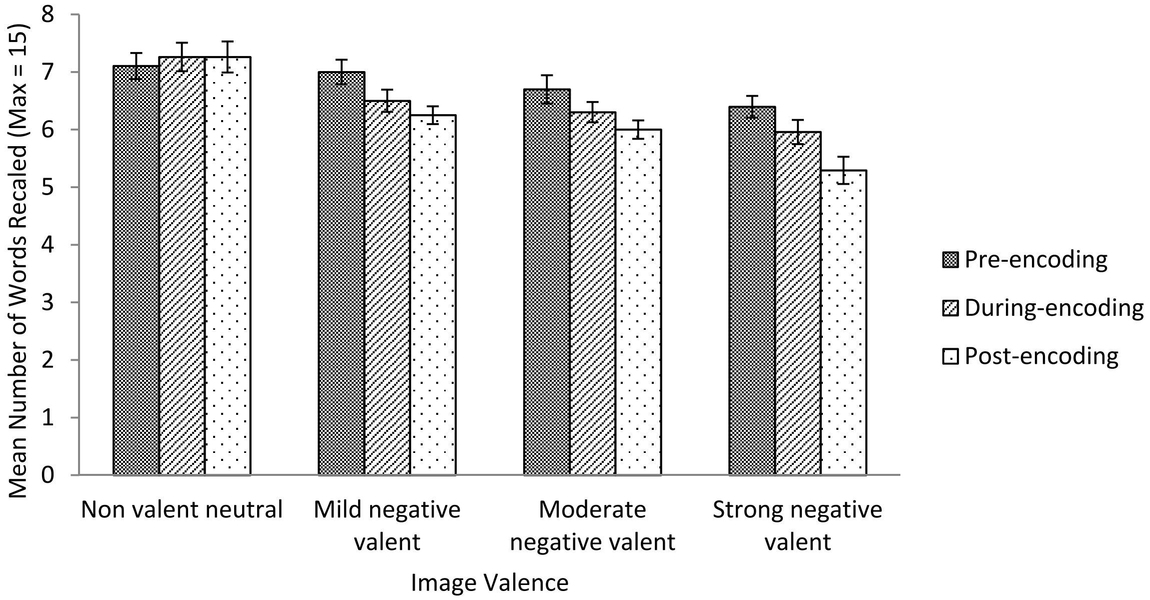

Figure 2. Effect of the image valence (positive) and secondary task position on number of words recalled (Experiment 2). Error bars show standard error of mean.

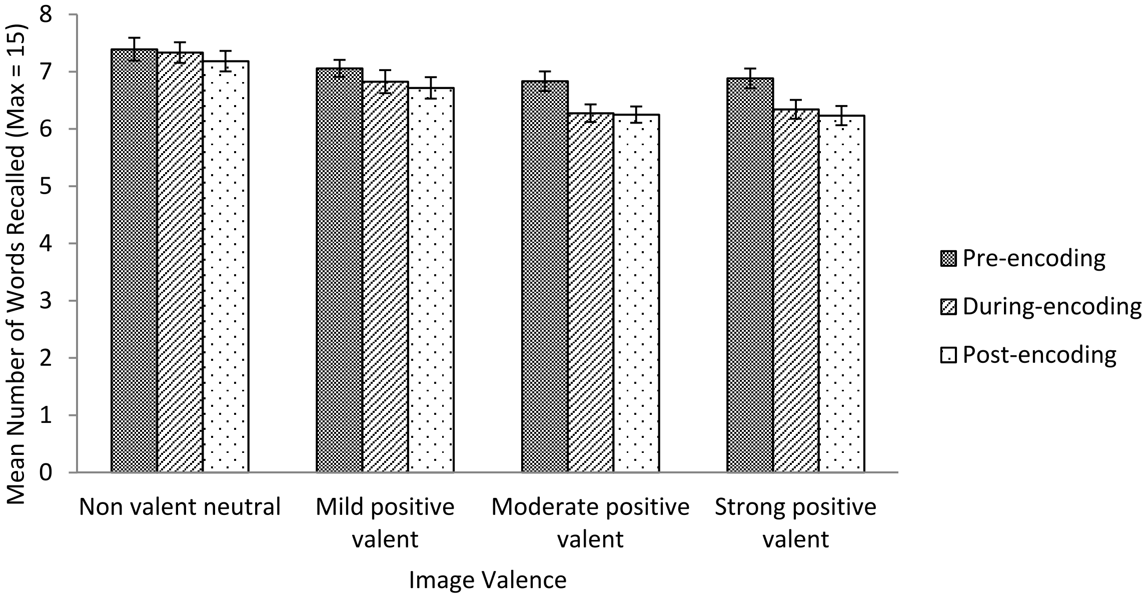

Table 1

IAPs (Lang et al., 2008) Valence and Arousal Ratings for Images used in Experiment 1

Mild Negative Valence Images

Image Number	Image Content	*Valence*	*Arousal*
1202	spider	4.03	6.20
1931	shark	4.00	6.80
2795	snake	3.90	6.94
1304	attack dog	3.89	6.39
3250	open chest	3.78	6.29
3280	dental exam	3.72	5.39
9270	toxic waste	3.72	5.24
8480	biker on fire	3.70	6.28
9005	HIV tattoo	3.69	5.18

Moderate Negative Valence Images

Image Number	Image Content	*Valence*	*Arousal*
9925	fire	2.84	5.59
6830	guns	2.82	6.21
9321	vomit	2.81	6.24
3212	animal surgery	2.79	6.57
9909	burning car	2.78	5.98
2981	deer head	2.76	5.97
9611	plane crash	2.71	5.75
6370	attack mask	2.70	6.44
2683	war	2.62	6.21

Strong Negative Valence Images

Image Number	Image Content	*Valence*	*Arousal*
6563	burnt face	1.91	5.60
9413	hanging	1.76	6.81
9183	hurt dog	1.69	6.58
9040	starve child	1.67	5.82
9940	explosion	1.62	7.15
3266	injury	1.56	6.79
3015	accident	1.52	5.90
9410	soldier	1.51	7.07
3170	baby tumour	1.46	7.21

Table 2

Mean Recall and IAPs (Lang et al., 2008) Arousal Ratings for Images in Experiment 1

Mild Negative Valence Images

Image Number	Image Content	*Mean Recall*	*Arousal*
1202	spider	6.97	6.20
1931	shark	6.78	6.80
2795	snake	6.69	6.94
1304	attack dog	5.69	6.39
3250	open chest	6.56	6.29
3280	dental exam	6.56	5.39
9270	toxic waste	6.53	5.24
8480	biker on fire	6.78	6.28
9005	HIV tattoo	6.69	5.18

Moderate Negative Valence Images

Image Number	Image Content	*Mean Recall*	*Arousal*
9925	fire	6.66	5.59
6830	guns	6.06	6.21
9321	vomit	6.44	6.24
3212	animal surgery	6.28	6.57
9909	burning car	6.34	5.98
2981	deer head	6.38	5.97
9611	plane crash	6.25	5.75
6370	attack mask	6.25	6.44
2683	war	6.34	6.21

Strong Negative Valence Images

Image Number	Image Content	*Mean Recall*	*Arousal*
6563	burnt face	6.56	5.60
9413	hanging	5.50	6.81
9183	hurt dog	5.44	6.58
9040	starve child	5.56	5.82
9940	explosion	5.94	7.15
3266	injury	5.84	6.79
3015	accident	5.97	5.90
9410	soldier	6.28	7.07
3170	baby tumour	5.84	7.21

Table 3

IAPs (Lang et al., 2008) Valence and Arousal Ratings for Images used in Experiment 2

Mild Positive Valence Images			
Image Number	Image Content	*Valence*	*Arousal*
2092	clowns	6.28	4.32
2374	woman	6.29	3.86
4598	couple	6.33	5.53
5622	shark ride	6.33	5.34
8467	runners	6.35	5.12
8280	diver	6.38	5.05
7450	cheeseburger	6.40	5.05
1604	butterfly	6.40	3.17
7499	concert	6.47	5.58
Moderate Positive Valence Images			
Image Number	Image Content	*Valence*	*Arousal*
5199	garden	6.93	4.70
2352	kiss	6.94	4.99
4597	romantic	6.95	5.91
8162	hot air balloon	6.97	4.98
8186	sky surfer	7.01	6.84
7508	Ferris wheel	7.02	5.09
1722	jaguars	7.04	5.22
7325	watermelon	7.06	3.55
2306	boy	7.08	4.46
Strong Positive Valence Images			
Image Number	Image Content	*Valence*	*Arousal*
2057	father	7.81	4.54
2347	children	7.83	5.56
1920	porpoise	7.90	4.27
2340	family	8.03	4.90
5825	sea	8.03	5.46
2070	baby	8.17	4.51
5833	beach	8.22	5.71
1750	bunnies	8.28	4.10
1710	puppies	8.34	5.41

Table 4

Mean Recall and IAPs (Lang et al., 2008) Arousal Ratings for Images in Experiment 2

Mild Positive Valence Images

Image Number	Image Content	*Mean Recall*	*Arousal*
2092	clowns	6.80	4.32
2374	woman	6.95	3.86
4598	couple	6.83	5.53
5622	shark	6.68	5.34
8467	runners	7.20	5.12
8280	diver	6.63	5.05
7450	cheeseburger	7.05	5.05
1604	butterfly	6.75	3.17
7499	concert	6.93	5.58

Moderate Positive Valence Images

Image Number	Image Content	*Mean Recall*	*Arousal*
5199	garden	6.68	4.70
2352	kiss	6.25	4.99
4597	romantic	6.38	5.91
8162	hot air balloon	6.20	4.98
8186	sky surfer	6.83	6.84
7508	Ferris wheel	6.48	5.09
1722	jaguars	6.45	5.22
7325	watermelon	6.18	3.55
2306	boy	6.65	4.46

Strong Positive Valence Images

Image Number	Image Content	*Mean Recall*	*Arousal*
2057	father	6.45	4.54
2347	children	6.78	5.56
1920	porpoise	6.35	4.27
2340	family	6.80	4.90
5825	sea	6.13	5.46
2070	baby	6.50	4.51
5833	beach	6.63	5.71
1750	bunnies	6.38	4.10
1710	puppies	6.38	5.41