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Brief exercise enhances intrusive memories of traumatic stimuli

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ABSTRACT

Brief physical exercise enhances memories for neutral events, and recently has been shown to modulate fear learning in animals. To date there is no evidence pertaining to the impact of exercise on emotional memories in humans. Accordingly, this study investigated the role of brief exercise in the development of emotional intrusive memories. Forty-nine university students (18–29 year olds) viewed a car accident film depicting accident and injury, and were then randomly assigned to engage in either 10 min of intense exercise or easy walking. Two days following the experiment participants were assessed for both intrusive memories of the film and intentional recall of film details. Results indicated that participants in the exercise relative to the walking condition reported more intrusive memories, but not voluntarily recalled memories, of the car accident film two days later. These findings are consistent with recent evidence of exercise-induced emotional learning in animals, and point to the potential for physical activity to contribute to the development of intrusions in the context of encoding emotionally-laden information.
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1. Introduction

Intrusive memories are unwanted and repetitive recollections of an emotional event that often involve vivid, sensory impressions such as images, sounds, and body sensations (Brewin, Gregory, Lipton, & Burgess, 2010). They are experienced in the context of many psychological disorders including posttraumatic stress disorder, social phobia, and obsessive compulsive disorder (American Psychiatric Association, 2013). The non-volitional nature of intrusions can make them difficult to control leading to high levels of distress, and disruption of ongoing cognitive activity (Clark & Rhyno, 2005). An understanding of intrusions has relevance beyond clinical populations as involuntary memories of emotional autobiographical events are common in daily life (Bywaters, Andrade, & Turpin, 2004; Rubin & Berntsen, 2009).

Most theoretical models of intrusions suggest that altered encoding and/consolidation processes contribute to subsequent intrusions. These models typically involve the proposition that elevated arousal at the time of encoding/consolidation impact on how these memories are stored (Brewin, 2001; Ehlers & Clark, 2000). These propositions are consistent with evidence that noradrenergic and hypothalamic pituitary axis activation at the time of an emotional event are known to facilitate subsequent memories (McGaugh, 2004). For example, endogenous noradrenergic activity, as indexed by salivary alpha amylase, correlates positively with emotional memory (van Stegeren, Rohleder, Everaerd, & Wolf, 2006), and blocking the noradrenergic system selectively impairs memory for an emotional but not neutral event (Cahill, Prins, Weber, & McGaugh, 1994). Further, glucocorticoid activation following encoding of emotional stimuli enhances subsequent emotional but not neutral memory (Cahill, Gorski, & Le, 2003). This research has overwhelmingly focused on intentionally retrieved memories. However, there is also convergent research that activation of stress hormones can impact intrusive emotional memories. As emotionality of memories are correlated with intentional memory occurrence (Ferree & Cahill, 2009), it is reasonable to expect that these stress hormones could modulate intrusive memories as well. Supporting this proposition is evidence that salivary amylase and cortisol contribute to predicting intrusive negative memories in males (Bryant, McGrath, & Felmingham, 2013). It is worth noting that increasing evidence suggests that sex may moderate the extent to which arousal consolidates emotional memories, with females more likely to consolidate emotional memories (Bryant et al., 2013; Felmingham, Tran, Fong, & Bryant, 2012). Moreover, increasing arousal at the time of memory reactivation has been shown to increase subsequent intrusive memories, and this is predicted by cortisol levels (Cheung, Garber, & Bryant, 2015).

The role of arousal in emotional and intrusive memories points to the potential role of physical exercise in modulating intrusive memories. There is increasing evidence from animal research indicating exercise-induced modulation of fear memories following fear conditioning (Baruch, Swain, & Helmstetter, 2004). Specifically, rats

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that engage in acute exercise (involving wheel running) immediately before or after fear conditioning express augmented fear in subsequent days relative to rats not exercised (Siette, Reichelt, & Westbrook, 2014). The activation of physiological mechanisms, including secretion of stress hormones and brain derived neurotrophic factor (BDNF; Greenwood, Strong, Foley, & Fleshner, 2009), may underpin such emotional memory modulation. BDNF is a growth factor implicated in learning and memory processes and found in high concentration in the hippocampus (Cotman & Berchtold, 2002) and amygdala (Greenwood et al., 2009). Indeed, BDNF is upregulated dose-dependently following just a single bout of exercise (Winter et al., 2007), and appears necessary for the acquisition of fear memories in animals (Rattiner, Davis, French, & Ressler, 2004; Rattiner, Davis, & Ressler, 2005). Relatedly, noradrenergic activation following acute aerobic cycling has been found to increase salivary amylase activity and lead to enhanced intentional memory for positive stimuli (Segal, Cotman, & Cahill, 2012). Similarly, the glucocorticoid system is activated following acute exercise (Fryer et al., 2012; Labsy et al., 2013; Mastorakos, Pavlatou, Diamanti-Kandarakis, & Chrousos, 2005; Wahl, Zinner, Achtzehn, Bloch, & Mester, 2010) and is found necessary for subsequent memory enhancement in animals (Hajisoltani et al., 2011). Together, it is possible that physical exercise induced stress hormone release in close proximity to an emotional learning episode could potentially extend to modulating intrusive memory occurrences. As intrusive memories may be seen as conditioned emotional responses following an emotionally arousing event (Wegerer, Blechert, Kerschbaum, & Wilhelm, 2013), this convergent evidence points to the possibility that exercise may impact intrusive memories. Although there is increasing evidence that elevated levels of physical activity are associated with a reduction in posttraumatic stress symptoms, which includes intrusive memories (Rosenbaum et al., 2015), this body of evidence pertains to the impacts of elevated levels of exercise on generic symptoms of the disorder rather than the impact of acute bouts of exercise on intrusive memories.

A major goal of the current study was to extend previous animal research by examining the role of brief exercise on intrusive emotional memory development. A stepping exercise task was chosen for the current study as aerobic exercise has been shown to enhance learning (Tang, Chu, Hui, Helmeste, & Law, 2008), increase BDNF (Winter et al., 2007), noradrenergic (Segal et al., 2012), and glucocorticoid levels (Labsy et al., 2013). Participants watched an emotional film depicting the aftermath of a highway car accident, after which they were randomised to either an exercise or walking condition. Two days later, participants completed a surprise measure of intrusive memories and free recall. We hypothesised that exercise relative to the walking would be associated with increased intrusions and intentional recall for the car accident film.

2. Method

2.1. Participants

The sample included 49 healthy University of New South Wales undergraduate students (16 males, 33 males) aged between 18 and 29 years who participated in exchange for course credit. Participants were randomly allocated to either the exercise (n = 25; 16 females, 9 males) or walking condition (n = 24; 17 females, 7 males).

2.2. Measures

2.2.1. Intrusions questionnaire

The Impact of Event Scale (IES; Horowitz, Wilner, & Alverez, 1979) was adapted to measure intrusive memories of the car accident film. Participants were instructed to think about the car accident film that they had seen during the experimental session, and to record the occurrence of intrusive experiences in relation to the film. The items were "Pictures about it popped into mind", "Other things kept making me think about it", and "I thought about it when I didn't mean to". Each item was rated on a five-point Likert scale ranging from 0 ("Not at all") to 4 ("Extremely"). These items were selected because they could be related to the experimental stimuli; other IES items were omitted because this is a clinical measure that measures a range of posttraumatic stress symptoms that do not relate specifically to intrusive memories (e.g. sleep disturbance) and would be inappropriate in the current context.

2.2.2. Cued recall test

A 25-item questionnaire that has been previously adapted to the car accident film was used to index intentional recall in the current study (Devilly, Varker, Hansen, & Gist, 2007.). This questionnaire included items relating directly to the central features of the car accident (e.g., "How many of the injured victims had dark skin and how many had light skin?"), whilst others assessed memory for details relating to the peripheral/surroundings (e.g. "How many police vehicles surrounded in the scene").

2.2.3. Depression anxiety and stress scales-21 item version

Baseline depression was assessed using the Depression Anxiety and Stress Scales (DASS; Lovibond & Lovibond, 1995) 21-item version, which indexes depression, anxiety and stress. This measure possesses strong reliability and internal consistency (Henry & Crawford, 2005; Lovibond & Lovibond, 1995).

2.2.4. Pre-exercise questionnaire

Participants were asked to indicate if they were currently suffering from any health and/or physical conditions that would prevent them from engaging in moderate to strenuous physical activity. Examples included high blood pressure, asthma, chronic pain, and a current heart condition. Indication of current significant suffering led to an automatic exclusion from partaking in the study, such that any illness was not further exacerbated by the exercise task (nil were excluded).

2.2.5. Godin-Shephard Leisure-Time Exercise Questionnaire (LTEQ)

The Leisure-Time Exercise Questionnaire (LTEQ; Godin & Shephard, 1997) was used to index the frequency of light-intensity, moderate-intensity, and vigorous-intensity leisure-time physical activity undertaken on a weekly basis. This questionnaire has demonstrated good construct validity and strong test re-test reliability (Godin & Shephard, 1997). The LTEQ was modified by asking participants to indicate how much time (in min) is spent on strenuous, moderate and light activity for more than 15 min in a given 7-day period, such that the duration of engagement in each type of activity could be assessed, and factored into when estimating weekly metabolic equivalent (METS). Accordingly, a modified formula (Andrykowski, Beacham, & Jacobsen, 2007) was utilised to do this: [(total METS = minutes of strenuous exercise/15) × 9] + [(total minutes of moderate exercise/15) × 5] + [(total minutes of light exercise/15) × 3].

2.2.6. Heart rate measurement

A Garmin FR70 heart rate watch and chest belt was used to record participants' heart rate. This monitoring belt consists of two smart fabric sensors to acquire cardiac activity. HR data was wirelessly transmitted to the Garmin Connect Training centre and was stored as average beats per minute over the 10 min period. Heart rate data was sampled at a rate of 2.4 GHz.

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