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Inducing positive involuntary mental imagery in everyday life: an experimental
investigation

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Abstract

Positive involuntary mental imagery occurs frequently in daily life but evidence as to its functions and importance is largely indirect. The current study investigated a method to induce positive involuntary imagery in daily life, which would allow direct testing of its impact. An unselected student sample ($N = 80$) completed a single session of a positive imagery cognitive bias modification (CBM) paradigm, which involved listening to and imagining brief positive imagery scripts. Participants then recorded any involuntary memories of the imagined training scenarios in a three-day diary before returning to the lab for a follow-up assessment. Participants were randomized to imagine the scenarios in either an emotionally involved or emotionally detached manner, providing a test of the role of emotion in the subsequent experience of involuntary memories. Participants reported experiencing involuntary memories of the training scenarios in their daily life, but the number recorded did not differ between the experimental conditions. Exploratory analyses suggested that more vivid imagery and recall testing were associated with a greater number of involuntary memories. The study highlights the potential of the imagery CBM paradigm to further our understanding of the functions and potential importance of positive involuntary mental imagery in daily life.

Keywords: involuntary imagery, mental time travel, mental imagery, involuntary autobiographical memories, positive affect

Inducing positive involuntary mental imagery in everyday life: an experimental investigation

For most of us, the experience of mental imagery is a frequent part of everyday life. Much of this imagery occurs involuntarily, without any deliberate or conscious effort, for example when images of an upcoming holiday destination or social event pop spontaneously into mind while we are engaged in a tedious task at work. Further, a substantial amount of the involuntary imagery experienced in daily life is *positive* in its emotional tone. However, we have very little direct evidence as to the importance and functions of such positive involuntary imagery in daily life, and to generate such evidence we need new methods of investigation.

Mental imagery can be defined as “representations and the accompanying experience of sensory information without a direct external stimulus.” (Pearson et al., 2015, p. 590), and is perhaps most commonly experienced in daily life in the context of ‘mental time travel’ (Berntsen & Jacobsen, 2008). Mental time travel refers to the process by which we can replay and re-experience events from the past or simulate and pre-experience possible future events. It has been argued that mental time travel is an important process in our everyday functioning, for example in relation to emotion regulation, planning for the future, and decision-making (e.g., Barsics et al., 2016; Berntsen, 2019; D’Argembeau et al., 2011; Kensinger & Ford, 2020; Schacter et al., 2007) and in fact appears to be a ‘default’ activity that our mind engages in when there is little else to occupy it (Schacter et al., 2007). Mental imagery provides a key component of the experience of mental time travel, acting as a simulation of reality and evoking emotional, physiological, and even behavioural responses as if the imagined event was unfolding in the present (Ji et al., 2016). The emotional tone of the mental imagery we experience over the course of a day may be of particular importance (Blackwell, 2019). For example, if each time we think about upcoming events we readily experience a positive memory of a similar event or a positive freshly-constructed image of the future event flashing into our mind, we are more likely to anticipate a positive experience and feel optimistic and

motivated than if the images we retrieve or generate tend to be relatively negative.

Interestingly, involuntary mental imagery, at least when future-oriented, appears to be more often positive than negative (Berntsen & Jacobsen, 2008; Cole et al., 2016), fitting with the idea of an adaptive ‘optimism bias’ (Sharot, 2011; Weinstein, 1980) that helps to keep us motivated in the context of ambiguity and resilient in the face of adversity.

However, despite the apparent frequency of positive involuntary mental imagery in daily life, statements about its role and impact generally rely on indirect inference from observational data or studies of deliberately-generated imagery. Most research investigating the occurrence of involuntary memories or future projections (see e.g., Barsics et al., 2016; Cole & Kvavilashvili, 2019) has tended to rely on naturally occurring or cued (in lab contexts) autobiographical memories or future projections rather than standardized scenes, which means that factors important at encoding cannot be studied and observed individual differences may be confounded by differences in participants’ histories (see James et al., 2016, for a discussion of these issues in relation to negative memories). Although deliberate (instructed) generation of standardized imagery scenes may allow a more controlled investigation of the impact of imagery generation on factors such as mood (e.g., Holmes et al., 2009), decision-making (e.g., Gaesser & Schacter, 2014), or behaviour (e.g., Pictet et al., 2011; Renner et al., 2019), we need to be cautious about extrapolating from this to involuntary, spontaneously occurring imagery, particularly as there is some evidence that involuntary mental imagery may differ in its emotional impact and other phenomenological characteristics compared to its voluntarily generated counterparts, and this is a matter of ongoing debate (e.g., Barsics et al., 2016; Barzykowski & Staugaard, 2016; Berntsen & Hall, 2004; Cole et al., 2016; Schlagman & Kvavilashvili, 2008). In fact aside from participants’ subjective reports (e.g., Barsics et al., 2016; D’Argembeau et al., 2011; Duffy & Cole, 2020; Rasmussen & Berntsen, 2013) we have very little, if any, *direct* evidence as to the functions and impact of what seems to be one of the most commonly-experienced forms of mental

imagery. To gather such evidence we need to be able to induce or otherwise manipulate the occurrence of positive involuntary images of standardized scenes in daily life and observe their effects.

The current study investigates the potential use of brief standardized imagery scripts to induce positive involuntary imagery in everyday life. The original impetus for the study came from research investigating the potential of a computerized cognitive training paradigm, termed imagery cognitive bias modification (CBM), as an intervention in the context of depression (e.g., Blackwell et al., 2015; Blackwell & Holmes, 2010). During positive imagery CBM, participants listen to training scenarios that consist of brief descriptions of mostly everyday situations, which are structured such that they start ambiguous as to how they might end, but then always end positively. As they listen to each training scenario, participants are required to imagine themselves in the situation described as it unfolds, as if actively involved. The paradigm was derived from experimental psychopathology research (e.g., Holmes et al., 2009), and is an adapted version of an interpretation training paradigm (Mathews & Mackintosh, 2000); the rationale for its application in depression was that via being repeatedly constrained to imagine positive outcomes for ambiguous situations during the training, a bias would be trained to automatically imagine positive outcomes for ambiguous events in daily life. Such a cognitive training might therefore help to counteract the negative interpretation bias (Everaert et al., 2017) and broader dysfunction in positive imagery (Holmes et al., 2016) that characterize depression.

Following this rationale, studies investigating the clinical potential of imagery CBM as an intervention in the context of depression have tended to assess the impact on interpretation bias (e.g., Pictet et al., 2016; Williams et al., 2013), and measures of imagery (Blackwell et al., 2015; Torkan et al., 2014), as potential mechanisms via which there may be effects on symptoms of depression. However, conversations with participants in the clinical studies suggested another potential mechanism for the improvement they experienced in their

symptoms of depression: the experience of involuntary memories of the imagined positive training scenarios in their daily life (Blackwell & Holmes, 2010, 2017). Some participants who experienced particularly large reductions in symptoms of depression while completing one of the imagery CBM clinical studies reported that the imagined training scenarios sometimes ‘popped back’ into their mind during the day. Further, they felt that these involuntary images had positive effects on their mood, cognition, and even behaviour. For example, one participant reported that one day while at home, a training scenario involving going for a walk and feeling invigorated had popped into her mind. She felt that this led her to think that perhaps going for a walk would be a good idea, and in fact she then went out for a walk – an unusual thing for her to do (Blackwell & Holmes, 2017). The apparently powerful effect of this spontaneous imagery makes sense if we consider the multi-faceted nature of imagery, which may include cognitive, emotional, and simulated behavioural response components (Ji et al., 2016). Further, such imagery may be especially noticeable and have particular impact amongst people who are depressed and who otherwise would experience a paucity of positive imagery in daily life.

That participants taking part in imagery CBM studies may experience involuntary memories of the training scenarios in daily life makes sense if we consider that involuntary memories and future projections are often triggered by cues in the environment (e.g., Berntsen & Jacobsen, 2008), which may prime retrieval of memories with overlapping content (e.g., Barzykowski & Niedźwieńska, 2018; Mace, 2005). Given that the training scenarios are predominantly of everyday situations unfolding in the participants’ everyday environments, we could expect that participants would frequently encounter potential triggers for involuntary memories of the training scenarios in their daily lives. The anecdotal accounts from participants in the clinical studies indicated that such involuntary memories may have beneficial effects, and thus suggested the hypothesis that increasing the extent to which participants experienced involuntary memories of the training scenarios in daily life would

lead to better clinical outcomes from imagery CBM (Blackwell & Holmes, 2017). However, given that even the existence of the phenomenon of such involuntary memories was only supported by anecdotal evidence, an important first step in taking this idea forwards would be to investigate the occurrence of such involuntary imagery formally in an experimental setting. Establishing the occurrence of this phenomenon would pave the way for future work to investigate it as a potential mechanism of imagery CBM as an intervention. Further, and of broader relevance, it would suggest that the imagery CBM paradigm could be used as an experimental tool to induce involuntary positive imagery in everyday life, opening opportunities for testing hypotheses about the impact and importance of such imagery. The current study therefore aimed to provide a first formal investigation of the occurrence of involuntary memories of imagery CBM training scenarios in daily life, via asking unselected student participants to complete a session of imagery CBM in the laboratory and then record any involuntary memories of the training scenarios in a simple diary over the next few days.

The study also aimed to investigate one potential factor that could modulate the frequency of involuntary memories: the emotion induced by the training scenarios while imagining them. Studies using positive (Clark et al., 2013) and negative (Clark et al., 2015) film clips as stimuli had found that the emotion induced by the films (as indexed by mood change) predicted the number of involuntary memories of the films that participants experienced over the subsequent week, in that greater mood change was associated with more involuntary memories of the film clips. However, these results do not allow causal conclusions about the impact of emotion on subsequent involuntary memories to be drawn, in that we cannot confidently conclude that participants had more or fewer involuntary memories because of the greater or lesser level of emotion they experienced. Potential evidence for a causal role of emotion in the experience of involuntary memories is provided by a study by Staugaard and Berntsen (2014), in which participants were presented with stimuli consisting of a positive, neutral, or negative picture paired with a sound. In a

subsequent laboratory-based involuntary memory provocation task, participants heard the sounds through the left or right headphone, and had to indicate whether the sound occurred on the same or opposite side to a star presented on the computer screen. Additionally, participants had to report if they experienced any involuntary memories of the previously-presented pictures. When tested immediately post-encoding, there appeared to be no effect of stimuli emotional valence on occurrence of involuntary memories, but when tested 24 hours or one week post-encoding, participants reported more involuntary memories of emotional compared to neutral pictures. Although these results imply an effect of emotion on involuntary memory, at least after there has been time for memory consolidation and sleep, the emotion here refers to the emotional valence of the stimuli and not the intensity of emotion experienced by individuals while exposed to the stimuli. The current study therefore aimed to conduct a causal test of the impact of emotion experienced at the time of memory encoding on the occurrence of subsequent involuntary memories.

To achieve an experimental manipulation of emotion we randomly allocated participants to one of two groups with different instructions as to how to imagine the imagery CBM training scenarios. Participants in one group were instructed to imagine the scenarios in an emotionally-involved manner, and participants in the other were instructed to imagine the scenarios in an emotionally-detached manner. To facilitate emotional involvement or detachment our instructions also included a perspective manipulation; that is, participants in the emotionally involved group were instructed to imagine the scenarios from a ‘field’ perspective, seeing the events as if through their own eyes, and participants in the emotionally-detached group were instructed to imagine the events from an ‘observer’ perspective, seeing the events from the outside as if watching a film of themselves (see e.g., Nigro & Neisser, 1983). This use of a perspective manipulation to influence the emotion experienced drew on literature indicating that, in general, observer-perspective imagery and memories are generally experienced as less emotional than field-perspective imagery (e.g.,

Kuyken & Moulds, 2009; Vella & Moulds, 2014; Wallace-Hadrill & Kamboj, 2016). In the context of imagery CBM, previous studies instructing participants to use either a field or observer perspective to imagine scenarios have not consistently found a difference in the effects on state positive affect (Holmes et al., 2008; Nelis et al., 2012). However, as part of a broader manipulation of emotional engagement we anticipated that the instruction to use a particular perspective would facilitate achieving differential experience of emotion between our two groups. We investigated the effect of this experimental manipulation on the number of involuntary memories experienced in daily life, as recorded in the diary. We further included a lab-based involuntary memory task adapted from that used by Berntsen and colleagues (Berntsen et al., 2013; Staugaard & Berntsen, 2014), both immediately after the imagery CBM session and at a follow-up appointment three days later, to investigate whether we would also found a time-dependent effect of emotion.

One ongoing discussion in research investigating involuntary memories is their relation with voluntary memory. In the study by Staugaard and Berntsen (2014), voluntary memory for the picture stimuli was also assessed, and showed a similar pattern to that found for involuntary memories: Participants demonstrated better voluntary memory for emotional compared to non-emotional picture stimuli, but this effect of emotional valence was only present at 24 hours and one week post-encoding. In contrast, other studies, such as those using negative film stimuli, have found dissociations between voluntary and involuntary memory (e.g., Lau-Zhu et al., 2019). We therefore included measures of voluntary memory of the imagery CBM training scenarios in our study to investigate whether effects of our emotion manipulation would also be found for voluntary memories of the scenarios.

In summary, the current study aimed to investigate whether the imagery CBM paradigm could be used to induce involuntary positive imagery in daily life, to investigate the role of emotion in the occurrence of involuntary memories, and to further explore whether the impact of emotion is similar for both involuntary and voluntary memory. The following

hypotheses were specified a priori: Our primary hypothesis was that participants instructed to imagine the training stimuli in an emotionally involved way (emotional condition) would report more involuntary memories in the three-day involuntary memory diary than participants instructed to imagine the training stimuli in an emotionally-detached manner (non-emotional condition). A secondary hypothesis was that participants in the emotional condition would report more involuntary memories in the lab-based involuntary memory provocation tasks than participants in the non-emotional condition. There were no specific hypotheses specified for other measures such as of voluntary memory, which were included primarily for exploratory purposes to better characterize any effects found. We planned a number of further analyses to investigate potential mechanisms underlying the occurrence of involuntary memories.

Materials and Methods

Design

The study used a randomized experimental design with two parallel groups ('emotional condition' and 'non-emotional condition') and two lab-based testing sessions three days apart. The main outcome of interest was involuntary memories of scenarios imagined during an imagery CBM procedure in the first testing session, as recorded in a diary completed between the two testing sessions. Additional outcome variables included involuntary memories recorded in a lab-based involuntary memory provocation task and voluntary memory for the imagery CBM scenarios, measured in both lab-based sessions. The study was pre-registered via uploading the study protocol to the Open Science Framework prior to testing the first participant (<https://osf.io/whk2b/>).

Participants

Participants were recruited via advertisements on the university campus, social media, the Faculty of Psychology website, and personal contact. Potential participants who contacted the research team expressing an interest in the study were first emailed a copy of the

information sheet, and if they were still interested and potentially eligible they were invited to the lab-based testing sessions. Inclusion criteria were: Aged between 18 and 30 and currently a student; willing and able to complete all study procedures (e.g. able to attend the two sessions, sufficient German language); and not taking part in other studies that might influence their participation in this one (e.g. using similar mental imagery paradigms). By restricting participation in the study to students aged 18-30, we intended to achieve a relatively homogeneous sample for whom the study materials would be relevant.

Eighty-one participants attended the first testing session and were randomized, but one participant did not return for the second session and did not return the diary, and thus was excluded from analyses (as pre-specified in the study protocol). This left a sample of 80 participants (Age: $M = 23.35$, $SD = 2.77$, range = 18-30 years; Gender: 70% female). One participant (emotional condition) did not return for the second testing session, but did return the diary. Another participant (non-emotional condition) cancelled the second appointment due to illness and attended it two days late. Data from these two participants were included in analyses. Participants were rewarded with either 25€ or course credit necessary to achieve the bachelor's degree in psychology. The study was approved by the local ethics committee of the faculty of psychology at Ruhr-Universität Bochum (No. 320). All participants provided written informed consent.

Materials

Positive imagery cognitive bias modification. The positive imagery cognitive bias modification (imagery CBM) paradigm with which we aimed to induce positive involuntary memories was adapted from previous experimental (e.g., Holmes et al., 2009) and clinical (e.g., Blackwell et al., 2015) studies, and implemented in Java. Training stimuli were 40 brief descriptions (~10 s audio recordings) of scenarios describing everyday activities (e.g., meeting a friend, catching a bus). The scenarios were designed to start ambiguously and resolve positively (e.g., "You are in the cafeteria eating lunch alone. You join a group you do

not know well. As they welcome you, you realize that *they are really happy that you joined them*"; positive resolution in italics). The scenarios were newly created for this study, and designed to be relevant to participants currently studying at the university. Twenty were recorded in a female voice, and twenty in a male voice.

The imagery CBM session consisted of five blocks of eight scenarios, with a short self-paced break after every block. In the initial breaks, the experimenter checked that the participant was following the instructions according to the experimental manipulation (see below), by asking them to describe the last scenario they had imagined. The participant was also given the opportunity to ask any potential questions. Presentation of each scenario started with a screen (1.5 s) prompting the participant to close their eyes. The participant then heard the scenario played via stereo headphones (with a blank computer screen). There was then a 2 s pause, after which a tone prompted the participants to open their eyes and rate how vividly they had imagined the scenario on a 5-point scale ranging from 1 (*not vivid at all*) to 5 (*very vivid*). Order of scenarios was randomized for each participant. A relatively brief session (40 scenarios, compared to 100 or 64 as most commonly used in experimental or clinical studies, respectively) was used as we were not interested in the training as a means to change e.g. mood or bias, and 40 scenarios would provide a sufficient selection of potential scenes to be later re-experienced as involuntary memories.

Imagery instructions. Before the participant completed the imagery CBM, the researcher provided them with instructions and practice in generating mental imagery. This followed a standardized script adapted from previous studies (e.g., Blackwell et al., 2015; Holmes et al., 2008). First, mental imagery was defined and an example provided, after which comprehension was checked by asking the participants to provide an example themselves. Participants were then instructed in the specific way in which they should generate mental imagery according to their experimental allocation (i.e. emotional, via field perspective, or non-emotional, from observer perspective, see below). Afterwards, participants were guided

through a standardized imagery practice task in which they were instructed to imagine themselves cutting a lemon. This was followed by further instructions to avoid verbal analysis and not be put off by unrealistic imagery content (using the examples of seeing a flying elephant and winning the lottery). The researcher then read aloud two practice scenarios, similar to those imagined during the imagery CBM, which the participant imagined and provided feedback on. Throughout, the researcher elicited feedback from participants in order to verify that they were generating imagery according to their specific instructions, and to provide corrective guidance if necessary. Participants were repeatedly asked to rate the vividness of their mental images on the 5-point scale used during the imagery CBM program to familiarize them with this rating scale. A final practice example followed on the computer (prior to starting the first block of scenarios).

Experimental manipulation: Emotional vs. non-emotional imagery. Participants in the ‘emotional’ condition were instructed to imagine the scenarios as if actively involved, as if seeing through their own eyes (i.e. field perspective), and experiencing the relevant emotions (i.e. the standard instructions used in most imagery CBM studies). Participants in the ‘non-emotional’ condition were instructed to imagine the scenarios in an emotionally detached manner, and to facilitate this, were instructed to imagine the scenarios as if seeing themselves from the outside (i.e. observer perspective), for example as if seeing CCTV footage of themselves (e.g., Holmes et al., 2008). As in previous studies, the distinction was illustrated using two pictures to represent imagining ‘lying on your back, looking up at the sky’, one of the sky itself (i.e. field perspective) and one showing a person looking at the sky (i.e. observer perspective). These different instructions were repeated and reinforced throughout the practice examples, and within the breaks in the imagery CBM task itself.

Involuntary memory diary. Between the two days of assessment, participants were instructed to use a standardized diary to note every involuntary memory of a training scenario they experienced. This was adapted from studies using film paradigms (e.g., Clark et al.,

2013), and comprised 2 A4 sheets of paper folded into an A5-sized booklet. Participants were instructed to record only involuntary memories of training scenarios (“memories that come to mind spontaneously”, and not to record deliberately-recalled memories (“memories that come when you actively think about the event”). Participants noted when each involuntary memory occurred, via putting a tick in a grid representing the time between the first and second assessment session. On a separate page they then made a brief note of the content, and rated its emotional valence on an 11-point scale ranging from -5 (*very negative*) to 5 (*very positive*). Participants were instructed in completing the diary by the researcher at the end of the first session. During the second session, while the participant was completing the questionnaires and computer-based tasks, the researcher checked whether they could match the involuntary memories against specific scenarios by comparing the participant’s description of the content against a list of the scenario texts. If there were any diary entries for which it was not clear whether the content reflected an involuntary memory of a specific training scenario or not, or for which there was some ambiguity as to which specific scenario the description referred to, the researcher queried these entries with the participant at the end of the second session by asking for further information about the content of the involuntary memory. Only diary entries that could be matched to a specific training scenario were included in analyses (i.e. entries were excluded if they were clearly of something other than a training scenario, such as another aspect of the study, or if they could not be matched to a specific training scenario even after discussion with the participant). Of 164 diary entries in total, 42 were excluded as clearly related to something other than a training scenario (e.g. a memory of the music filler task), and a further 7 were excluded because they could not be matched to a specific scenario (e.g., the entry was too brief and the participant could not remember clearly enough to clarify the content).

Involuntary Memory Task. To provide a lab-based measure of involuntary memories of the training scenarios, we used a computerized involuntary memory provocation task

(IMT) adapted from that used by Berntsen, Staugaard, and Sørensen (2013) and Staugaard and Berntsen (2014). The IMT consisted of 40 trials in which participants heard a sound cue presented via either the left or right headphone. A yellow star was presented 1500 ms after sound onset on either the left or the right hand side of the monitor (with a black background throughout)¹. After 500 ms an instruction screen appeared asking participants to press a key to indicate whether the sound and the star were presented on the same (pressing '1') or different side (pressing '2'). Additionally, participants were instructed that if they experienced a spontaneous mental image they should instead press '3'. On pressing '1' or '2', the task moved immediately to the next trial. On pressing '3', a screen was presented asking the participant to type in a brief description of the spontaneous image and a rating of its valence on a 11-point scale ranging from -5 (*very negative*) to +5 (*very positive*). Participants were also asked to indicate whether the star and sound had been on the same or different sides by typing 1 or 2 into a text box. On clicking a button to submit these answers, the task moved onto the next trial.

The cue sounds were a random selection of 20 brief snippets (2 to 3 words) taken from the start of the imagery CBM scenarios to provoke spontaneous memories of them and 20 everyday sounds (e.g., a car door closing) to assess the general tendency to report spontaneous images in response to cue sounds (as a control measure). The cues were presented in a random order. The IMT was implemented as a desktop application in Java.

Split half reliabilities [95% CIs] for number of involuntary memories recorded were 0.83 [0.74, 0.89] for scenario cues and 0.77 [0.64, 0.85] for everyday sound clips in the first session, and 0.82 [0.72, 0.89] for scenario cues and 0.84 [0.74, 0.89] for everyday sound clips in the second session.

¹ We note that this order of presentation is different from that in the study protocol, which stated that the star was presented on the screen first, and followed by hearing the sound. This is most likely a mistake in the study protocol.

Voluntary Memory Test. Voluntary memory for the training scenarios was assessed via a cued recall memory test presented in form of a paper questionnaire, created specifically for this study. Participants were presented with the ambiguous stems of 10 training scenarios without their positive resolution (e.g., “You are in the cafeteria eating lunch alone. You join a group you do not know well. As they welcome you, you realize that ...”). They were instructed to try to complete each scenario, writing down the ending. Participants were asked to rate their confidence in the answer on a 5-point scale ranging from 1 (*very unconfident*) to 5 (*very confident*). As a test of episodic recall of hearing the scenario, participants were asked to indicate whether the scenario had been read out in a male or female voice, and then also rated their confidence in this response. Finally, participants were asked to rate the emotional valence of their memory of the scenario on an 11-point scale ranging from -5 (*very unpleasant*) to 5 (*very pleasant*). Two versions of the voluntary memory task were created (A and B), each with ten different scenarios. The scenarios were selected and divided between the two forms in such a way to roughly equate them for scenario content and length of the (missing) endings, and such that half of the scenarios in each version had been heard in a female voice. Participants completed a different version of the voluntary memory test in both the first and second session (with the exception of 6 participants, who due to an administrative error were given the same test each time), with the order counterbalanced across participants.

Participants’ completions on the voluntary memory recall task were scored as either 0 (*incorrect*), 1 (*partially correct*), or 2 (*completely correct*). Responses were scored independently by two raters (SEB and FW), who initially practiced on a set of data gathered during piloting and used this to establish and agree a scoring guide. After both raters had completed their ratings for the study data set, Cohen’s kappa was calculated to determine inter-rater reliability, and ranged from 0.72 to 0.82. Disagreements in scoring were resolved through discussion, resulting in generation of a consensus score for each response. Split half reliabilities for recall accuracy ranged from 0.44 to 0.61 (see Supplementary Material for full

details). Therefore, although the coding scheme resulted in reasonable inter-rater reliability, internal consistency of the resulting scores were low, and thus analyses using the total scores must be treated cautiously.

Music filler task. A music filler task was used to equalize state mood between the two experimental conditions (in case of differences in induced mood) after the imagery CBM and before completing cognitive measures, to reduce the likelihood that any group differences found on the cognitive tasks were simply a reflection of differences in state mood. Participants listened to fifteen 40 s clips of classical music presented via stereo headphones and rated their ‘pleasantness’ on a 9-point scale ranging from 1 (*extremely unpleasant*) to 9 (*extremely pleasant*) on a paper questionnaire. The filler task therefore took 10 mins in total, and the task and clips used were the same as those used in previous studies for this purpose (e.g., Holmes et al., 2009).

Questionnaire measures.

Demographic and screening information. A questionnaire adapted from other studies in the department was used to collect demographic information and also some screening items intended to capture participants’ general mental state at the time of testing and help explain potential unusual patterns of responding. These included asking how well the participant had slept the previous night (on a scale from 1 = *very badly* to 10 = *very well*) and how they had felt in general over the past three days (on a scale from 1 = *very bad* to 10 = *very good*).

Spontaneous Use of Imagery Scale (SUIS; Reisberg, Pearson, & Kosslyn, 2003; German version by Görden, Hiller, & Witthöft, 2016). Participants’ tendency to spontaneously experience imagery in everyday life was measured using the German version of the Spontaneous Use of Imagery Scale (SUIS), a 12-item scale comprising various everyday situations in which people might experience mental imagery. Participants are asked to rate each item according to how applicable it is to them, on a 5-point scale ranging from 1 (*never applicable*) to 5 (*always completely applicable*). The internal consistency of the scale

(Cronbach's alpha) in our sample was 'questionable', α [95% CIs] = 0.65 [0.53, 0.73], which is comparable to that reported by G6rgen et al. (2016).

Depression Anxiety Stress Scales – 21 item version (DASS-21; Lovibond & Lovibond, 1995; German version by Nilges & Essau, 2015). The DASS-21 consists of three seven-item subscales assessing symptoms of depression, anxiety, and stress. Each item is rated on a 4-point scale ranging from 0 (*did not apply to me at all*) to 3 (*applied to me very much or most of the time*). Internal consistencies for the subscales in our sample (Cronbach's alpha) were as follows: Depression: 0.80 [0.73, 0.86]; anxiety: 0.64 [0.53, 0.73]; stress: 0.79 [0.71, 0.84].

Involuntary Autobiographical Memory Inventory (IAMI; Berntsen et al., 2015). The IAMI consists of two 10-item subscales that measure the occurrence of (a) involuntary memories and (b) involuntary thoughts of the future. Every item describes the occurrence of either an involuntary memory or a thought of the future in everyday life and is rated on a 5-point scale ranging from 0 (*never*) to 4 (*once an hour or more*). In our sample, Cronbach's alpha was excellent for both the past subscale, $\alpha = 0.92$ [0.88, 0.94], and the future subscale, $\alpha = 0.92$ [0.89, 0.94].

Positive and Negative Affect Schedule – Positive Scale (PANAS; Watson & Clark, 1994; German translation: Gr6uhn, Kotter-Gr6uhn, & R6ocke, 2010). State positive mood was measured using a 21-item positive subscale from the extended Positive and Negative Affect Schedule (Watson & Clark, 1994). Participants were asked to rate each item word according to how they felt "right now/ in the past few minutes", using a 5-point scale ranging from 1 (*not at all*) to 5 (*extremely*). This scale has been used to measure change in state mood in previous studies investigating the effect of a single session of positive mental imagery CBM (e.g., Holmes et al., 2008, 2009). Cronbach's alphas in the current study ranged from $\alpha = 0.90$ [0.86, 0.93] at pre-training to $\alpha = 0.96$ [0.94, 0.97] at the very last measurement of the study.

Manipulation check questionnaire (MCQ). To check the extent to which participants completed the imagery CBM session in accordance with our instructions, we used a questionnaire adapted from those used in previous studies (e.g., Holmes et al., 2009). Participants were asked first to rate how difficult or easy they had found it to imagine the scenarios on a 9-point scale ranging from 1 (*extremely hard*) to 9 (*extremely easy*). On five subsequent items participants were asked to indicate how much they had thought about the scenarios verbally, how much they had thought about them in mental images, the extent to which they used an observer perspective, the extent to which they used a field perspective, and how often they felt emotionally involved in the scenarios, on a 9-point scale ranging from 1 (*never*) to 9 (*all the time*).

Debriefing questionnaire. A debriefing/demand effects questionnaire was used to investigate potential participant awareness of the experimental hypotheses (see Supplementary Materials for details).

Procedure

Participants were tested individually by one of five researchers, two of whom were completing their Bachelor degree, and three of whom were completing their Masters degree. Researchers followed a written experimental protocol, including brief verbal instructions for each questionnaire and task, in order to standardize administration. The same researcher conducted both testing sessions with each participant.

Figure 1 provides an overview of the study procedure. On arrival in the laboratory for the first testing session, participants were provided with a brief oral summary of the study by the researcher, and were asked to read once more over the written information sheet to check whether they had any questions. They then provided written informed consent. Participants next completed the set of baseline and pre-training questionnaires in the following order: Demographics, DASS, SUIS, IAMI, and the first PANAS. While participants were

completing the PANAS, the researcher allocated them to their experimental condition and counterbalance order (see Supplementary Material for details).

The researcher then guided the participant through the introduction to mental imagery according to their experimental condition allocation, after which the participant completed the session of imagery CBM. Participants then completed the second PANAS and the MCQ, followed by the music filler task. Afterwards, participants completed the third PANAS, the first Involuntary Memory Task, a fourth PANAS, and the Voluntary Memory Task. At the end of this first testing session, participants were instructed in completing the involuntary memory diary. Participants received a reminder the day before the second testing session about the time for the testing session itself and to remember to bring their diary.

The second testing session was scheduled to take place three days after the first (e.g. Thursday if the first session was on a Monday). At the start of the session, the researcher collected the diary, and the participants then completed in the following order: a fifth PANAS, the second IMT, a final sixth PANAS and the second administration of the voluntary memory test. The researcher then discussed any ambiguous diary entries with the participant. Finally, participants completed the debriefing questionnaire, and were then debriefed regarding the aims of the study and provided with the cash incentive (if applicable).

Statistical Analysis Plan

Sample size calculation. In the absence of relevant data to guide a power calculation, a pragmatic sample size of $N = 80$ (i.e. 40 per condition) was planned. This would provide 80% power to detect between-group effect sizes of Cohen's $d = 0.65$ (i.e. medium/large), 95% power to detect between-group effect sizes of $d = 0.8$ (i.e. large), and 50% power to detect between-group effect sizes of $d = 0.45$ (i.e. small/medium).

Participant inclusion in analyses and missing data. As per the study protocol, all participants who returned the diary were included in analyses. If a participant did not complete a particular measure (due to e.g. data not saving properly or not returning for the

second session), they were excluded from analyses of that measure only. To handle missing responses on questionnaires (three items in total across all questionnaires and all participants), total scores were calculated by multiplying the participants' mean score by the total number of items on that questionnaire.

Planned and exploratory statistical analyses. Statistical analyses were conducted in RStudio 1.2.1335 (RStudio, Inc., 2016), with the initial Results section produced using RMarkdown (Allaire et al., 2018). The analyses followed the plan specified in the protocol, with some deviations and additional post-hoc analyses (as noted where appropriate).

Comparison of groups on baseline, pre-training, vividness ratings during the training, and manipulation check measures was via Welch's t-tests (i.e. without the assumption of equal variance) for continuous variables or Chi-squared tests for categorical variables. Potential differential effects of the two experimental training conditions on state mood was analysed via an ANCOVA with the post-training score as outcome, experimental condition as between-subjects factor, and pre-training score as covariate.

For comparing the experimental conditions on number of involuntary memories in the diary, plots of the data indicated a highly skewed distribution that most closely resembled a negative binomial distribution. Therefore, rather than the original planned t-test, a negative binomial regression (with number of involuntary memories as dependent variable and experimental condition as independent variable) was conducted, using the package MASS (Venables & Ripley, 2002).

The distribution of number of involuntary memories in the involuntary memory tasks also appeared to be negative binomial in form, and thus rather than the planned repeated measures ANOVA, a negative binomial regression was conducted within the framework of a generalized linear model, using the package lme4 (Bates et al., 2015) to allow for within-subject factors. The initial model run was equivalent to the original planned ANOVA, with number of involuntary memories as dependent variable and experimental condition, session

number, and type of cue (scenario clip or everyday sound) as predictors (with all 2 and 3-way interactions, and a random intercept for participant).

Bootstrapping was used to check robustness of results when exploratory analyses suggested potential violations of assumptions. Details of exploratory analyses are described within the results section, and further sensitivity and exploratory analyses are in the supplementary materials.

Results

Participant Characteristics

Participant characteristics are shown in Table 1. Overall, the groups were balanced with regards to demographic and baseline data.

Manipulation Checks

The results of the manipulation checks are presented in Table 2. Overall, these were consistent with a successful manipulation, in that on average the groups differed in terms of how much they used field or observer perspective, and their self-reported emotional impact of the scenarios.

An ANCOVA with post-training PANAS as dependent variable, experimental condition as between-subjects factor, and pre-training PANAS as covariate, found a statistically significant effect of condition, $F(1,77) = 4.09$, $p = 0.047$, $\eta^2 = 0.050$, 90% CIs: [0.00039,0.145], suggesting that the manipulation was successful (albeit only weakly) in inducing a higher level of positive emotion in the emotional compared to the non-emotional condition².

² Conducting this analysis instead as a repeated-measures ANOVA with between-subject factor of condition and within-subject factor of time (pre vs. post-training) provided a similar result: a significant interaction of time by condition, $F(1,78) = 4.12$, $p = 0.046$, $\eta^2 = 0.050$, 90% CIs: [0.0005,0.145]. Decomposing this interaction via paired t-tests indicated a significant increase in positive affect in the emotional condition, $M = 4.95$, $SD = 9.23$, $t(39.00) = 3.39$, $p = 0.002$, d [95% CIs] = 0.54 [0.08,0.99], but not in the non-emotional condition, $M = 1.12$, $SD = 7.54$, $t(39.00) = 0.94$, $p = 0.351$, d [95% CIs] = 0.15 [-0.30,0.59].

After the music filler task, PANAS scores were higher for participants in the emotional condition, $M = 73.45$, $SD = 15.52$, than for participants in the non-emotional condition, $M = 63.73$, $SD = 12.74$, $t(75.14) = 3.06$, $p = 0.003$, d [95% CIs] = 0.68 [0.23,1.13], indicating that the filler task had not been successful in equalizing the two groups' moods.

Primary hypothesis: Involuntary memories recorded in the three-day diary

Contrary to our hypothesis, a negative binomial regression with total number of involuntary memories in the diary as dependent variable, and experimental condition as independent variable, found no statistically significant relationship between experimental condition and number of involuntary memories, OR [95% CIs] = 0.95 [0.53,1.71], $p = 0.86$. See Table 3 for means and standard deviations for this and other outcome measures.

Secondary Analyses

Involuntary memories in the lab-based involuntary memory task. A negative binomial generalized linear model with number of involuntary memories as dependent variable and experimental condition, session number, and type of cue (scenario clip or everyday sound) as predictors (with all 2 and 3-way interactions, and a random intercept for participant) showed no significant effect of experimental condition, OR [95% CIs] = 1.03 [0.43,2.51], $p = 0.94$, and weak, not statistically significant effects of session number, OR [95% CIs] = 0.72 [0.52,1.01], $p = 0.05$, and cue type, OR [95% CIs] = 0.48 [0.22,1.05], $p = 0.07$, and no statistically significant 2 or 3-way interactions.

Voluntary memory recall. The effect of experimental condition on voluntary memory recall was investigated via a mixed model (using the package lmerTest) with condition and voluntary memory version (A or B first) as between-subject factors, session (1 or 2) as a within-subject factor, all 2-way interactions, and a 3-way interaction of condition by voluntary memory version by session. A random intercept at the participant level was included. This mixed model approach was chosen rather than the originally planned ANOVA equivalent to allow inclusion of all participants in one analysis, including those missing data

at the second session. This analysis revealed only a main effect of testing session, $t(78.99) = 4.99, p < 0.01, d = 1.10 [0.64, 1.58]$, indicating that recall performance was weaker at the second testing session.

Relationship between mood change and involuntary memories. The potential relationship between emotion induced while imagining the scenarios and number of involuntary memories was explored. Standardized residuals from a regression predicting PANAS at post-training from PANAS at pre-training were used as the index of mood change in order to control for differences in starting mood state (as used by Clark et al., 2013). This was included as a predictor of number of involuntary memories (in the diary) in a negative binomial regression alongside experimental condition and an interaction term. PANAS change from pre to post training did not predict number of involuntary memories, $OR [95\% CIs] = 1.05 [0.64, 1.73], p = 0.83$.

These regressions were repeated using all subscales of the PANAS and the self-reported emotional impact of the scenarios as predictors, and none of these potential indicators of induced emotion predicted number of intrusions.

Additional exploratory analyses

Further post-hoc analyses explored potential predictors of the number of involuntary memories experienced in the diary

Imagery Vividness. The relationship between vividness ratings during the training and number of involuntary memories was investigated via negative binomial regression with number of involuntary memories as dependent variable, and with participants' mean vividness ratings and experimental condition as independent variable. There was a statistically significant relationship between mean vividness rating and number of involuntary memories, $OR [95\% CIs] = 1.99 [1.12, 3.61], p = 0.02$, indicating that the higher participants' vividness ratings during the training, the more involuntary memories they reported in the diary.

Interference from the Voluntary Memory Task. A further post-hoc analysis investigated whether the completion of the voluntary memory task at the end of the first session had interfered with subsequent experience of involuntary memories. Because via the counterbalancing participants had been essentially randomly assigned to complete one of two versions of the voluntary memory test ('A' or 'B') at the end of the session, each of which included 10 of the 40 scenarios, we could investigate whether testing tended to increase or decrease the likelihood of the scenario returning as an involuntary memory.

To take into account the probable variation between scenarios in their likelihood of reoccurring as involuntary memories, and the variation between participants in tendency to experience involuntary memories, a binary logistic regression was run within the framework of generalized linear models. The dependent variable was whether a specific scenario occurred as an involuntary memory in the diary for each individual participant (i.e. each of the 40 scenarios was coded as yes (1) or no (0) for each of the 80 participants), and the independent variables were voluntary memory task version, tested/untested, and the interaction of these terms. Random intercepts at the level of both the participant and the individual scenarios were used. There was no main effect of voluntary memory test version, $OR [95\% CIs] = 0.85 [0.39, 1.85]$, $p = 0.69$. However, there was a main effect of testing, $OR [95\% CIs] = 2.16 [1.05, 4.45]$, $p = 0.04$, indicating that those scenarios included in the voluntary memory test were more likely to reoccur as involuntary memories in the subsequent 3 days, and an interaction between voluntary memory task version and testing, $OR [95\% CIs] = 3.91 [1.46, 10.43]$, $p = 0.01$, indicating that the effect of testing differed between the two memory test versions. Decomposing this interaction showed a statistically significant effect of testing for both voluntary memory test version A, $OR [95\% CIs] = 2.19 [1.07, 4.52]$, $p = 0.03$, and for version B, $OR [95\% CIs] = 9.49 [4.69, 19.20]$, $p < 0.01$.

Discussion

The current study investigated whether involuntary positive imagery could be induced in everyday life by means of brief positive imagery scripts, and the potential role of emotion in this process. Participants completed a computerized cognitive training procedure, imagery cognitive bias modification (CBM), which involved imagining themselves in a series of situations that started ambiguously and ended positively, and then recorded any involuntary memories of these scenarios in a diary over a subsequent three-day period. The majority of the participants reported experiencing at least one involuntary memory of the scenarios in the three days after the experimental session. Further, the experimental manipulation was successful in inducing a greater level of positive emotion in an ‘emotional’ condition than in a ‘non-emotional’ condition at the time of imagining the scenarios. However, contrary to our hypotheses there was no difference in the number of involuntary memories experienced by participants in these two conditions, either in the diary, or in a lab-based cued involuntary memory task. Further, we found no evidence for a relationship between the amount of positive emotion induced by imagining the scenarios and the number of involuntary memories. Rather, in exploratory analyses we found that participants who reported imagining the scenarios more vividly recorded more involuntary memories in the diary, and that participants experienced more involuntary memories of scenarios for which they had completed a voluntary memory task at the end of the first testing session. The results demonstrate that the imagery task used in the current study, imagery CBM, can be used to induce and study the modulation of involuntary positive memories in daily life, and shed some first light on factors that may influence their occurrence.

One possible explanation for the lack of a between-group difference in the number of involuntary memories could be that the relative between-group difference in positive affect induced was too small to have an impact. However, given that we also found no correlational relationship between induced positive affect and number of involuntary memories, in the context of a large variation in positive affect across participants, it seems more plausible that

the induced positive affect simply had no effect on the number of involuntary memories in the current study. How might this fit with the literature using negative (Clark et al., 2015) or positive (Clark et al., 2013) film stimuli, in which change in mood from pre to post-film viewing predicted the number of involuntary memories over the subsequent week? One possibility is that the nature and intensity of the emotions elicited in the film studies differ from those in the current study. The positive scenes in the current study were generally ‘everyday’ positive events, which might elicit only relatively mild levels of positive emotion. The scenes in the negative and positive film studies, on the other hand, were intended to be analogues of trauma and (hypo)mania respectively, and therefore to induce more extreme and intense emotional states. It may be that relatively extreme levels of emotion are required for it to have an impact on subsequent involuntary memory. Another possible reason for finding no relationship between induced emotion and number of involuntary memories in the current study may be the inclusion of the involuntary memory task and the voluntary memory test in the first session, which could have interfered with the consolidation of memories of the training scenarios in such a way as to wipe out the potential effect of induced positive emotions (e.g. selectively enhancing consolidation of tested vs. untested scenarios). In the film studies, in contrast, after the film there were no further tests or stimuli related to the film material. Given the exploratory analyses indicating that the voluntary memory test had an impact on which scenes were recalled involuntarily (to be discussed below), this seems a plausible explanation, but would ideally require following up by conducting a study in which there were no further memory tests after completing the imagery CBM, or a study comparing the presence versus the absence of such tests.

The apparent lack of effect of emotion on experience of involuntary memories in our study also needs to be interpreted within the context that our experimental manipulation was achieved via the instructions provided to participants, and included a perspective manipulation (field vs. observer perspective imagery). The manipulation check ratings (in

Table 2) suggest that participants complied with the instructions and the manipulation was therefore successful, but these are based on self-report and thus subject to potential demand effects. Although the rating of ease of the imagery CBM session did not differ on average between the two conditions, the means and standard deviations indicate both some degree of effort needed on the part of participants, and some variation in how able participants were to engage in the imagery CBM as instructed. This could have reduced the chance of finding an effect of our manipulation, and future studies could try to find methods to experimentally manipulate emotion that would not be so dependent on the abilities of participants to follow the task instructions as required, or that would allow a more objective measurement of success with instruction compliance.

The inclusion of a perspective manipulation within our study also needs to be considered when interpreting our results. Building on literature suggesting that using an observer perspective may lead to generation of less emotion while imagining scenes (e.g., Holmes et al., 2008; Vella & Moulds, 2014), we included an instruction to use observer perspective during the imagery CBM in our non-emotional condition. However, the difference in perspective in imagining the scenarios at encoding would also likely lead to the memories themselves including these different perspectives, which might itself cause differences in the qualities of the memories. In general, recall of memories with an observer perspective appears to be associated with less emotion (e.g., McIsaac & Eich, 2002; Nigro & Neisser, 1983), and a more abstract processing style (Hart-Smith & Moulds, 2020). While re-imagining memories that were originally recalled in field perspective from an observer perspective results in reduced emotionality, reimagining memories that were originally observer perspective from a field perspective does not lead to increased emotionality (Vella & Moulds, 2014; Williams & Moulds, 2008), possibly implying impoverishment in the information and associations stored in these memories themselves, rather than simply an effect of perspective at the time of recall. In relation to the current study, it may be that having imagined the scenarios from an observer

perspective in the non-emotional group affected not only emotion at the time of encoding but also the nature of the subsequently stored memory and associated emotion. While the apparent lack of an effect of experimental condition on characteristics of the memories of the scenarios does not suggest any substantial effect of this manipulation, in future a purer manipulation of emotion at encoding without a perspective manipulation would help avoid potential confounding of perspective and emotion effects. Alternatively, a perspective manipulation could be used to deliberately investigate the effect of (stored) memory perspective on subsequent involuntary memories. Interestingly, in the context of negative emotional material (listening to descriptions of car accidents), studies have found that imagining the scenes from a field perspective led to no more intrusive memories than imagining them from an observer perspective (Mooren et al., 2016), but subsequently recalling the imagined scenes from a field perspective led to a greater number of intrusive memories than recalling them from an observer perspective (Mooren et al., 2019). The relationship between imagery perspective, emotion, and experience of involuntary memories therefore seems to be complex and in need of further investigation.

The finding that scenarios included in the voluntary memory test at the end of the first testing session were more likely to reoccur as involuntary memories in the subsequent days arose from an exploratory analysis to investigate the idea that the voluntary memory task may have interfered with memory consolidation. It is well-known that retrieval practice (e.g. during testing) often enhances subsequent memory for information (Kensinger & Ford, 2020; Roediger & Butler, 2011), and as such our finding may appear unsurprising. However, in the context of involuntary emotional memories (as opposed to voluntary recall or recognition) the effects of manipulations on voluntary and involuntary memory measures do not necessarily always correspond (Lau-Zhu et al., 2019). One study has investigated the effect of a memory test on occurrence of involuntary emotional memories after viewing a negative film (Krans et al., 2009). However, in this study participants experienced *fewer* intrusions of scenes on

which they had been tested after film viewing. The explanation for this effect was that testing helped to contextualize the (analogue) trauma memory and facilitate its integration in a form that was less likely to lead to involuntary triggering. However, while such a mechanism may be plausible for highly arousing negative content, it may be less applicable for mildly positive content as in the current study. It is still unclear to what extent the mechanisms of involuntary memory retrieval can be extrapolated from memories of one valence and intensity to another, and the results in the current study suggest that in the case of mildly positive scenes, voluntary testing may in fact be a useful mechanism to increase the likelihood of later involuntary retrieval. However, given that the voluntary memory task involved several components we cannot conclude that it was specifically the recall part that led to this effect.

A relationship between vividness of imagery generated and subsequent involuntary memories of the training scenarios, as suggested by our results, seems plausible in that imagining scenarios more vividly during the imagery CBM would be expected to lead to memories that are better encoded and more accessible. This result also fits with previous findings indicating the importance of vivid imagery generation during imagery CBM. For example, in the RCT by Blackwell et al. (2015), the more vividly participants imagined the training scenarios, the greater the clinical benefits they experienced, in terms of reductions in symptoms of depression and increases in behavioral activation (Blackwell et al., 2015; Renner et al., 2017). We cannot conclude from the current data that participants experienced more involuntary imagery *because* they imagined the scenarios more vividly, but this direction seems a plausible hypothesis and useful to investigate in future research.

One question about the involuntary memories of training scenarios recorded in the current study is how best to conceptualise and understand them within broader taxonomies of memory type. This study aimed to elicit and document for the first time in an experimental setting a phenomenon previously reported anecdotally in clinical studies, involuntary memories of imagery CBM training scenario, but was atheoretical in terms of how best these

memories should be understood and we did not collect phenomenological data about what exactly participants were experiencing. One important consideration is the type of involuntary memory experienced, for example whether participants re-experienced the imagined scenarios as if re-experiencing autobiographical events, or whether the memories are better conceived of as (non-autobiographical) event memories (Rubin & Umanath, 2015). It is also unclear to what extent participants' involuntary memories were purely of the scenario or image themselves, or whether they included other autobiographical information, verbal thoughts, or even the experience of hearing and imagining the scenario in the laboratory. Given that the exact nature of the involuntary memories resulting from imagery CBM sessions will have an impact on how best to conceptualise them within theoretical frameworks of memory, it would be valuable to collect further phenomenological information from participants in future studies.

The current study has to be interpreted in the context of a number of limitations. Because the study of involuntary and voluntary memory in relation to these kinds of imagery scripts had not previously been carried out, the methods and measures were predominantly adapted from other areas of research, and had not yet been validated for the uses they were put to in the current study. Despite the use of a standardized testing script, the use of multiple researchers may have increased the random 'noise' in the data, while the lack of blinding of researchers to participant condition would leave the study open to researcher-induced bias. In addition to the lack of phenomenological information noted in the previous paragraph, we also cannot be certain how many of the involuntary memories recorded in the diary or involuntary memory task were in fact retrieved involuntarily; our instructions to record only involuntary memories were brief and did not elaborate extensively on the distinction between involuntary and voluntary retrieval, and there is evidence that people may misperceive intentionally-recalled memories as involuntary if they are easily accessible (Sanson et al., 2020). Our instructions to record only involuntary memories, and those specifically of

training scenarios, are in line with the kinds of instructions commonly used in diary studies (e.g. using the trauma film; James et al. 2016) and thus enable comparisons with this extensive literature. However, there is evidence, for example from lab-based studies, that such specific instructions may influence the number and qualities of memories recorded (e.g., Barzykowski & Niedźwieńska, 2016; Vannucci et al., 2014). These factors could potentially alter the sensitivity of the study to detect the effects of a subtle experimental manipulation. Finally, the use of a student sample precluded the possibility of investigating the impact of the involuntary images on e.g. reducing low mood, and limits generalizability.

Taking these limitations into consideration, the results of the current study open up a range of opportunities and ideas for future research. At a narrow level, following on from the findings in the current study, it would be useful to investigate whether an experimental manipulation could increase the vividness with which participants imagine the scenarios, and whether this would lead to a greater number of involuntary memories. Testing the effect of recall on number of involuntary memories in a pre-planned design would also help confirm this effect and indicate whether it may have utility in increasing the extent to which people experience positive involuntary memories. Using the imagery CBM as an involuntary imagery induction within a depressed sample may not only allow better capture of events (as presumably positive involuntary images would be less normal and thus better noticed), but also allow investigation of whether the induced involuntary images had an impact on mood or, over a longer time-scale, symptom outcomes. Given that there is evidence that both dysphoric and depressed individuals may respond differently to non-depressed individuals in response to emotional involuntary memories, for example using different emotional regulation strategies (e.g., del Palacio-Gonzalez et al., 2017; Watson et al., 2012), recording participants' cognitive, as well as emotional and behavioural, responses to experience of involuntary memories of imagery CBM scenarios, may be particularly useful when moving to a depressed sample.

At a broader level, the study needs to be placed in the context of the literature on involuntary positive imagery in daily life. Such imagery is apparently common, and thought to have important functions, for example in the context of mental time travel (Berntsen & Jacobsen, 2008). Deficits in positive imagery and the tendency to experience it involuntarily have been hypothesized to contribute to core aspects of depression, such as pessimism, hopelessness, lack of motivation, and the reduced ability to anticipate reward or pleasure (i.e. anhedonia; Holmes et al., 2016; Ji et al., 2019). Testing hypotheses about the importance and functions of positive mental imagery in daily life requires the induction and modulation of its occurrence, and the current study indicates that the imagery CBM paradigm provides a means by which this can be done. While positive involuntary autobiographical memories of standardized scenes had previously been experimentally induced using film stimuli (Clark et al., 2013; Davies et al., 2012), this was as an analogue of (hypo)manic imagery, and the scenes used were relatively extreme, such as riding a rollercoaster or graduation celebrations. It is therefore particularly notable that in the current study it was possible to induce involuntary memories of relatively mildly positive everyday events (e.g. managing to catch a bus, meeting friends), as these potentially correspond more closely to ‘everyday’ positive involuntary imagery.

From a clinical perspective, viewing the imagery CBM paradigm as a method to induce involuntary positive imagery in daily life and optimizing it for this purpose may be a particularly useful line of research to pursue, particularly given that observational studies suggest that involuntary imagery has a greater impact on emotion and behavioral responses than voluntarily generated imagery (Barsics et al., 2016; Berntsen & Hall, 2004). From both this clinical perspective, but also more broadly for theory-testing purposes, it may be useful to investigate tailoring the content and emotional intensity of the imagery scripts to facilitate triggering in particular contexts or to incorporate specific emotional states, expectancies, or behavioral responses. Interestingly, a version of the ‘method of loci’ technique in which

specific self-affirming memories are linked via imaginal rehearsal to objects or places along familiar routes has been suggested as a way to enhance accessibility of such memories for mood repair in depression (Dalgleish et al., 2013; Werner-Seidler & Dalgleish, 2016), and one effect of this may be the triggering of involuntary recall of these memories when the ‘loci’ are encountered in daily life.

To conclude, although much of the imagery we experience in daily life occurs involuntarily, research investigating the effects of mental imagery has tended to rely on observational data or has focused on the impact of deliberately generated imagery. Further, although much of the involuntary imagery we experience in daily life is positive, and this positive involuntary imagery is thought to be crucial for healthy functioning and wellbeing, it is *negative* involuntary imagery that has received the brunt of experimental research interest (e.g., in the context of trauma; James et al., 2016). The current study demonstrates that a lab-based imagery procedure can be used to induce positive mental imagery relating to everyday concerns in daily life. This enables more direct testing of hypotheses about the causal role or impact of such imagery, important for the development and further refinement of theory, and opens up possibilities for future clinical interventions.

Data Availability

Data, materials (with the exception of standardized questionnaire measures), analysis scripts and pre-print are available on the Open Science Framework at <https://osf.io/whk2b/>.

Disclosure Statement

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Table 1. Participant baseline characteristics

	Emotional Condition	Non-Emotional Condition		
	<i>M (SD)</i>	<i>M (SD)</i>	<i>t</i> (df)	<i>p</i>
Age	23.18 (2.66)	23.52 (2.90)	0.56 (77.42)	0.58
Session Time Difference (mins)	0.37 (3.27)	0.63 (8.12)	0.19 (51.58)	0.85
Sleep last night	7.22 (1.83)	7.30 (2.19)	0.17 (75.69)	0.87
Mood past 3 days	7.70 (1.29)	7.50 (1.48)	0.64 (76.42)	0.52
DASS21-Depression	2.52 (2.43)	2.45 (2.71)	0.13 (77.09)	0.90
DASS21-Anxiety	1.38 (1.78)	2.20 (2.49)	1.70 (70.53)	0.09
DASS21-Stress	4.03 (3.27)	4.08 (3.23)	0.07 (77.99)	0.95
PANAS	68.35 (13.59)	66.10 (11.87)	0.79 (76.62)	0.43
IAMI-Past	23.12 (8.33)	21.57 (7.04)	0.90 (75.90)	0.37
IAMI-Future	19.55 (8.45)	18.12 (8.53)	0.75 (77.99)	0.46
SUIS	40.42 (6.39)	37.38 (7.53)	1.95 (76.00)	0.05
	<i>N</i> (%)	<i>N</i> (%)	<i>X</i> ²	<i>p</i>
Gender (female)	29 (72.5%)	27 (67.5%)	0.06	0.81

Note. Session Time Difference (mins) = difference in time (minutes) between the time of the first and second testing sessions (e.g. if the first session was at 13:00 and the second at 13:20, this would be 20); Sleep last night = self-rated quality of sleep the previous night, from 1 = very bad to 10 = very good; DASS21-Depression/ Anxiety/ Stress = Depression, Anxiety and Stress Scales (short form) Depression/ Anxiety/ Stress subscale; PANAS = Positive and Negative Affect Schedule - Positive subscale; IAMI-Past/Future = Past / Future subscale of the Involuntary Autobiographical Memory Inventory; SUIS = Spontaneous Use of Imagery Scale

Table 2. Manipulation checks

	Emotional Condition	Non-Emotional Condition		
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>t</i> (df)	p
Ease of task	7.08 (1.72)	6.65 (1.59)	1.15 (77.58)	0.25
Thinking in words	2.42 (1.91)	2.83 (2.10)	0.89 (77.29)	0.38
Thinking in images	8.45 (0.64)	7.92 (1.14)	2.54 (61.24)	0.01
Observer perspective	2.27 (1.18)	7.88 (0.99)	23.02 (75.84)	0.00
Field perspective	8.07 (1.19)	2.83 (1.72)	15.88 (69.15)	0.00
Emotional impact	6.40 (2.15)	3.33 (1.93)	6.74 (77.11)	0.00
Mean vividness	4.11 (0.42)	3.91 (0.63)	1.61 (68.05)	0.11

Note. All ratings made on a 1 (*not at all*) to 9 (*all the time*) rating scale, except for ease of task (1 = *extremely difficult* to 9 = *extremely easy*), emotional impact (1 = *never* to 9 = *all the time*), and vividness (1 = *not at all vivid* to 5 = *very vivid*).

Table 3. Outcome measures

	Emotional Condition	Non-Emotional Condition
	<i>M (SD)</i>	<i>M (SD)</i>
PANAS		
PANAS T1	68.35 (13.59)	66.10 (11.87)
PANAS T2	73.30 (16.64)	67.22 (13.56)
PANAS T3	73.45 (15.52)	63.73 (12.74)
PANAS T4	67.88 (16.64)	63.05 (15.48)
PANAS T5	66.69 (16.33)	65.60 (14.86)
PANAS T6	67.54 (16.00)	64.53 (16.11)
Involuntary Memories in Diary	1.40 (1.68)	1.48 (2.23)
Involuntary Memory Task		
IMs Scenarios 1	3.10 (3.31)	2.50 (3.08)
IMs Everyday sound clips 1	4.23 (4.15)	4.22 (4.67)
IMs Scenarios 2	2.11 (2.54)	2.33 (3.91)
IMs Everyday sound clips 2	3.42 (3.52)	3.20 (4.24)
Voluntary Memory Test		
Recall 1	11.60 (2.55)	10.82 (3.20)
Recall 2	8.90 (3.34)	7.83 (3.13)

Note. PANAS = Positive and Negative Affect Schedule - Positive subscale; T1 = pre-training, T2 = post-training; T3 = post-music filler task/ pre-involuntary task 1; T4 = post-involuntary memory task ; T5 = start of session 2 (pre-involuntary memory task 2); T6 = post-involuntary memory task 2; Involuntary Memory Task IMs Scenarios/ Everyday sound clips 1/2 = Number of involuntary memories reported during the involuntary memory task in response to Scenario cues/ Everyday sound clips in session 1 / session 2; Voluntary Memory Task: Recall 1/2 = Total score on recall test in session 1 / session 2. For analyses of between-group differences, see the main text.

Figure 1. Overview of study procedure

Supplementary Materials

Supplementary Methods

Recruitment and data collection. Data collection for the study took place between 15th May 2017 and 1st June 2018. One amendment was made to the study protocol after start of data collection, specifically the addition of a cash alternative to course credit in return for participation, in order to help recruitment. At this timepoint (22nd January 2018), approximately half of the sample ($N = 39$) had been recruited and tested.

Imagery CBM. At the start and end of the imagery CBM program, participants completed a short mood rating in which they rated three positive (happy, calm, optimistic) and three negative emotions (sad, anxious, hopeless) according to how they felt ‘right now, in the past few minutes’ on a 5-point scale ranging from 1 (*not at all*) to 5 (*extremely*). These ratings were included for exploratory purposes (i.e. to investigate their potential utility to inform future studies) and not analysed here.

Voluntary memory task. Cohen’s kappa (for inter-rater reliability) and 95% Confidence Intervals were calculated using the package ‘psych’ (Revelle, 2017). Internal consistency for each aspect of the voluntary memory task was calculated as a split-half reliability, using the ‘brute force’ method in which split-half reliabilities for all possible combinations of items are calculated and then averaged (also using the package ‘psych’; Revelle, 2017), with 95% confidence intervals calculated using the package ‘cocron’ (Diedenhofen & Musch, 2016).

For Voluntary Memory Test Version A at pre-training, full reliability data were as follows. For recall, percentage agreement (between raters) was 84.88%, Cohen’s kappa [95% CIs] = 0.77 [0.71, 0.82]; split-half reliability [95% CIs] = 0.47 [0.01, 0.72]. Split-half reliabilities for other scores were: recall confidence 0.79 [0.60, 0.89], gender accuracy 0.14 [-0.62, 0.54], gender confidence 0.84 [0.71, 0.92], valence rating 0.80 [0.62, 0.89]. For

Voluntary Memory Test Version B at pre-training, percentage agreement (between raters) for recall was 83.21%, Cohen's kappa [95% CIs] = 0.75 [0.69, 0.80]; split-half reliability [95% CIs] = 0.49 [0.03, 0.73]. Split-half reliabilities for other scores were: recall confidence 0.89 [0.78, 0.94], gender accuracy 0.13 [-0.66, 0.54], gender confidence 0.88 [0.76, 0.94], valence rating 0.81 [0.63, 0.90].

For Voluntary Memory Test Version A at post-training, percentage agreement (between raters) for recall was 88.25% Cohen's kappa [95% CIs] = 0.82 [0.77, 0.87]; split-half reliability [95% CIs] = 0.61 [0.27, 0.79]. Split-half reliabilities for other scores were: recall confidence 0.84 [0.69, 0.91], gender accuracy 0.01 [-0.86, 0.47], gender confidence 0.90 [0.82, 0.95], valence rating 0.81 [0.64, 0.90]. For Voluntary Memory Test Version B at post-training, percentage agreement (between raters) for recall was 80.77%, Cohen's kappa [95% CIs] = 0.70 [0.64, 0.76]; split-half reliability [95% CIs] = 0.44 [-0.06, 0.71]. Split-half reliabilities for other scores were: recall confidence 0.69 [0.42, 0.84], gender accuracy 0.44 [-0.07, 0.71], gender confidence 0.86 [0.73, 0.93], valence rating 0.82 [0.66, 0.91].

Involuntary Autobiographical Memory Inventory. We also asked about the valence (positive or negative) and emotional intensity of spontaneous memories and thoughts of the future using the items provided by Berntsen et al. (2015). Participants noted the average valence of spontaneous memories and thoughts of the future in everyday life on a 5-point scale ranging from -2 (*extremely negative*) to 2 (*extremely positive*), and the average emotional intensity on a 5-point scale ranging from -2 (*not intensive at all*) to 2 (*extremely intensive*). Split-half reliabilities for the number of involuntary memories (reported in the methods section of the main text) were calculated using 10,000 random split half samples, with confidence intervals then calculated using the package 'cocron' (Diedenhofen & Musch, 2016).

Ambiguous Scenarios Test for Depression (AST-D; Rohrbacher & Reinecke, 2014). The AST-D is a measure of interpretation bias developed to be particularly relevant for depression. In the current study it was administered before and after the imagery CBM session, specifically immediately after the first and third PANAS administrations. Its inclusion in the current study was to check whether there were differences in the effects of the experimental conditions on interpretation bias, in case this was a mechanism of other between-group differences (e.g. in number of involuntary memories). Hence it was not of primary interest and is reported only in the Supplementary Materials. The AST-D comprises 30 items that can be split into two 15-item parallel questionnaires (Version A and B), where each item is an ambiguous scenario (e.g., *You are at the beach on a cloudy day. As you look into the sky, you realise that the weather is changing*). Participants are instructed to imagine the scenario and then rate the pleasantness of their image on an 11-point scale ranging from -5 (*very unpleasant*) to 5 (*very pleasant*). The AST-D was developed from tasks previously used to assess the immediate impact of a single session of imagery CBM on interpretation bias (e.g., Holmes et al., 2009), and we used it in the current study for this same purpose. Participants completed a different set (A or B, order counterbalanced) pre and post-CBM. Due to a mis-reading of the paper by Rohrbacher and Reinecke (2014), the A and B forms in the current study did not correspond to those detailed in the validation paper, but rather were the first and last 15 items from the full scale. Cronbach alphas in our sample for version A were: pre-training, $\alpha = 0.79$ [0.65, 0.86], post-training, $\alpha = 0.82$ [0.70, 0.88], and for Version B: pre-training, $\alpha = 0.82$ [0.61, 0.90], and post-training, $\alpha = 0.82$ [0.66, 0.89].

Debriefing questionnaire. There were first four open-ended questions asking participants their beliefs about the aims of the study and the purpose of their specific imagery instructions (*What do you think the aim of the study was?*, *What do you think we expected to find out?*, *Why do you think you had to complete the first computer task in which you listened*

to scenarios? Why do you think you were meant to imagine the scenarios from a particular perspective?). A diary compliance question then asked participants to rate how carefully they had completed the diary, from 1 (*not at all carefully*) to 9 (*extremely carefully*). Three final questions asked participants to rate the extent to which they think the way they were asked to imagine the scenarios in the imagery CBM task influenced how well they could remember the scenarios, first for the voluntary memory task, then for the diary, and finally for the involuntary memory task. These questions were all answered on a scale from -5 (worsened) to +5 (improved).

Randomization. Randomization of participants to experimental condition was via a computer program implemented in Java and written by the first author (SEB). Randomization was in blocks and stratified by testing researcher and by gender. The randomization sequence was generated by the first author using a true random number generator (www.random.org). Allocation was to a combination of experimental condition (emotional vs. non-emotional) and counterbalance order (A first vs. B first) for the Ambiguous Scenarios Test and Voluntary Memory Test (i.e. the counterbalance order was the same for both tasks). Thus there were four possible allocations: emotional + A first, emotional + B first, non-emotional + A first, non-emotional + B first. For purposes of allocation concealment, researchers involved in participant recruitment and testing were not made aware of the construction of the randomization sequence or block lengths, and the randomization sequence was concealed within the (compiled) Java program. Further, participants were allocated to condition as late as possible in the testing session (while the participant was completing the PANAS pre-training, prior to completing the pre-training AST) to avoid biasing pre-training measures. The testing researcher entered the participant number, the participant's gender, and who the testing researcher was in order to reveal the participants' allocation. Following random allocation, the testing researcher was no longer blind to participant allocation.

Statistical Analyses. Where exploratory data analyses suggested non-normality, t-test comparisons between the two experimental conditions were supplemented via bootstrapped t-tests (10,000 bootstrap samples) conducted using the package ‘tpepler/nonpar’ (Pepler, 2017), although as there were no disagreements in results the standard t-test results are reported.

ANCOVAS were conducted using the package ‘afex’ (Singmann et al., 2019), with the default setting for sums of squares (Type III) and effect coding, so as to produce the same results as when conducting these analyses with the default settings using commercial programs such as SPSS.

Where regression diagnostics indicated potential violation of assumptions (e.g. heteroscedasticity), bootstrapped versions of the analyses were conducted with 10,000 bootstrap samples using the package ‘boot’ (Canty & Ripley, 2017). Effect sizes for t-tests were calculated as Cohen’s *d* with 95% Confidence Intervals using the package ‘MBESS’ (Kelley, 2019). Effect sizes for ANOVAs were calculated as eta squared with 90% confidence intervals (Steiger, 2004) using the package ‘MBESS’. Effect sizes for fixed effects in mixed models (carried out using the package lmerTest; Kuznetsova et al., 2017) were calculated as Cohen’s *d* equivalents with 95% Confidence Intervals from the *t* and *df* values for the effects of interest using the package ‘MBESS’.

Supplementary Results*Supplementary Table 1: Additional Outcome Measures*

	Emotional Condition	Non-Emotional Condition
	M (SD)	M (SD)
AST-D T1	17.68 (19.19)	17.30 (17.06)
AST-D T3	25.18 (18.09)	22.35 (18.65)
Diary IM valence	1.80 (1.74)	1.92 (1.71)
Involuntary Memory Task		
Valence Scenarios 1	0.94 (1.59)	0.81 (1.53)
Valence Everyday sound clips 1	0.92 (2.19)	0.94 (1.88)
Valence Scenarios 2	1.25 (1.89)	0.84 (1.85)
Valence Everyday sound clips 2	0.56 (1.76)	0.46 (1.81)
Voluntary Memory Test		
Recall Confidence 1	3.51 (0.65)	3.10 (0.89)
Recall Confidence 2	2.66 (0.57)	2.45 (0.74)
Gender Accuracy 1	6.34 (1.69)	6.47 (1.48)
Gender Accuracy 2	5.59 (1.60)	6.12 (1.90)
Gender Confidence 1	2.50 (0.75)	2.41 (0.86)
Gender Confidence 2	1.96 (0.70)	2.01 (0.85)
Recall Valence 1	2.81 (1.08)	2.60 (1.14)
Recall Valence 2	2.06 (1.11)	1.90 (1.21)

Note. AST-D = Ambiguous Scenarios Test for Depression, T1 = Pre-training, T3 = Post-training and filler task; Diary IM valence = mean valence rating (from -5 = *very unpleasant* to +5 = *very pleasant*) for involuntary memories recorded in the diary; IMT Valence Scenarios/ Everyday sound clips 1/2 = Mean valence rating for involuntary memories reported during the involuntary memory task in responses to Scenario cues/ Everyday sound clips in session 1 / session 2 (same scale as for diary valence ratings). Voluntary Memory Task: Recall Confidence = Mean confidence ratings for recall task (1 = *very unconfident* to 5 = *very confident*); Gender Score = total number of correctly recalled voice genders; Gender Confidence = mean confidence ratings for gender question (scale as for recall confidence); Recall Valence = Mean Valence rating for the recalled memory (same scale as the involuntary memory valence ratings).

Interpretation Bias

An ANCOVA with post-training AST as dependent variable, experimental condition and AST version (A vs B) as between-subjects factors, pre-training AST as covariate, and including an interaction term for AST Version by Condition, found no significant effect of condition, $F(1,75) = 0.99$, $p = 0.32$, $\eta^2 = 0.013$, 90% CIs: [0.000,0.080], indicating no differential effect of experimental condition on induced interpretation bias.

Rater coding of Involuntary Memories in the Involuntary Memory Task

As per our original protocol, the main analysis of the involuntary memory data (as reported in the main text) grouped the involuntary memories recorded by participants according to cue type, i.e. whether the cue it was reported in response to was an audio snippet from an imagery CBM scenario, or an everyday sound. However, as participants were asked to report *any* spontaneous imagery, they could report images that were not involuntary memories of the imagery CBM scenarios in response to scenario cues, or images that were involuntary memories of the scenarios in response to the everyday sound cues. As an additional exploratory analysis, we therefore attempted to categorise participants' spontaneous imagery (based on their free text descriptions entered during the involuntary memory task) as to whether they were involuntary memories of an imagery CBM scenario or not. As participants' typically entered only a few words of description, it was often not possible to confirm with any certainty that any spontaneous image had been an involuntary memory of a training scenario. Hence, we coded these as being an involuntary memory of a scenario if relevant scenario-related content was recorded, unless additional information was provided that excluded this possibility (or made it very unlikely). Two coders (SEB and FW) carried out this categorization independently, and then resolved any discrepancy through discussion to reach a consensus score. As the relative frequencies of involuntary memories of training scenarios versus other spontaneous images were highly imbalanced, we calculated

inter-rater agreement using Holley & Guilford's G , as this is more robust than indices such as Cohen's Kappa in the context of skewed distributions (Xu & Lorber, 2014). For involuntary memories recorded in response to scenario cues, there was 83.25% agreement between the raters, corresponding to an inter-rater reliability of $G = 0.66$. In the final consensus scoring, 299 of these 394 involuntary memories (75.89%) were classed as being of a scenario. For involuntary memories recorded in response to everyday sound cues, there was 99.49% agreement between the raters, corresponding to an inter-rater reliability of $G = 0.99$. In the final consensus scoring, 3 of these 592 involuntary memories (0.51%) were classed as being of a scenario.

We then repeated the analysis previously conducted for number of involuntary memories in the involuntary memory task as reported in the main text, but with classification of involuntary memory type according to our categorization rather than cue type, that is, a negative binomial generalized linear model with number of involuntary memories as dependent variable and experimental condition, session number, and involuntary memory content (scenario or not) as predictors (with all 2 and 3-way interactions, and a random intercept for participant). This showed a similar pattern of results to the main analysis, with no significant effect of experimental condition, $OR [95\% CIs] = 1.12 [0.47, 2.67]$, $p = 0.80$, a weak, not statistically significant effects of session number, $OR [95\% CIs] = 0.74 [0.54, 1.02]$, $p = 0.06$, and no statistically significant 2 or 3-way interactions. There was a main effect of involuntary memory content, indicating that involuntary memories recorded were more likely to be of non-scenario content, $OR [95\% CIs] = 0.32 [0.14, 0.73]$, $p = 0.01$.

Involuntary Memories Controlling for Baseline IAMI Scores

When controlling for participants' baseline tendencies to experience involuntary memories (via the IAMI-Past) in a negative binomial regression with number of involuntary memories in the diary as dependent variable, and IAMI-Past and experimental condition as

independent variable, experimental condition remained a non-significant predictor of number of involuntary memories, OR [95% CIs] = 0.83 [0.46,1.49], $p = 0.53$. Scores on the IAMI-past predicted number of involuntary memories, OR [95% CIs] = 1.04 [1.00,1.08], $p = 0.04$, indicating that when controlling for experimental condition, participants who tended to experience involuntary memories in daily life in general also tended to report more involuntary memories of the training scenarios in the diary. However, the confidence intervals for the regression coefficient for IAMI-past overlapped with 0 (0.04 [-0.0004, 0.08]), and a bootstrapped version of the regression conducted as a robustness check returned a similar result (95% CIs: [-0.008, 0.08]). Scores on the IAMI-past scale did not predict number of involuntary memories in the IMT, OR [95% CIs] = 1.00 [0.96,1.04], $p = 0.96$.

Effect of Involuntary Memory Task on Mood

Due to the between-group difference in PANAS score prior to the first involuntary memory task, (T3), we did not run the planned ANCOVA to investigate the effect of the involuntary memory task on mood, as this would have violated the assumption of independence between covariate and between-groups factor. Instead, we compared change in mood from before to after the involuntary memory task (T3 to T4) via a t-test on the change scores. Contrary to expectations, this showed a greater *negative* change (i.e. decrease) in PANAS scores for participants in the emotional condition, $M = -5.57$, $SD = 9.37$, compared to those in the non-emotional condition, $M = -0.67$, $SD = 10.10$, $t(77.56) = 2.25$, $p = 0.027$, d [95% CIs] = 0.50 [0.06,0.95]. This greater decrease in the emotional condition is most likely a reflection of the higher levels of positive affect in the emotional condition prior to starting the task.

For the involuntary memory task in the second session we could conduct an ANCOVA as planned, with PANAS after the involuntary memory task as dependent variable, and experimental condition and PANAS before the involuntary memory task as independent

variables. This found no effect of condition, $F(1,76) = 1.83$, $p = 0.180$, $\eta^2 = 0.024$, 90% CIs: [0.000,0.101].

Valence Ratings for Involuntary Memories

In relation to valence ratings for involuntary memories recorded in the diary, there was no difference between the two experimental conditions, $t(49.83) = 0.26$, $p = 0.793$, d [95% CIs] = 0.07 [-0.47, 0.62].

For the involuntary memory task, valence ratings were analyzed via a mixed model with within-subject factors of session number and cue type, a between-group factor of experimental condition, and a random intercept at the participant level. There were no statistically significant main effects or interactions, indicating that valence ratings did not vary according to cue type, session, or experimental condition (see the analysis scripts at <https://osf.io/whk2b/> for full details).

Voluntary Memory Task: Additional analyses

A mixed model with participants' ratings of their confidence in their recall for the scenario endings found both a main effect of session, $t(79.16) = 5.98$, $p < 0.01$, $d = 1.31$ [0.84,1.80], indicating higher confidence in the first session compared to the second, and a main effect of condition, $t(107.83) = 2.31$, $p = 0.02$, $d = 0.44$ [0.06,0.82], indicating higher ratings of confidence amongst participants in the emotional condition compared to those in the non-emotional condition.

For participants' recall of the gender of the speaker for the scenario recordings, there were no statistically significant main effects or interactions. For confidence ratings of the gender responses, there was only a main effect of session, $t(79.25) = 3.25$, $p < 0.01$, $d = 0.71$ [0.27,1.17], indicating higher confidence in the first session compared to the second.

Similarly, for valence ratings of the recalled scenarios, there was only a main effect of session, $t(79.20) = 2.95$, $p < 0.01$, $d = 0.65$ [0.21,1.10], indicating more positive valence ratings in the first session compared to the second.

Involuntary Memories over Time

As specified in the study protocol, changes in occurrence of involuntary memories recorded in the diary over time were investigated. Given the distribution of the data, this was conducted by grouping the involuntary memories into three time 24-hour time bins starting from immediately following the first testing session, and running a negative binomial regression within the framework of generalized linear models. This had the number of involuntary memories as dependent variable, and experimental condition, time bin (as a categorical variable), and the interaction of condition by time as independent variables. A random participant-level intercept was specified. This found a statistically significant interaction between condition and time (time bin 2 compared to time bin 1), OR [95% CIs] = 3.42 [1.36,9.02], $p = 0.007$. This was decomposed via two separate negative binomial generalized linear models over time bin 1 to time bin 2, separately per condition. There was a significant effect of time only in the non-emotional condition, OR [95% CIs] = 0.43 [0.21,0.82], $p = 0.01$, indicating fewer involuntary memories in the second, compared to the first, time bin. Inspection of the data suggested that this decrease (relative to the emotional condition) was due to a relatively greater number of involuntary memories experienced in the first time bin in the non-emotional compared to the emotional condition, although a negative binomial regression analyzing only this time bin did not find a statistically significant effect of condition, OR [95% CIs] = 0.54 [0.23,1.21], $p = 0.14$.

Demand Ratings

There was no difference between the two conditions in terms of ratings for how accurately they reported having completed the diary (Emotional condition: $M = 7.31$, $SD =$

1.75; Non-Emotional Condition: $M = 6.58$, $SD = 2.10$, $t(75.20) = 1.69$, $p = 0.096$, d [95% CIs] = 0.38 [-0.07,0.82]). However, participants in the emotional condition provided a higher rating than those in the non-emotional condition for how much they felt their instructed perspective (i.e. field perspective) helped them remember the scenarios in the voluntary memory task, (Emotional condition: $M = 1.46$, $SD = 1.89$; Non-Emotional Condition: $M = 0.30$, $SD = 2.04$, $t(76.80) = 2.63$, $p = 0.010$, d [95% CIs] = 0.58 [0.14,1.04]); completing the diary (Emotional condition: $M = 1.05$, $SD = 1.59$; Non-Emotional Condition: $M = -0.10$, $SD = 2.01$, $t(73.86) = 2.83$, $p = 0.006$, d [95% CIs] = 0.63 [0.18,1.09]); and in the involuntary memory task (Emotional condition: $M = 0.95$, $SD = 1.88$; Non-Emotional Condition: $M = 0.12$, $SD = 1.60$, $t(74.55) = 2.09$, $p = 0.040$, d [95% CIs] = 0.47 [0.02,0.91]). However, in the written feedback provided prior to debriefing it did not appear that participants had guessed the study's hypotheses.

Effects of tester

As specified in the study protocol, the potential effects of different testers or rooms was explored via including these as fixed effects in the main analyses (ANCOVA predicting mood post-training, regression predicting involuntary memories in the diary). There were no main effects of tester or interactions with condition (see analysis scripts at <https://osf.io/whk2b/> for full details).

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