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MINI-REVIEW

Exercise and Emotional Memory: a Systematic Review

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Abstract

Memories are often vividly recalled when experienced during an emotional event (i.e., emotional memory). Exercise has been shown to subserve episodic memory function, but its role in influencing emotional memory is less clear. In this systematic review, we discuss the potential underlying mechanisms that subserve emotional memory and summarize an emerging body of research investigating the effects of exercise on emotional memory. We also highlight recommendations for future work in this emerging field of inquiry.

Keywords Amygdala · Cognition · Cues · Episodic · Norepinephrine · Perceptual · Physical activity

Introduction

Autobiographical events are often coupled with rich emotional perceptions that dictate storage and later retrieval of such potent experiences from memory. When hippocampal and amygdalar networks operate in synchrony to consolidate emotional memories, the information stored illuminates subjective, hedonic features that are absent with activation from the hippocampus alone (LeDoux 1992). Further, stimulation of the amygdalar system is thought to induce a degree of arousal (either positive or negative), which may confer involuntary behavioral and hormonal responses, which accumulate to intensify the facilitative effects of emotion on memory capacity (LeDoux 1993).

Evolution may offer one explanation for memory enhancement following emotional events (i.e., emotional memory). Learning to recognize important environmental cues is essential for survival, making events that are coupled with emotional salience (e.g., presence of a predator), particularly memorable. Indeed, anecdotally, individuals often experience vivid recall of emotionally charged information (e.g., their spatial location when they heard the news of a terrorist attack), as supported by extensive research, demonstrating that emotionally arousing events are more memorable than non-emotional, neutral-based events (Reisberg and Heuer 1992). What remains uncertain, however, is whether emotional memories are more accurately recalled, or merely enhance the subjective sense of recollection (Phelps and Sharot 2008). Importantly, emotional memory may be considered a double-edged sword, as emotional arousal can also impair memory accuracy, particularly if the arousing event is associated with high levels of stress (Lupien and McEwen 1997). In the context of stress-related markers, low doses of corticosterone-receptor agonist administration (as opposed to high doses) has sometimes been found (depending on the context) to enhance memory consolidation in mice (Ebada et al. 2014; Marks et al. 2015).

Potential mechanisms of emotional memory have been discussed elsewhere (Buchanan 2007; Cahill 2003; Cahill and McGaugh 1998; Hamann 2001; Tully and Bolshakov 2010). The intricacy of emotional memory systems is highlighted in both conscious and unconscious networks capable of guiding behavioral and physiological functions linked to emotional stimulation. In brief, implicit, procedural memories reflect the ability to perform habitually practiced activities, reflexive behavior, transient emotional reactions, and classical conditioning models (as discussed previously), with research demonstrating compelling links between implicit emotional memory and central nervous system functionality (Schacter 1987). With regard to explicit emotional memory (in contrast to implicit emotional memory (Buchel and Dolan 2000); e.g., fear conditioning), such as declarative memory, which includes personally salient memory of specific facts and/or events and

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"flashbulb" memories for culturally significant emotional events (e.g., September 11, 2001), potential mechanisms incorporate psychological, neural, and hormonal systems. Regarding psychological parameters, candidate mechanisms of emotional memory include factors such as increased rehearsal, enhanced attention, and increased elaboration. As will be discussed herein to follow, studies have suggested that emotional memory may be influenced by noradrenalin-mediated mechanisms (Thomas et al. 1996; Yang et al. 2002). While this may be the case, however, it is also important to consider that many past experimental paradigms alternated rapidly between emotional and neutral stimuli (e.g., words), challenging attributions of emotional memory to hormonal mechanisms that would have to be associated with persisting adrenoceptor activation carrying over from emotional to neutral stimuli. Since emotional stimuli are often better recalled than neutral stimuli, it seems plausible in these instances that superior emotional memory may be driven, in part, from increased attention or other psychologically based parameters.

Concerning neural and hormonal factors, studies by McGaugh and others have demonstrated four key factors of emotional memory dynamics: (a) the amygdala is the primary orchestrator of emotional memory processes, (b) the amygdala can affect explicit memory by modulating (or enhancing) the neural activity of other brain regions, (c) emotional arousal can influence emotional memory through the release of stress hormones, and (d) the amygdala acts on consolidation processes in other brain regions as the hippocampus (Hamann 2001; McGaugh 2000). The key role of the amygdala in modulating memory critically depends on activation of β-adrenoreceptors in the basolateral complex (BLA) of the amygdala (Ferry and McGaugh 1999). To illustrate, a blockade of this receptor has been shown to impair memory of an emotionally arousing story (Cahill et al. 1994). Highlighting the significant role of the amygdala in emotional memory, individuals with greater amygdala neural activity during the encoding of an emotional film had better memory recall 3 weeks later. Importantly, Canli and colleagues (Canli et al. 2000) demonstrated the possibility of a minimum threshold of emotional arousal. When they showed various negative images to participants, memory was enhanced only for stimuli that produced the highest arousal levels. Since amygdala neural activity can enhance both positive and negatively charged stimuli (Hamann et al. 1999), there may also be valence-specific neuronal processes, with positive images activating various reward systems (Canli et al. 2000; Hamann et al. 1999). Providing further support for the amygdala's role in enhancing emotional memory, both animal and human studies have shown that amygdala lesions impair emotional memory (Cahill et al. 1995; Markowitsch et al. 1994). In fact, a wealth of animal research suggests that the amygdala is intimately involved in implicit emotional memory formation (e.g., fear conditioning), with the amygdala implicated in critical processes directing the strength of new associations that form as a result of converging neural pathways that may also specifically involve the thalamus (LeDoux et al. 1990), hippocampus, and cortical regions (Jones and Powell 1970; Turner et al. 1980). Interestingly, the degree to which the amygdala influences emotional memory may be influenced by the context of the stimuli (e.g., verbal stimuli or picture stimuli), with verbal stimuli less dependent on amygdala involvement than picture stimuli (Phelps et al. 1997), though a possible confound in this comparison is that verbal (recording of word list) stimuli may be less emotionally arousing than picture stimuli (e.g., graphic images).

Another brain region pivotal to facilitating emotional memory may be the locus coeruleus (located in the brain stem). Projections of the locus coeruleus spread throughout the central nervous system, with heavy innervation in the amygdala, hippocampus, and hypothalamus (Loizou 1969), as well as in cortical regions (neocortex) for long-term memory storage (Iwai and Yukie 1987). In the amygdala, norepinephrine (NE), a catecholamine produced by dopamine β-hydroxylase (Coyle 1977), is increased 75% above basal levels during emotional events (Galvez et al. 1996) in mouse models. Other animal work suggests that the effects of stress hormones on memory performance are mediated by NE release in the amygdala, which further underscores the critical role of amygdalar activity on emotional memory modulation. Notably, animal models have also indicated that both repeated stressors (Ida et al. 1985; Pacak et al. 1993; Tanaka et al. 1991), and isolated, acute stressors can effectuate substantial NE release in the brain (Galvez et al. 1996). NE in the brain is primarily synthesized in the locus coeruleus (Smythies 2005), and actions of NE (binding to G protein-coupled adrenergic receptors results in intracellular cyclic AMP concentrations and PKA activation, and may also facilitate AMPA receptor trafficking to synaptic sites; Hu et al. 2007) in the BLA promote the induction of long-term potentiation (Ikegaya et al. 1997) and the expression of Arc protein (implicated in synaptic plasticity) in the hippocampus. Additionally, NE may enhance memory during emotionally arousing events by inhibiting protein phosphatases that typically oppose the facilitation of long-term potentiation (Thomas et al. 1996; Yang et al. 2002). Moreover, memory-enhancing actions of NE may contribute via glucose-releasing effects (Gold 1995; Sherwin and Sacca 1984). Further, pharmacological agents known to modulate emotional memory (via, for example, GABAergic agonists and antagonists) may exert their effects by controlling NE levels in the amygdala (Hatfield et al. 1999).

As for behavioral strategies (e.g., exercise) that may influence emotional memory, animal models have shown that acute exercise immediately before or after fear conditioning may promote exaggerated fear responses on subsequent days

(Siette et al. 2014). Additional evidence for exercise influences on emotional memory can be found in studies showing that exercise can increase NE levels (Segal et al. 2012) and activate the glucocorticoid system (Fryer et al. 2012), both of which (as described above) are implicated in emotional memory (Hajisoltani et al. 2011). Additionally, since, as stated previously, arousal appears to play an important role in emotional memory, exercise has the potential to induce physiological and cerebral arousal (Lanier 1997; Lanier et al. 1989, 1994). In addition to exercise-induced activation of muscle spindles sending a direct pathway to increase cerebral arousal (Lanier 1997; Lanier et al. 1989, 1994), research has shown that, after learning a task, electrical stimulation of the vagus nerve (which carries sensory information from the periphery to the brain) can augment memory (Clark et al. 1999). Thus, exercise may a play a role via exercise-induced cardiorespiratory stimulation of the vagus nerve (Howland 2014). Finally, there can be a link between psychological-based emotional memory mechanisms (e.g., cognitive attention) and exercise, since research demonstrates that exercise may help increase P3 amplitude and shorten P3 latency (Magnie et al. 2000; Scudder et al. 2012), both of which are important neuroelectrical indices of cognitive attention.

Taken together, emotional memory may be influenced by a variety of psychological, neural, and hormonal mechanisms, which may be modulated through behavioral exercise. Although previous review papers have discussed the effects of exercise on non-emotional episodic memory (Bherer et al. 2013; Gomez-Pinilla and Hillman 2013), to our knowledge, there are no published systematic review papers evaluating the effects of exercise on emotional memory.

Method

Evidence Acquisition and Inclusionary Criteria

We conducted this systematic review in alignment with the PRISMA guidelines.

Studies included were published in English; indexed in PubMed, PsychInfo, Sports Discus, Scopus, or Google Scholar; employed an experimental design (e.g., traditional parallel group RCT; either acute intervention or chronic/training intervention study); were conducted among human adults; and employed an outcome measure of emotional memory. Outside these criteria, no specific exclusionary criteria were applied.

Search Strategy and Data Abstraction

Databases searched included PubMed, Sports Discuss, PsychInfo, Google Scholar, and Scopus. Search terms included exercise, physical activity, emotion, emotional memory, and amygdala. The authors screened these studies based on the study's title and abstract, and identified 17 papers that appeared to meet the inclusion criteria for review. The full text of these 17 articles were read and identified six that met the study criteria. That is, 11 of the articles either did not employ an experimental design, did not manipulate exercise, or did not include an emotional memory variable as the outcome measure.

Table 1 represents a data extraction table for summarizing the following information from these studies: authors, research design, participant sample size, exercise intervention, memory assessment, and results.

Results

Sample Characteristics

Among the evaluated six studies, all employed an experimental design using an acute exercise protocol. Some employed young adult participants (Keyan and Bryant 2017b; Michalak et al. 2015; Weinberg et al. 2014), whereas others assessed older adults (Segal et al. 2012).

Exercise Protocol Characteristics

The exercise protocols varied drastically across studies, and included a 6-min bout of cycling exercise at 70% of VO_{2max} (Segal et al. 2012), incremental cycling exercise (Keyan and Bryant 2017a), six sets of 10 repetitions of maximal isokinetic dynamometer knee extension exercises (Weinberg et al. 2014), 15 min of walking (speed not specified) on a treadmill (Michalak et al. 2015), and 10 min of stepping exercises at 50–85% of HR_{max} (Keyan and Bryant 2017b) and 60–85% (Keyan and Bryant 2017c). Some studies imposed the exercise session immediately after the emotional stimulus exposure (Keyan and Bryant 2017b; Segal et al. 2012; Weinberg et al. 2014), whereas others induced the emotional stimuli shortly after the commencement of the exercise bout (Michalak et al. 2015).

Emotional Memory Characteristics

All six studies included emotional stimuli of multiple valence components, such as positive, neutral, or negative emotional elicitation. The methodology of the emotional stimuli varied, with some utilizing images from the International Affective Picture System (IAPS; Segal et al. 2012; Weinberg et al. 2014), one study utilizing words to elicit the intended emotion (Michalak et al. 2015), and others utilizing a short (10-min) film clip (Keyan and Bryant 2017b).

Table 1 Data extraction table for the evaluated studies

Authors	Study design	Acute or chronic intervention	Population	Exercise stimulus	Exercise-emotion sequence	Memory valence	Memory assessment	Results
Segal et al. (2012)	RCT	Acute	31 older adults ($M = 69$ y) and 23 older adults ($M = 71$ y) with amnestic mild cognitive impairment	Exercise group, 6 min at 70% of VO_{2max} on cycle; control group, rested quietly	Emotion elicitation first, then exercise	Positive emotional memory; IAPS images included, for example, beautiful landscapes, sport scenes, and baby animals	20 positive images from IAPS were presented. Details on the memory retrieval (e.g., protocol, length of follow-up period) were not provided.	Post-memory exercise enhanced memory recall in the amnestic group as well as the healthy participants, with a greater effect among the amnestic group. Exercise also increased salivary alpha-amylase levels (marker of norepinephrine activation), with these biomarker levels significantly positively correlated with memory recall.
Weinberg et al. (2014)	RCT	Acute	23 participants ($M = 20.6$ y) in the exercise group and 23 ($M = 20.2$ y) in the control group.	Isokinetic dynamometer knee extension exercise. Session consisted of submaximal voluntary dynamic contractions for a warm-up, maximal voluntary isometric contractions, and 6 sets of 10 repetitions of maximal voluntary knee extension contractions. Both legs were exercised. In the control (passive) group, the experimenter passively moved the participant leg between extension and flexion.	Emotion elicitation first, then exercise	Positive, neutral and negative images from the IAPS	180 images from the IAPS. Follow-up memory recall assessment took place 48-h later. The retrieval task included 90 studied images and 90 new images. Participants were instructed to indicate "remember," "familiar," or "new" after seeing each image.	There was no valence × group interaction effect. There was a main effect for valence in that participants remembered more positive and negative images than neutral images.
Michalak et al. (2015)	RCT	Acute	20 participants with a happy gait ($M = 21.7$ y) and 19 with a depressed gait ($M = 20.7$ y)	Participants walked on a treadmill for 15 min. Those in the "happy" gait group walked with normal gait kinematic, whereas those in the depressed gait group walked with an inefficient depressed gait posture.	First started walking for 4 min; while walking the experimenter read a list of 40 words; after walking for approximately 8 min, participants were asked to recall the words while still walking	Positive and negative valence	A list of 40 words, including positive and negative words. See "exercise-emotion sequence" for the assessment order	Affective memory bias was observed in that those who walked with a depressed posture remembered more negative words. Those who walked with a happy posture remembered slightly more positive

Table 1 (continued)

Authors	Study design	Acute or chronic intervention	Population	Exercise stimulus	Exercise-emotion sequence	Memory valence	Memory assessment	Results
				Walking speed was matched for both groups.				words, but this was not significant.
Keyan and Bryant (2017a, b, c)	RCT	Acute	25 participants in the stepping exercise group ($M = 19.9$ y) and 24 in the walking group ($M = 19.7$ y)	The stepping exercise group engaged in stepping exercises at 50–85% of HR_{max} for 10 min and the walking group walked for 10 min at an easy speed (not disclosed).	Emotion elicitation first, then exercise	Negative and neutral emotion	A 10-min film depicting emergency workers attending to the scene of a motor vehicle accident. Participants completed an on-line assessment of intentional recall or intrusion recall after 48 h. The intentional recall survey asked questions about central aspects of the car accident (e.g., "how many victims had dark skin?") as well as peripheral aspects (e.g., "how many police vehicles were at the scene?"). Intrusion items included statements such as, "pictures about the scene popped into my mind."	No group × cued recall interaction effect. There was an interaction effect for intrusion memories. The stepping exercise group recalled more intrusive memories than the slow walking group.
Keyan and Bryant (2017a, b, c)	RCT	Acute	31 participants in the intense stepping exercise group (11 males, 20 females) and 31 in the slow walking group (9 males, 22 females)	The intense stepping exercise group engaged in stepping exercises at 60–85% of HR_{max} for 10 min and the slow walking group walked for 10 min at an easy speed (not disclosed).	Emotion elicitation first, then exercise	Positive and negative emotion	Participants were asked to recall as many IAPS images as they could remember seeing (48-h recall)	No group × recall interaction effect. There was a main effect for condition. The intense stepping exercise group recalled more emotional images than the slow walking group. Regression models indicated an interaction between BDNF genotype (Val homozygote) and elevated cortisol response, which was predictive of total emotional memory recall for the intense stepping group, but not the slow walking group.
	RCT	Acute						

Table 1 (continued)

Authors	Study design	Acute or chronic intervention	Population	Exercise stimulus	Exercise-emotion sequence	Memory valence	Memory assessment	Results
Keyan and Bryant (2017a, b, c)			18 participants in the Reactivation/Exercise group (11 males, 7 females) and 18 in the Reactivation/No exercise group (9 males, 9 females) and 18 in the No Reactivation/Exercise group (8 males, 10 females)	The exercise group engaged in 20–25 min of incremental cycling at 60–70 rpm	Emotion elicitation first, then exercise	Negative and neutral emotion	A 10-min film depicting emergency workers attending to the scene of a motor vehicle accident. Participants completed an on-line assessment of intentional recall or intrusion recall after 48 h. The intentional recall survey asked questions about central aspects of the car accident (e.g., “how many victims had dark skin?”) as well as peripheral aspects (e.g., “how many police vehicles were at the scene?”). Intrusion items included statements such as, “pictures about the scene popped into my mind.” Participants listened to a 2-min audio clip (ambulance sirens and voices of distressed victims) edited from the 10-min film clip served as the reactivation reminder cue. Participants were ask to recall the original film clip and imagine it in as much detail as possible.	The Reactivation/Exercise group recalled more central (but not peripheral) details of the 10-min trauma film than Reactivation/No exercise and Only Exercise groups. There were no statistically significant differences in intrusive memory recall.

HR$_{max}$ heart rate max, *IAPS* International Affective Picture System, *M* mean, *RCT* randomized controlled trial, *VO*$_{2max}$ volume of maximal oxygen consumption

One study provided no details on exactly when the memory retrieval took place (Segal et al. 2012), one study assessed memory retrieval toward the end of the exercise bout (i.e., approximately 15 min after the emotional stimuli (Michalak et al. 2015), and other studies assessed memory retrieval 48 h after the emotional stimuli (Keyan and Bryant 2017b; Weinberg et al. 2014). One study assessed cued recall 96 h after the emotional stimuli (Keyan and Bryant 2017a).

Effects of Exercise on Emotional Memory

Five of the six studies presented reasonable (explained below) evidence to suggest that exercise influenced emotional memory (results also shown in Table 1). Using IAPS images, Segal et al. (2012) demonstrated that (post-memory) exercise (6 min at 70% of VO_{2max}) enhanced memory recall (time period of follow-up assessment was not disclosed) in both an older adult amnestic group and an older healthy sample. A greater effect was demonstrated among the amnestic group.

During a 15-min treadmill walk, Michalak and colleagues (Michalak et al. 2015) had participants either walk with normal gait kinematics or walk with an inefficient depressed gait posture (speed was matched across both conditions; between-group study design). Affective memory bias was observed in that those who walked with a depressed posture remembered more negative words (memory recall occurred approximately 15 min after the memory encoding), while those who walked with a "happy" (normal gait) posture remembered slightly more positive words, but this was not statistically significant.

Keyan and Bryant (2017a) had one group engage in 10 min of stepping exercise (50–85% of HR_{max}) with an active control group instructed to walk on a treadmill for 10 min (exact speed not reported). They used a 10-min film depicting emergency workers attending to the scene of a motor vehicle accident as the emotional cue, and a follow-up survey assessment occurred 48 h later. The intentional cued recall survey asked questions about both central aspects of the car accident (e.g., "how many victims had dark skin?") and peripheral aspects (e.g., "how many police vehicles were at the scene?"), whereas intrusion statements such as "pictures about the scene popped into my mind" were stimuli for participant responses on a Likert scale. The authors observed no group × cued recall interaction effect, but they found an interaction effect for exercise group × intrusion memories in that the stepping exercise group recalled more intrusive memories than the slow walking group. Relatedly, Keyan and Bryant (2017c) administered a similar stepping protocol (60–85% of HR_{max}) with an active control group engaging in slow treadmill walking, as previously described. Using IAPS images, no group × cued recall interaction effect was observed. However, the intense stepping exercise group recalled more emotional images than the slow walking group. Regression models indicated an interaction between BDNF genotype (Val homozygote) and elevated cortisol response, which was predictive of total emotional memory recall for the intense stepping group, but not the slow walking group.

Keyan and Bryant (2017a) utilized the same 10-min film, with a memory reactivation period occurring 48-h post-emotional activation, and cued recall occurring 96-h post-emotional activation, but 48 h following the exercise manipulation. The acute exercise bout included 20–25 min of incremental cycling at 60–70 rpm, with a time-matched non-exercise control condition. Findings from this experiment demonstrated statistically significant main effects for the reactivation/exercise group, which recalled more central (but not peripheral) details of the 10-min trauma film than both the reactivation/no exercise and exercise only groups. There were no statistically significant differences in intrusive memory recall.

Lastly, Weinberg et al. (2014) had an exercise group engage in six sets of 10 repetitions of maximal isokinetic dynamometer knee extension exercises, and, in a passive control group, the experimenter passively moved the participant's leg between extension and flexion. Using the IAPS images as stimuli, a follow-up memory recall 48 h after the emotional stimuli exposed participants to 90 of the studied images and 90 new images and required participants to indicate "remember" if they were certain they had seen the image 2 days prior and could recollect specific associations with the image (responding "familiar" if they were certain they saw the image but could not recollect any specific associations, and "new" if they were certain they had not previously seen the image). Weinberg et al. (2014) observed no valence by group interaction effect, but they observed a main effect for valence, in that participants remembered more positive and negative images than neutral images. Among other factors, the null finding for the interaction effect may have been due to using positive and negative IAPS images that were only roughly matched for arousal; some evidence suggests that arousal, not valence, is the key factor in determining why emotional items are remembered better than neutral items (Kensinger and Corkin 2003). Although Weinberg et al. (2014) did not demonstrate strong evidence of an exercise-induced emotional memory enhancement effect, they provided suggestive evidence that physiological arousal may influence emotional memory. For example, when they classified participants in the active leg extension group as responders or non-responders (based on a median split of exercise-induced physiological responses of heart rate and blood pressure, high responders, compared to low responders, showed memory impairments for the neutral items, while memory in the two groups was comparable for the emotional items).

Molecular Mechanisms to Explain the Exercise-Emotional Memory Relationship

As described in the "Introduction" section, NE may be an important biomarker mediating emotional memory. Several (Segal et al. 2012; Weinberg et al. 2014) of the six studies measured salivary alpha-amylase (sAA) levels, a marker of NE. Keyan and Bryant (2017a) did not observe reliable sAA response following memory reactivation and exercise, and no statistically significant main effects relative to changes in sAA concentration. Although the Weinberg et al. (2014) study did not present strong evidence for an exercise-enhanced emotional memory effect, their sAA findings showed that the active knee extension exercise group had higher post-exercise sAA levels than the passive exercise control group. Unlike the Weinberg et al. (2014) study, Segal et al. (2012) demonstrated more convincing evidence of an exercise-induced emotional memory effect. In their study, exercise significantly increased sAA levels (relative to baseline) in both the cognitively intact (healthy older adult sample) and amnestic older adult group, suggesting that sAA may partially mediate the relationship between exercise and emotional memory. Additionally, Keyan and Bryant (2017c) provide evidence for the moderating role of exercise-stimulated BDNF, which may substantially influence glucocorticoid release and downstream processes underlying emotional memory.

Discussion

The purpose of this brief systematic review was to evaluate literature regarding the potential relationship between exercise and emotional memory. While a limitation of this review was its basis on only six relevant articles, its strength is the systematic evaluative review of a novel topic. We found too few studies of human participants to render meaningful conclusions, but this newly emerging literature provides suggestive evidence that exercise may augment emotional memory, via various psychological, neural, and hormonal mechanisms. Clearly, additional research on this under-investigated topic is warranted.

We encourage future work to specifically evaluate potential gender interaction effects. Some prior studies demonstrate that gender moderates the emotion-memory relationship (Canli et al. 2002). Another useful factor to consider may be whether the timing of exercise (i.e., before, during, or after the emotional stimuli) moderates the relationship between exercise and emotional memory. Exercise occurred after the emotional stimuli in five of the six evaluated studies, which makes sense from a memory consolidation perspective. In the context of other memory types (e.g., non-emotional episodic memory), it appears that exercising prior to the memory task may be optimal (Labban and Etnier 2011). Of course, given the paucity of research on this specific topic, there are countless other variables to consider as well (e.g., exercise modality, varying population samples, candidate mediating mechanisms).

Continuation of research on this topic will offer important implications for the development of specific strategies to modulate emotional memory outcomes. Although not yet widely investigated, exercise may serve as a safe and efficacious stimulus, linking stress and arousal to targeted amygdalar activity and heightened encoding, recall, and maintenance of emotionally salient information. To this end, exercise may be a viable supplement to rehabilitation programs for patients whom have experienced emotional trauma or those diagnosed with clinical affective disorders. Moreover, delineating various methods for employing exercise as a eustressor capable of inducing arousal sufficient to activate, and reactivate, emotional memories will be integral to healthy populations, such as college students, adult professionals, and lifelong learners devoted to accumulating and retaining knowledge for the betterment of society.

Conflict of Interest The authors declare that they have no conflicts of interest.

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