

## Spotlight

## Subliminal backdoors to forgetting emotional memories

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**Weakening negative memories often requires first remembering those events. To bypass this distressing process, Zhu *et al.* elicited forgetting by subliminally reactivating negative memories near in time to retrieval suppression of unrelated memories. Casting an amnesic shadow over harmful, reactivated memories thereby brings new therapeutic possibilities, and questions, to light.**

Identifying safe and effective methods to weaken or update emotional memories is essential for promoting mental health and well-being. Current treatments for fear-related disorders often require explicit recollection of traumatic experiences. Yet, reliving aversive events can elicit significant distress and lead to attrition from treatment. It is therefore imperative to find ways to bypass the unpleasantness of re-exposure when weakening unwanted emotional memories.

One promising method is to elicit an ‘amnesic shadow’ in which suppressing memory retrieval globally and transiently disrupts hippocampal processing, making any memories reactivated in temporal proximity prone to forgetting [1]. Inducing the amnesic shadow has been shown to successfully weaken memory for unrelated ‘bystander’ items that are explicitly presented within this window [1]. In a recent study, Zhu *et al.* [2] pushed this idea even further by testing if retrieval suppression also impairs emotional memories reactivated indirectly and outside of conscious awareness.

In two experiments, participants first learned to separately associate a neutral object and a neutral word with the same emotional scenes. The neutral objects would later serve as reminders to reactivate emotional scenes during the amnesic shadow. By contrast, scene-associated words were not presented as reminders and were instead used to test for generalized forgetting. Next, participants learned unrelated cue–target word pairs that would specifically be used in a Think/No-Think procedure to induce the amnesic shadow. In this procedure, participants were presented with a neutral cue word and either retrieved or suppressed its corresponding target word. Objects previously paired with emotional scenes were then presented consciously, subliminally, or not at all (control condition) between two of these retrieval or suppression attempts using a masking procedure.

Zhu *et al.* found that during a window of retrieval suppression, both subliminal and supraliminal reactivation led to greater forgetting of bystander emotional scenes compared with scenes that were not reactivated. Thus, unconscious reactivation rendered negative memories vulnerable to the amnesic shadow, even when suppression was performed on benign, unrelated memories. These amnesic effects of suppression occurred for both essential details and more general recollection of emotional scenes, suggesting widespread impairment of hippocampal-

dependent memories. Retrieval of emotional scenes was also impaired when individuals were cued with their corresponding words, despite those words not being presented during the amnesic shadow. Finally, retrieval suppression of target words, an index of the strength of the amnesic shadow, was correlated with shadow-induced forgetting of general but not specific memories of emotional scenes.

These exciting findings reveal new ways of weakening unwanted memories without the unpleasantness of explicit recollection. However, successfully translating these effects to the clinic poses several challenges. Some participants had above-chance recognition in an offline consciousness check and several subliminal items were reported as visible in online trial-by-trial checks. Such inconsistencies raise the question of how many ‘breakthrough’ perceptions are acceptable in a clinical context. Individuals with post-traumatic stress disorder (PTSD) also exhibit deficient prefrontal inhibitory control, complicating the use of suppression techniques needed to induce amnesic shadows [1,3]. Thus, unconscious methods that do not require effortful suppression may be more suitable in certain contexts (Box 1).

Another critical question is whether the amnesic shadow affects reconsolidation of older emotional memories, which are most often targeted for intervention. The shadow may fail to modify remote memories that have undergone systems consol-

#### Box 1. Unconscious methods for weakening aversive memories during wake and sleep

Several state-of-the-art subliminal techniques may be used to weaken different aspects of emotional memories outside of conscious awareness. Neurofeedback uses real-time decoding of multivariate fMRI signals to guide participants to incidentally reactivate neural representations of feared stimuli [9]. This procedure has been shown to successfully reduce measures of fear while avoiding the typical requirement of repeated exposure to the feared stimulus. Specifically, hyperalignment can be used to extrapolate neural representations, or templates, of feared stimuli from a separate group of participants. These neural templates can then be used as the target of neurofeedback during a different participant’s reinforcement sessions to prevent explicit re-exposure to negative stimuli [9]. Interestingly, forgetting has also been successfully induced offline. Targeted memory reactivation (TMR) is typically used to reactivate and strengthen associative memories during slow wave sleep. However, more recent work has applied TMR to instead weaken object memories by presenting sounds previously paired with those objects with an auditory forget signal [10]. Together these innovative techniques may be effective for reducing physiological and conscious aspects of fear while also avoiding the unpleasantness of remembering traumatic experiences.

idation and no longer recruit hippocampal processes. Additionally, subliminal cues may diminish prediction errors necessary for updating existing memories [4]. Future interventions could aim to boost prediction errors by manipulating patients' expectations about how or when they will be re-exposed subliminally to aversive memories during treatment. Relatedly, the strength and fidelity of memory reactivation can modulate forgetting, with moderate reactivation eliciting the greatest weakening effects [4]. Weaker and lower fidelity scene reactivation during subliminal cueing may help explain Zhu *et al.*'s finding that retrieval suppression was closely linked to forgetting general but not specific aspects of emotional representations.

Which aspects of an emotional memory should be targeted to maximize the therapeutic benefit of the amnesic shadow? So far, the shadow has been shown to reduce retrieval accuracy. However, while some methods of retrieval suppression can initially cause forgetting, they can also promote later memory intrusions and potential relapse [5]. According to one framework, retrieving a weakened emotional memory may paradoxically increase its accessibility in the future [6]. Dampening negative memories might therefore backfire if therapy ends prematurely and these memories resurface. Rather than eliminating negative memories, treatments could instead aim to remove the sting or vividness of aversive experiences. Indeed, several leading therapies, such as cognitive behavioral therapy, try to address patients' emotions and subjective qualities of negative memories during explicit retrieval. Retrieval suppression has also been shown to reduce the vividness of emotional memories [7], but

less is known about whether the amnesic shadow affects the discomfort or intensity of recollection.

The far-reaching and generalized forgetting effects of subliminal reactivation also raise several ethical issues. Zhu *et al.* found that amnesic shadow effects occurred for nonpresented information and were related to greater forgetting of more general aspects of bystander emotional scenes. One strength of this technique, then, is that it may enable a wide range of reminders to reactivate more complex real-world emotional memories, especially when certain details of the original event are unclear. However, a patient's mental autonomy could be compromised if forgetting spreads beyond the agreed-upon target memory to interconnected autobiographical memories. Unconscious methods also limit patients' ability to verify which memories were weakened. Further, individuals with severe PTSD may develop more overgeneralized autobiographical memories, which in turn interact with a larger associative memory network [8]. Broader networks could either increase the extent of undesirable forgetting in these individuals or, conversely, promote recovery of aversive memory traces when these networks are activated.

In summary, subliminal reactivation is an exciting first step toward developing therapies that can dampen harmful memories without inducing mental distress. Future studies should test if the amnesic shadow can be cast on emotional autobiographical memories. They should also consider the ethical implications of using unconscious methods to treat fear-related disorders.

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### Declaration of interests

No interests are declared.

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