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An Experimental Investigation of the Causal Role of Mental Imagery in the Experience of Involuntary Memories

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Abstract

Involuntary memories are thought to affect emotion, cognition, and behaviour, and it is often assumed that their impact is amplified when they are rich in mental imagery. However, this assumption has yet to be directly investigated. The current study tested a newly-developed paradigm designed to induce involuntary memories and provide a means to test the role of mental imagery directly. In a within-subject design, an unselected young adult (mostly student) sample ($N = 53$) participated in a lab-based study. Participants generated emotionally-valenced mental images or sentences via combining ambiguous pictures with positive or negative word captions. They then completed tasks designed to trigger involuntary memories of the previously generated images and sentences. Voluntary retrieval of the picture-word pairs was also assessed. Participants reported experiencing involuntary memories of previously generated images and sentences, but there were no detectable effects of mental imagery on measures of involuntary memory. However, participants recalled more word captions from picture-word pairs used to generate images than those used to generate sentences. Overall, the newly developed paradigm provides a means to test assumptions about the impact and functions of involuntary memories directly via experimental manipulation, opening up a number of opportunities for future research.

Keywords: involuntary imagery, mental imagery, emotion, involuntary emotional memory, involuntary autobiographical memory.

Introduction

Most people experience involuntary memories (IMs) frequently in their daily lives (Berntsen & Jacobsen, 2008). IMs are thought to play an important role in many processes such as emotion regulation, problem solving, and decision making (Berntsen, 2021; Blackwell, 2021), and dysfunctions in the experience of IMs characterise many psychological disorders (Blackwell, 2021). However, despite extensive research into IMs, direct evidence for their hypothesised causal effects is scarce. One potential reason for this is a lack of suitable experimental methods for testing causal hypotheses.

Much of our knowledge about the natural experience of IMs comes from studies that have investigated their occurrence in people's daily lives, asking participants to record them in a diary (Barsics et al., 2016; D'Argembeau et al., 2011). Other studies have examined the experience of IMs of daily events in controlled laboratory settings, for example while participants complete an undemanding, often monotonous, task (Ji et al., 2022; Schlagman & Kvavilashvili, 2008). Both kinds of study have provided a wealth of information about the frequency of IMs, the circumstances of their occurrence, and their characteristics, e.g. valence, time orientation, and their content. However, the majority of these

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studies have only investigated the experience of IMs when they occur (i.e. at *retrieval*). This limits the causal inferences we can make about the effects or functions of IMs from such studies, as their content and characteristics were not under experimental control.

Other research has achieved a degree of experimental control over the content and characteristics of IMs via studying IMs of stimuli that were presented within the study itself. This provides the opportunity to manipulate what exactly was encoded into memory and thus the characteristics of what is later involuntarily retrieved. For example, participants have been asked to watch negative (e.g., trauma-related; Holmes, James, et al., 2009; Lau-Zhu et al., 2021) or positive (Clark et al., 2013) films, or to listen to descriptions of negative (Krans et al., 2010) or positive (Blackwell et al., 2020) situations and imagine these occurring. Participants have then later been asked to record involuntary memories of the films or imagined scenes both in daily life and in controlled laboratory tasks. These studies have provided useful information about the conditions at encoding of an event that can increase or decrease the probability of later retrieval of involuntary memories. However, the use of films or audio scripts at encoding as the basis for later IMs limits what exactly can be manipulated in terms of the content and characteristics of IMs and the kinds of questions that can be addressed.

For example, one key aspect of IMs thought to have an important role in their impact and functions is that they frequently involve the experience of mental imagery (Warden et al., 2019; see a review by Berntsen, 2019). That is, when a memory of an event pops spontaneously into someone's mind, they might see the scene in their mind's eye and even re-experience the event (including other sensory experiences such as sounds and smells, and the accompanying emotions). Based on experimental research showing that mental imagery has a greater impact on emotion, cognition, and behaviour than non-imagery (e.g. verbal) thought (Holmes et al., 2008; Blackwell, 2021), it has been assumed that the imagery component of IMs plays a crucial role in the beneficial effects of IMs in healthy functioning, as well as the negative effects of dysfunctional IMs in psychopathology, for example via increasing their emotional and motivational impact. However, this assumption is based on investigation of *voluntarily* generated mental imagery, and we cannot assume that the same holds for *involuntary* mental imagery. Although participants are often asked whether the IMs they record involve mental imagery or not, this has not been subject to experimental control. Without such experimental control (i.e. actively manipulating whether an IM includes imagery or not) it is not possible to directly evaluate whether imagery-based IMs do indeed have a greater impact on emotion or behaviour than IMs that do not involve imagery, and thus a major assumption of theories of IMs in health functioning and psychopathology remains untested.

Overview of the current study

In the current study we applied a new paradigm that we developed to facilitate more direct testing of causal hypotheses regarding IMs, in particular the role of mental imagery, via controlling crucial aspects of both encoding and retrieval. In the encoding phase, participants completed a picture-word task (PWT; adapted from Holmes et al., 2008) in which they viewed a series of ambiguous pictures, accompanied by a positive or negative caption word. For each picture-word pair, participants were asked to combine the picture and word by generating either a mental image or a sentence. This allowed experimental manipulation of what was encoded into memory both in terms of whether it was imagery-based or not (determined by the instruction), and in terms of its valence (determined by the caption). In the current study participants completed a version of the PWT organised into four blocks reflecting the different processing mode/valence combinations (imagery/verbal × positive/negative).

The involuntary retrieval part of the paradigm comprised two tasks: a Vigilance Intrusion Task and an Emotional Attentional Blink task. These used the pictures from the PWT as cues to induce involuntary retrieval of the previously generated positive or negative images and sentences. In this way, we could trigger and therefore directly contrast the effect of imagery vs. verbal and positive vs. negative IMs. This would allow investigation of the causal relevance of these different aspects of involuntary memories.

The Vigilance Intrusion Task (VIT) was adapted from that used by Lau-Zhu et al. (2019) and was used to assess the relative frequency of IMs from the different blocks of the PWT and their effect on state mood. The VIT is a monotonous sustained attention task in which participants responded to a series of numbers presented on the screen, with pictures periodically shown as background images as a means to cue IMs. In the current study, pictures from the PWT were included amongst the background images used as a means to cue IMs of the images and sentences generated. The VIT was arranged into four blocks corresponding to those of the PWT. That is, there were two ‘imagery blocks’, one positive and one negative, in which the pictures presented were those that had previously been used in the PWT for generating positive or negative images, respectively, and two corresponding ‘verbal blocks’, in which the pictures presented were those that had previously been used in the PWT for generating sentences. Participants provided ratings of state mood before and after each block, providing a measure of the impact of the IMs on mood.

The emotional attentional blink (EAB) task (adapted from Most et al., 2005) was used to provide a more indirect measure of the occurrence of IMs of images and sentences generated in the PWT. The EAB is a rapid serial visual presentation task in which participants have to detect certain features of pre-specified ‘target’ pictures from a stream of rapidly-presented distractors and non-target pictures. Presentation of negative pictures, as distractors, has been found to lead to an ‘attentional blink’ in that following their presentation participants are less likely to notice the target pictures when these are presented shortly afterwards (e.g. Ní Choisdealbha et al., 2017). In the current study we included pictures from the PWT as distractor pictures, with the rationale that if their presentation led to IMs of the previously generated images or sentences this might be detectable via an ‘attentional blink’ effect.

To summarise, participants completed the newly-developed paradigm (picture-word task, vigilance intrusion task, and emotional attentional blink task) in a lab-based study. Additional measures were completed during the PWT (state mood, and various ratings of the images/sentences generated) provided manipulation checks for the encoding part of the paradigm, and participants also completed questionnaires including measures of imagery to examine potential associations with the experimental tasks used. To allow further investigation of the effect of the experimental manipulations, participants also completed tasks assessing voluntary memory of the picture-word cues (recognition of the pictures, recall of the word captions), and provided subjective valence ratings for the pictures used.

We pre-specified a number of hypotheses. In relation to the VIT, our hypotheses drew on literature indicating that IMs tend to be imagery-based (e.g. Harris & Berntsen, 2019; Ji et al., 2022), and more frequently positive than negative (Finnbogadóttir & Berntsen, 2013), as well as on literature demonstrating greater effects on emotion of imagery than verbal thought (e.g. Holmes et al., 2008). We hypothesised that in the VIT participants would report more involuntary memories in response to picture cues for which they had generated images (i.e., during imagery blocks) compared to those for which they had generated sentences (i.e., during verbal blocks), and that participants would experience more involuntary memories in response to picture cues that had previously been paired with positive word captions, compared to those that had previously been paired with negative word captions. Additionally, we predicted that participants would show greater changes in state mood during imagery blocks of the VIT compared to verbal blocks. Further, we predicted that the relationship between block type (imagery vs. verbal) and mood change during the VIT would be mediated by the number of involuntary memories experienced.

In relation to the EAB, our hypotheses were also based on the literature indicating a greater impact on emotion of imagery compared to verbal thought, as well as results from studies using an EAB, which have tended to find that negative pictures in particular are associated with attentional blink (e.g. Ní Choisdealbha et al., 2017). We hypothesised that presentation of picture cues for which participants had generated images would lead to greater “attentional blink” than those for which they had generated sentences, at least for those picture cues that had previously been paired with negative word captions.

Method

Design

The study was a 2 (processing mode: imagery vs. non-imagery) × 2 (valence: positive vs. negative) within-subject experimental design. Further, participants were randomized to one of two counterbalance orders (imagery first or verbal first) to control for order effects in relevant tasks (see task descriptions for details).

Participants

Our sample comprised 53 participants (12 male, 40 female, 1 non-binary/other, mean age = 23.81, *SD* = 3.83, range = 19–33). The study was advertised on the website of the psychology faculty and social media, and participants were therefore mostly students recruited from Ruhr University Bochum. The two inclusion criteria were: (a) aged between 18 and 35 years old; (b) sufficient German language skills. Due to the absence of relevant data to instruct a power calculation, a pragmatic sample size of $N= 52$ was planned. This would offer 95% power to detect a within-group effect size of Cohen's $d = 0.50$ (i.e. medium) and 80% power to detect a within-group effect size of $d = 0.39$ (i.e. small/medium) at $p < .05$. Participants gave written consent prior to taking part in the study. Participants were reimbursed either €30 or course credit for participation. Ethical approval was received from the ethics committee for the Faculty of Psychology, Ruhr University Bochum (Nr. 679).

Materials

Experimental Tasks

All tasks were made using the PsychoPy software (Peirce et al., 2019) version 2021.1.2.

Picture-Word Task

The picture-word task (PWT) was adapted from Holmes et al. (2008). Ambiguous pictures were presented with a caption of a single word, which had either a positive or negative valence. The participants' task was to combine each picture-word pair to generate a mental image (in the imagery condition) or sentence (in the verbal condition) that was situated in the future and involved themselves. The future time orientation was specified so that the IMs could potentially serve as analogues of spontaneous future-oriented thoughts (Cole & Kvavilashvili, 2021), although this was not particular focus of the current study. Each trial started with a phrase instructing the participant how to combine the presented picture-word pair (mental image or sentences). After 1,000 ms the phrase was replaced by a picture with a word caption beneath, displayed for 3,500 ms. During this time the participant generated their mental image or verbal sentence (in their mind, i.e. they did not have to describe or report it). A beep sound then followed for 1,000 ms, as a signal to stop imagining the scene/thinking of their sentence. The participant then rated the vividness of their mental image/ease of sentence construction on a scale from 1 (*not at all vivid/ not at all easy*) to 7 (*extremely vivid / extremely easy*), followed by the time orientation of their image/sentence on a scale ranging from 1 (*in the past*) to 7 *(more than one year*) with a mid-point of 4 (*within the next week*).

The picture-word task was split into 4 blocks according to processing mode (imagery vs. verbal) instructions and valence (positive vs. negative captions). That is, within each block participants only had to use one processing mode (imagery or verbal), and all captions had the same valence (positive or negative). Order of processing mode was counterbalanced, with half of the sample completing the imagery blocks first and the other half completing the verbal blocks first (see supplementary materials for further details). However, to reduce the risk of floor effects for mood change over the positive blocks, the order of valence was fixed with the negative block for each processing mode always preceding the positive block for that same processing mode. Hence, two block orders were possible: negative imagery, positive imagery, negative verbal, positive verbal or negative verbal, positive verbal, negative imagery, positive imagery. At the end of each block, participants rated: (a) how emotionally arousing they found the emotionality of their images/sentences (from 1 = *not at all emotional* to 7 =

extremely emotional); (b) the self-relevance of their images (how personally involved they were) or sentences (how much the sentence referred to themselves); (c) and how much they combined the picture and their accompanying caption in the correct processing mode (mental images in the imagery blocks, words and sentences in the verbal blocks). The latter two questions were rated from 1 (*not at all*) to 7 (*totally*). Participants received detailed instructions from the researcher in imagery or verbal processing prior to starting the relevant blocks.

Imagery Condition

In the imagery condition participants were instructed to close their eyes as quickly as possible after seeing the photograph and the accompanying word caption, and generate a mental image that (a) combined the picture-word pair; (b) had a future time-orientation, e.g. experiencing as happening at some point in the future; and (c) in which they were personally involved, seeing the scene through their own eyes, i.e. "field" perspective. For instance, for a picture of a garden and the word of "happy" someone could imagine lying in a deck chair in the garden the following summer and feeling happy. Prior to the imagery blocks the researcher provided oral instructions and practice examples in generating mental imagery (adapted from previous studies, e.g. Holmes et al., 2008; Blackwell et al., 2015). As per previous studies, this included instructions to avoid thinking verbally but to instead focus on generating imagery.

Verbal Condition

In the verbal condition participants were asked to combine each photograph and the accompanying word caption to construct a sentence in their mind that was (a) future-oriented; (b) grammatically correct; (c) and involved themselves, i.e. using first-person pronouns such as "I", "me" etc. For instance, for a picture of a garden and the word of "happy" someone could construct a sentence such as "I will be happy spending time in the garden next weekend". Prior to the verbal blocks the researcher provided oral instructions and practice examples in thinking verbally and generating sentences (adapted from previous studies, e.g. Holmes et al., 2008; Blackwell et al., 2015). As per previous studies, this included instructions to avoid thinking in images but to instead focus on generating verbal sentences.

Picture Stimuli

A total of 140 pictures were selected from the Open Affective Standardized Image Set (OASIS; Kurdi et al., 2017). As almost none of the pictures are fully neutral, to obtain a relatively ambiguous set of picture stimuli we selected those with low valence ratings (70 mildly positive pictures, 70 mildly negative pictures). Pictures were also selected to have relatively low arousal ratings (less than 5 on a scale from 1 (*Very low*) to 7 (*Very high*) (see Kurdi et al., 2017). The pictures were stored as 800 × 600 pixel 24-bit Bitmap files.

Word Stimuli

A total of 140 word stimuli were selected, 137 from the Leipzig Affective Norms for German (LANG; Kanske & Kotz, 2010), and 3 from the Affective Norms for English Words Corpus (ANEW; Bradley & Lang, 1999). Words (70 positive and 70 negative) were chosen on the basis of being noun forms of the adjectives from the Positive and Negative Affect Schedules (PANAS) or their synonyms (e.g. the word "strength" from the LANG was used as a noun form of the word "strong" from the PANAS).

Picture-Word Pairs

Four fixed sets of picture-caption combinations were created using the picture and word stimuli described above (2 sets with positive and 2 sets with negative word captions), with allocation of these sets to processing mode (imagery or verbal) counterbalanced across participants (see Supplementary Materials for details). To avoid making generation of images/sentences too difficult within the task constraints, the mildly positive pictures were always in sets with positive word captions and the mildly negative pictures were always in sets with negative word captions.

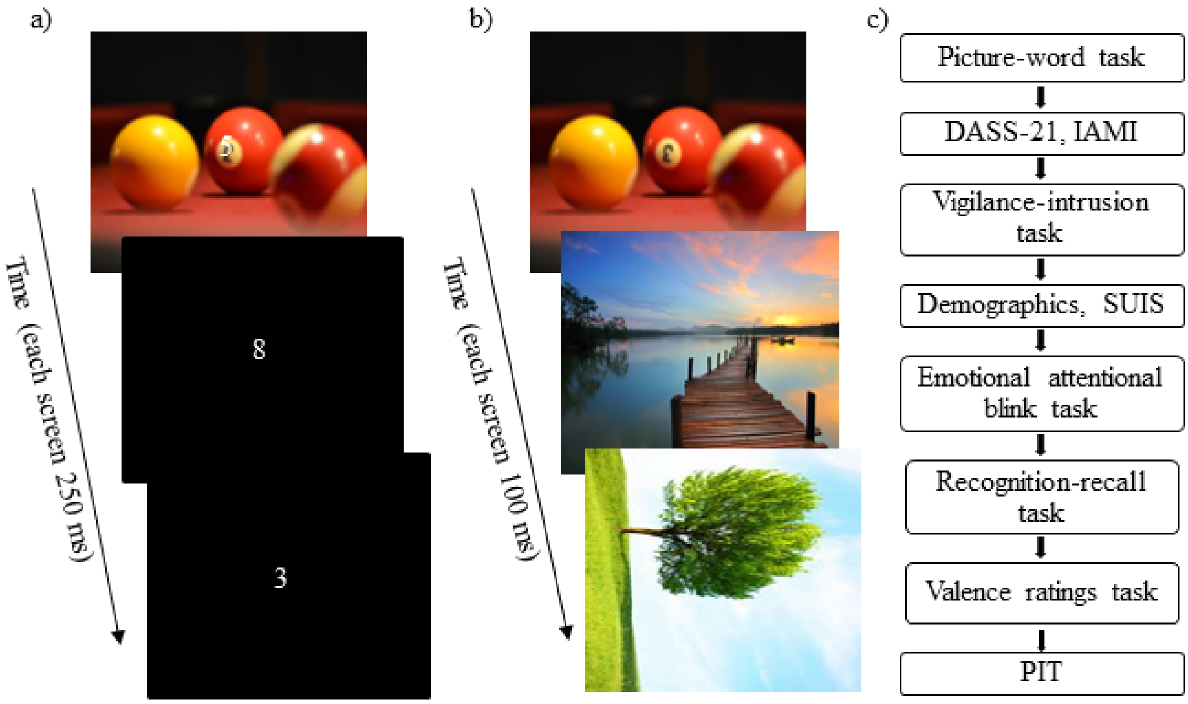
Vigilance-Intrusion Task

The vigilance-intrusion task (VIT) was used to trigger involuntary memories from the picture-word task and was adapted from that implemented by Lau-Zhu et al. (2019). It comprised 264 trials in total. On each trial, a digit from 1 to 9 was presented in the middle of a black background screen for 250 ms[1] and the black background remained visible for further 1,500 ms. On the first trial of every 3 sequential trials, for the first 250 ms (i.e. while the digit was presented) the black background was replaced by a picture. Hence a picture appeared on the screen every 5,000 ms (see Figure 1, panel a). The pictures and digits were displayed in a fixed randomised order. Participant were required to press the key "G" on the keyboard for all digits except "3", which was also never presented with a picture background. Participants were instructed beforehand that they might experience spontaneous memories during the task, and if so to press the key "S". On pressing "S", participants were prompted to type in a summary of their memory and then press enter to continue the task. Participants were simply told to report all spontaneous memories that occurred to them (i.e. without reference to the PWT), in order to avoid biasing their attention towards these specific memories (Barzykowski & Niedźwieńska, 2016).

The vigilance-intrusion task was split into four blocks that matched those of the picture-word task, i.e. negative-imagery, positive-imagery, negative-verbal, and positive-verbal. The block order for the VIT matched that of the picture-word task for each participant. In total, 88 pictures were used as background pictures for the VIT: 40 randomly selected (prior to the start of the study) from the picture-word task (10 from each block), and 48 foil pictures from the OASIS database (see Supplementary Materials for details). All 88 pictures were blurred using GIMP software version 2.10.22 (Gaussian blur 2.0), in line with previous studies (e.g., Lau-Zhu et al., 2019). The aim of blurring the pictures was to imitate environmental cues in everyday life, which are mainly out of focal attention (see Berntsen, 2021). As participants were told to report all spontaneous memories but we were only interested in memories derived from the PWT, at the end of the VIT the researcher asked the participant about each spontaneous memory that they had reported to ascertain whether it was one of the images/ sentences they had previously generated during the picture-word task. Only these were then used in the main analyses. In addition, the researcher asked whether each spontaneous memory was i) imagery-based, ii) verbal-based, or iii) a combination (see Supplementary Materials for analyses of these data).

[1] The tasks were programmed with timing based on time-frame based numbers rather than duration in ms as this allows more precise control over duration of presentation. However, to make it easier to comprehend in the task descriptions we describe the timings (in ms) we aimed to achieve via our frame numbers. Generally, the refresh rate of our testing computer screen was equal to 60 Hz, so the duration of a frame would be about 16.66 ms (1/60) and 250 ms presentation would be achieved via presenting a stimulus for 15 frames.

Figure 1. Overview of the Study Procedure and Schematic of Direct and Indirect Memory Tasks



Note. Panel a) shows sample trials of the vigilance-intrusion task. Panel b) shows sample stimuli of a stream of pictures within a trial of the emotional attentional blink task. Panel c) shows the order of tasks and questionnaires. During the picture-word task and vigilance-intrusion task, participants rated their state mood using the Self-Assessment Manikin before and after each of four blocks. DASS-21: Depression Anxiety Stress Scales-Short Version; IAMI: Involuntary Autobiographical Memory Inventory; SUIS: Spontaneous Use of Imagery Scale; PIT: Prospective Imagery Task.

Emotional Attentional Blink Task

The emotional attentional blink (EAB) task was adapted from Most and colleagues (Most et al., 2005) and used to examine potential attentional capture following presentation of pictures used in the picture-word task. There were a total of 160 trials. On each trial, a fixation cross was presented for 1,000 ms, followed by a rapid serial visual presentation (RSVP) stream of 17 images, each of which was displayed on a screen for 100 ms. Each trial included 3 kinds of pictures consisting of a distractor, a (rotated) target, and non-distractor pictures (see Figure 1 panel b). The distractor could be the 4th, 6th, or 8th photograph and the target photograph was at lag 2 or lag 8 after the distractor (Ní Choisdealbha et al., 2017), i.e. the target came as the 2nd or 8th photograph after the distractor respectively. Participants were asked to detect the direction of the rotated landscape/architecture picture and report whether it was rotated to the left (i.e. anti-clockwise) or right (i.e. clockwise) by pressing the left/right arrow key on the keyboard.

There were 160 distractor pictures in the EAB task, 80 of which were from the picture-word task (20 from each processing mode/valence condition and different from those presented in the vigilance-intrusion task), and 80 of which (40 negative and 40 neutral) were new pictures taken from the OASIS database. A further 80 architecture/landscape pictures were taken from the OASIS database, 40 left- and 40 right-rotated. The remaining pictures, used as non-distractor stimuli (i.e. all pictures in the RSVP stream that were neither distractors or targets), were 256 non-copyrighted pictures downloaded from the Pixabay website.[2] All pictures used in the task were 640 × 480 pixels saved as jpeg files. Each trial had one distractor.

Recognition-Recall Task

A recognition-recall task was used to examine the recognition of pictures and recall of words from the picture-word task. On each trial, participants were asked whether they had seen the presented picture during the picture-word task (recognition). If they answered yes, they were asked to type in the word that had accompanied that picture (recall). There were 40 pictures used in the task, with 20 taken from the picture-word task (5 from each processing mode/valence condition) and 20 chosen from the OASIS database. The images taken from the picture-word task had not been previously presented in the vigilance-intrusion task or the emotional attentional blink task. Participants were presented with the pictures in counterbalance orders comparable with the order of processing mode in the picture-word task and had unlimited time to record their answers.

Valence Ratings Task

The aim of this task was to investigate potential effects of processing mode on the perceived emotional valence of pictures (i.e. an evaluative conditioning effect; Holmes et al., 2008). Participants were presented with each photograph used in the picture-word task for 2,500 ms and asked to rate its emotional valence on a scale from 1 (*extremely negative*) to 7 (*extremely positive*), with the order of presentation randomized.

Questionnaires

All questionnaires were presented and completed on the study computer using the Qualtrics XM online questionnaire platform.

Depression Anxiety Stress Scales-Short Version

The Depression Anxiety Stress Scales-Short Version (DASS-21; Lovibond & Lovibond, 1995; German translation; Nilges & Essau, 2015) is made up of 3 subscales (depression, anxiety, and stress), each with 7 questions. Participants rate experiences of symptoms over the past week on a scale from 0 (*did not apply to me at all*) to 3 (*applied to me very much or most of the time*). In our sample, the internal consistencies (Cronbach's alpha) for the depression, anxiety, and stress subscales were α [95% CIs] = .83 [.76, .90], .78 [.70, .86], and .81 [.74, .89] respectively.

Spontaneous Use of Imagery Scale

We used the Spontaneous Use of Imagery Scale (SUIS; Reisberg et al., 2003; German version by Görgen et al., 2016) to measure to what extent participants spontaneously experienced mental imagery in their daily lives. The SUIS consists of 12 questions that participants rate from 1 (*never appropriate*) to 5 (*always completely appropriate*). The internal consistency of the SUIS in our sample was α [95% CIs] = .76 [.67, .85].

Involuntary Autobiographical Memory Inventory

The Involuntary Autobiographical Memory Inventory (IAMI; Berntsen et al., 2015) has 10 past- and 10 future-oriented statements. We used the IAMI to assess the frequency of involuntary memories and involuntary future thoughts in participants' daily lives. Participants rate each statement on a 5-point scale, ranging from 0 (*Never*) to 4 (*Once an hour or more*). The internal consistency in our sample for the past-oriented subscale was α = .87 [.82, .92], the future-oriented subscale was α = .90 [.86, .94], and the total scale of IAMI was α = .93 [.90, .96].

Prospective Imagery Task

We used the Prospective Imagery Task (PIT; Morina et al., 2011) to measure participants general ability to generate mental imagery. It consists of 20 (10 positive and 10 negative) hypothetical future events. Participants are asked to imagine each event happening to them in the future and then rate the vividness

[2] In the pre-registered protocol, the number of non-distractor pictures was mistakenly written as 252.

of their image on a scale from 1 (*no image at all*) to 5 (*very vivid*). The Cronbach's alpha in our study for the positive subscale was $\alpha = .78$ [.69, .87] and for the negative subscale was $\alpha = .83$ [.76, .90].

Self-Assessment Manikin-Pleasure Dimension

The Self-Assessment Manikin (SAM; Bradley & Lang, 1994) is a non-verbal pictorial measurement that assesses emotion in 3 independent dimensions: Pleasure, arousal, and dominance. In the current study, we used the pleasure/valence scale and asked participants to rate their mood at the current time on a 9-point scale from 1 (*most negative rating*) to 9 (*most positive rating*).

Procedure

The study took place in one lab-based testing session. After arrival, participants received information about the study then provided written informed consent.[3] Next, in the first, encoding, phase of the study they completed the picture-word task. At the start and end of the task, and between each of the 4 blocks, participants rated their state mood via the SAM. Subsequently, participants completed the DASS-21 and IAMI.

The second, retrieval, phase of the study started with the vigilance-intrusion task (VIT). Participants rated their state present mood via the SAM at the start and end of the VIT and in between each of the 4 blocks. After the VIT, participants completed a demographic questionnaire and then the SUIS. This was followed by the emotional attentional blink task, the recognition task, the picture-ratings task, and the PIT, in this order (see Figure 1, panel c). Participants were then debriefed and reimbursed for their time or provided with a code to claim course credit.

Transparency and openness

In line with Transparency and Openness Promotion (TOP; Nosek et al., 2015), we report how we planned our sample size, any data exclusions, all manipulations, and all measures used in the study. All data, analysis codes, and experimental tasks are available at the Open Science Framework and can be accessed using the following link: https://osf.io/khqc4. All statistical analyses were run using R version 4.1.3 (R Core Team, 2022), in RStudio version 2022.2.3.492 (Posit team, 2022). The study protocol, including design, hypotheses, tasks, and analysis plan, was pre-registered on the Open Science Framework prior to recruiting the first participant. The protocol is available using the link above.

Statistical analysis plan

Participant inclusion in analysis

Data from one participant were excluded from analyses as they exited the picture-word task part-way through and then restarted it. One participant did not complete the last two tasks, but their data for other tasks were included.

Planned and exploratory statistical analyses

The analyses were done as planned in the study protocol, except where otherwise specified, with some additional analyses to disentangle interactions and some further exploratory tests.

We ran Welch's t-tests for continuous and Fisher's exact test for categorical variables, as requirements of conducting Chi-squared tests were not met, to compare participants' characteristics across counterbalance orders and to test the manipulation impacts. As planned, effects of processing mode on mood during the VIT and PWT were examined with a mixed ANOVA, using the afex package (Singmann et al., 2021). Significant interactions were followed up via Welch's t-tests. To test potential effects of processing mode on the number of involuntary memories we used a Poisson regression analysis, using the package lme4 (Bates et al., 2015), rather than originally planned mixed ANOVA, for which the distribution of the data did not seem suitable. Sensitivity and further exploratory analyses, as well as correlations with questionnaire measures, are described in the supplementary materials.

[3] Participants also received information about complying with the pandemic rules in the laboratory, such as disinfecting the seat, keyboard, and mouse and completed a further consent form relating to the COVID-19 pandemic testing requirements.

Results

Participant characteristics

Participant characteristics are shown in Table 1. As questionnaires were completed after randomization to the counterbalance order used in several tasks, and after some of the experimental tasks, we compared characteristics between the two counterbalance orders (imagery-first vs. verbal-first). Participants in the imagery-first order rated their imagery on the PIT as more vivid than participants in the verbal-first group. Most participants were native German speakers, with proportionally more native speakers in the verbal-first order compared to the imagery-first order (see Table 1).

Manipulation checks

Results of the manipulation checks are presented in Table 2. Generally, these are consistent with a successful manipulation: On average, participants reported using a processing mode in line with the instructions. Further, participants' mental images/sentences were on average future-oriented and the time orientation between the two processing modes was comparable. Additionally, the ratings of emotional arousal for imagery versus verbal processing were as expected: participants provided higher emotionality ratings for the imagery blocks compared to the verbal blocks. Finally, the difference in mood change (as measured by the SAM) between positive and negative blocks was valence-congruent in both imagery and verbal blocks. We also found some effects of valence. Participants reported higher vividness/easiness ratings for positive compared to negative stimuli.

Table 1. Participant Characteristics (Separated by Counterbalance Order)

Variable	Imagery-first (n = 26) *M (SD)*	Verbal-first (n = 27) *M (SD)*	*t(df)*	*p*	Hedges *g*
Age	23.73 (4.22)	23.89 (3.50)	-0.15 (48.60)	.88	-0.04
DASS-21-depression	2.85 (2.38)	3.48 (3.77)	-0.74 (44.12)	.46	-0.20
DASS-21-anxiety	2.77 (3.25)	1.52 (1.76)	1.73 (38.19)	.09	0.47
DASS-21-stress	5.69 (3.97)	5.33 (3.26)	0.36 (48.39)	.72	0.10
SUIS	40.19 (8.08)	38.41 (7.23)	0.84 (49.88)	.40	0.23
IAMI-past	20.69 (6.64)	21.04 (7.65)	-0.18 (50.48)	.86	-0.05
IAMI-future	18.15 (8.87)	17.04 (8.03)	0.48 (50.05)	.63	0.13
PIT-positive	35.12 (5.40)	31.04 (6.56)	2.48 (49.81)	.02	0.67
PIT-negative	36.54 (6.81)	32.07 (7.47)	2.28 (50.86)	.03	0.61
	n (%)	*n (%)*	Fisher's exact test	*p*	
Gender					
Male	7 (26.92)	5 (18.52)		.63	
Female	19 (73.08)	21 (78)			
Other or X	0 (0.00)	1 (3.70)			
Relationship status					
Single	16 (61.54)	13 (48.15)		.49	
Single but in a stable relationship	10 (38.46)	13 (48.15)			
Married/ cohabiting	0 (0.00)	1 (3.70)			
Highest educational degree					
High school	19 (73.08)	15 (55.55)		.66	
College	2 (7.69)	3 (11.11)			
Bachelor	4 (15.38)	7 (25.93)			
Master	1 (3.85)	2 (7.41)			
Native German speaker	19 (73.08)	26 (96.30)	0.11	.02	
German nationality	24 (92.31)	27 (100.00)	0.00	.24	

Note. DASS-21-depression/anxiety/stress: Depression/anxiety/stress scales of Depression Anxiety Stress scales-short version; SUIS: Spontaneous Use of Imagery Scale; IAMI-past/future: Past/future subscales of Involuntary Autobiographical Memory Inventory; PIT-negative/positive: Negative/positive subscales of Prospective Imagery Task.

However, we also found some effects of the counterbalance order. Participants who completed the imagery blocks first reported more vivid imagery and a time-orientation further in the future than participants who completed the verbal blocks first. Similarly, participants who completed the imagery blocks first rated positive blocks more emotionally arousing, $t(50.75) = 2.49$, $p = .02$, g [95% CIs] = 0.67 [0.13, 1.23], but there were no such effects of counterbalance order for the emotionality of negative blocks, $t(49.65) = 0.53$, $p = .60$, g [95% CIs] = 0.14 [-0.39, 0.68]. Finally, for mood change we found an interaction between counterbalance order, valence, and processing mode: For participants who completed the imagery blocks first we found the expected processing mode × valence interaction, $F(1, 25) = 8.39$, $p = .008$, η_p^2 [90% CIs] = .25 [.05, .46], which reflected a greater (valence-congruent) change in mood over the positive imagery block compared to the positive verbal block, $t(25) = 2.94$, $p = .007$, g [95% CIs] = 0.70 [0.16, 1.01], but no difference in mood change between the negative imagery and verbal blocks, $t(25) = -1.40$, $p = .17$, g [95% CIs] = -0.27 [-0.68, .12]. For participants who completed the verbal blocks first, there was only the main effect of valence, F(1, 26) = 10.61, p = .003, ηp2 [90% CIs] = .29 [.07, .49], and no difference between mood change over imagery vs. verbal blocks.[4]

[4] Note that if we compare mood change over the imagery block amongst participants who completed imagery first to mood change over the verbal block amongst participants who completed verbal first (i.e. between-subjects comparison of imagery vs. verbal without potentially confounding by order effects), we find a significant processing modevs. valence interaction, $F(1,51) = 6.88$, $p = .01$, η_p^2 [90% CIs] =.12 [.02, .27], which when broken down by valence shows a greater improvement in mood in the imagery condition compared to the verbal condition in the positive block, $t(46.77) = 2.37$, $p = .02$, g [95% CIs] = 0.64 [0.10, 1.20], and a greater reduction in mood in the imagery condition compared to the verbal condition in the negative block, $t(43.27) = -2.26$, $p = .03$, g [95% CIs] = -0.62 [-1.18, -0.07].

Table 2. Manipulation Checks (Separated by Counterbalance Order)

Variable	Imagery blocks		Verbal blocks		Omnibus effects	
	Negative *M* (*SD*)	Positive *M* (*SD*)	Negative *M* (*SD*)	Positive *M* (*SD*)	$F(1, 51)$ [a]	η_p^2
Vividness						
Imagery first	4.74 (0.80)	5.06 (0.83)	-	-	O: 7.78**	.13
Verbal first	4.14 (0.90)	4.35 (0.97)	-	-	V: 21.29***	.29
Easiness						
Imagery first	-	-	4.73 (1.00)	5.00 (1.04)	V: 28.08***	.36
Verbal first	-	-	4.28 (0.91)	4.61 (0.92)		
Time-orientation						
Imagery first	5.23 (0.77)	5.11 (0.69)	5.03 (0.75)	5.03 (0.66)	O: 6.87*	.12
Verbal first	4.58 (1.13)	4.77 (0.92)	4.56 (0.78)	4.46 (0.75)		
Emotionality						
Imagery first	4.27 (1.34)	3.85 (1.35)	3.42 (1.36)	3.00 (1.47)	O × V: 7.47**	.13
Verbal first	3.81 (0.49)	2.85 (1.46)	3.59 (1.15)	2.30 (1.20)	M: 12.04**	.19
Thinking in images / verbally [b]						
Imagery first	5.69 (0.93)	5.50 (1.10)	5.38 (1.30)	5.54 (1.27)		
Verbal first	5.11 (1.42)	5.22 (1.42)	5.59 (1.08)	5.63 (1.24)		
Personal involvement in images						
Imagery first	5.69 (0.79)	5.12 (1.18)	-	-	V: 6.60*	.11
Verbal first	5.04 (1.32)	4.78 (1.53)	-	-		
Self-relevance of sentences						
Imagery first	-	-	5.12 (1.24)	5.58 (1.33)	V: 6.67*	.12
Verbal first	-	-	5.22 (1.31)	5.67 (0.92)		
State mood change						
Imagery first	-1.23 (1.27)	1.15 (1.22)	-0.92 (0.74)	0.38 (0.85)	O × M × V: 4.64*	.08
Verbal first	-0.70 (1.03)	0.26 (1.16)	-0.56 (0.85)	0.44 (0.93)		

Note. [a] For simplicity, only statistically significant interactions/main effects are presented. O: Order of presentation, M: Processing mode, V: Valence. [b] Thinking in images rated in the imagery condition, thinking verbally rated in the verbal condition (ratings not compared across processing modes).
**p* < .05. ***p* < .01. ****p* < .001

Vigilance Intrusion Task

Number of Involuntary Memories

Thirty-three participants reported no involuntary memories from the picture-word task during the VIT, 5 reported one, and 15 reported more than one (max = 23). Contrary to our hypotheses, a Poisson regression with number of involuntary memories as the dependent variable, and with processing mode, valence, and counterbalance order as independent variables, found no statistically significant main effects or interactions, including no main effect of processing mode, *OR* [95% CIs] = 0.92 [0.51, 1.63], $p = .77$, main effect of valence, *OR* [95% CIs] = 0.79 [0.43, 1.45], $p = .45$, or their interactions, *OR* [95% CIs] = 1.03 [0.43, 2.46], $p = .94$, indicting no difference between the different blocks in terms of number of involuntary memories from the PWT (see Figure 2).

Mood Change

Contrary to our hypotheses, a 2 (processing mode: imagery vs. verbal) × 2 (valence: positive vs. negative) × 2 (Counterbalance order: imagery-first vs. verbal-first) mixed ANOVA on state mood change found only a statistically significant interaction between valence and counterbalance order, $F(1, 51) = 6.53$, $p = .01$, η_p^2 [90% CIs] = .11 [.01, .26]. We therefore tested the effect of valence on mood change in each counterbalance order separately via paired t-tests. In the imagery first order, there was no significant difference between negative, $M = -0.33$, $SD = 0.55$, and positive blocks, $M = 0.04$, $SD =$

0.68, $t(25) = -2.02$, $p = 0.05$, g [95% CIs] = -0.58 [-0.81, 0.01]. In the verbal first order, there was also no difference between negative, $M = -0.09$, $SD = 0.37$, and positive blocks, $M = -0.28$, $SD = 0.38$, $t(26) = 1.55$, $p = 0.13$, g [95% CIs] = 0.48 [-0.09, 0.69].

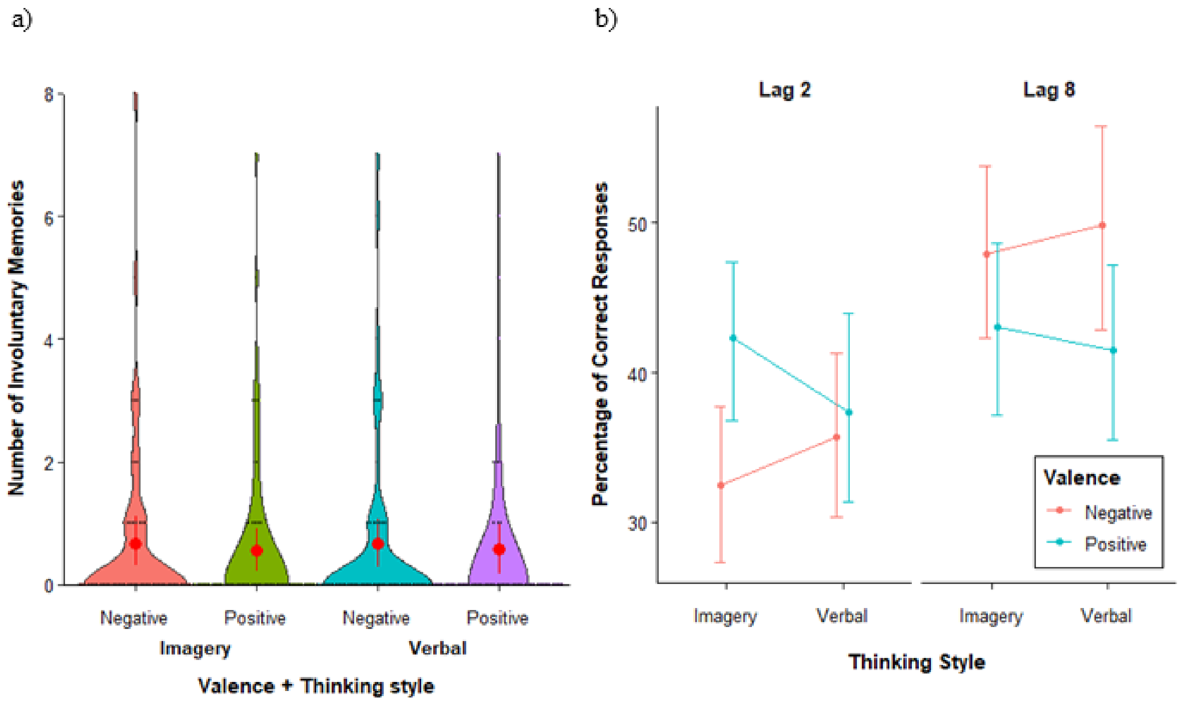
Relationships Between Number of Involuntary Memories and Mood Change

Contrary to our hypotheses, there were no significant correlations between number of involuntary memories from the picture-word task and mood change during the VIT. We therefore did not carry out the planned mediation analyses (see Supplementary Materials for details).

Emotional Attentional Blink Task

As the previous analyses had suggested a potential effect of counterbalance order on initial processing of the picture-word stimuli, we included counterbalance order as a between-subjects factor in our analysis of the EAB data (initially we had not planned to do so, as it does not influence order of presentation within the EAB task itself), resulting in a 2 (processing mode: imagery vs. verbal) × 2 (valence: positive vs. negative) × 2 (time: lag 2 vs. lag 8) × 2 (counterbalance order: imagery-first vs. verbal-first) mixed ANOVA.

Figure 2. Effects of Presentation of Picture Cues From the Picture-Word Task Assessed Directly (Number of Involuntary Memories on the Vigilance Intrusion Task, Left Panel), and Indirectly (Percentage of Correct Responses on the Emotional Attentional Blink Task, Right Panel).



Note. Panel a) shows number of involuntary memories, with mean and 95% confidence intervals, in response to presentation of picture cues from four different conditions: Negative imagery, positive imagery, negative verbal, and positive verbal. Panel b) shows percentage of correct responses, with mean and 95% standard errors, to the target picture when it was at lag 2 vs. lag 8 of picture cues from the four different conditions.

As expected, there was a main effect of time, $F(1, 51) = 30.36$, $p < .001$, η_p^2 [90% CIs] = .37 [.20, .52], indicating less frequent detection of the target picture at lag 2 vs. lag 8, and thus the occurrence of an emotional attentional blink at lag 2 (see Figure 2). However, this was qualified by a time × valence interaction, $F(1, 51) = 26.41$, $p < .001$, η_p^2 [90% CIs] = .34 [.17, .49]. Follow-up t-tests for each valence between the two time lags indicated that for the negative valence there were fewer correct responses (i.e. greater attentional blink) at lag 2, $M = 34.06$, $SD = 17.04$, relative to lag 8, $M = 48.87$, $SD = 21.41$, $t(52) = -7.52$, $p < .001$, g [95% CIs] = -0.73 [-1.38, -0.70]. However, for the positive valence, there was no difference between the two time lags in the amount of correct detection (of the target picture) at lag 2, $M = 39.81$, $SD = 18.53$, relative to lag 8, $M = 42.26$, $SD = 19.38$, $t(52) = -1.26$, $p = .21$, g [95% CIs] = -0.13 [-0.45, 0.10]. The only significant effect of counterbalance order was an order × time × processing mode interaction, $F(1, 51) = 4.57$, $p = .04$, η_p^2 [90% CIs] = .08 [.00, .22], but when broken down this did not alter interpretation of the results (see Supplementary Materials for details).

Exploratory Analyses

Recognition of Pictures

A Poisson regression with number of incorrect responses as the dependent variable,[5] and with processing mode, valence, and counterbalance order as independent variables, found a main effect of valence, *OR* [95% CIs] = 0.52 [0.27, 0.99], $p = .046$, indicating that participants recognised more pictures that had been paired with positive captions than those that had been paired with negative captions.

Recall of Word Captions

A Poisson regression with number of words correctly recalled as the dependent variable, and with processing mode, valence, and counterbalance order as independent variables, found a main effect of processing mode, *OR* [95% CIs] = 0.50 [0.26, 0.97], $p = .04$, indicating that participants recalled more word captions of picture-word pairs for which they had generated images relative to those pairs for which they had generated sentences. There was no main effect of valence, *OR* [95% CIs] = 1.00 [0.58, 1.72], $p = 1.00$, and no interaction effects of processing mode and valence *OR* [95% CIs] = 1.31 [0.53, 3.23], $p = 0.56$.

Valence Ratings

A (processing mode: imagery vs. verbal) × 2 (valence: positive vs. negative) ×2 (order of presentation: imagery first vs. verbal first) mixed ANOVA with emotional ratings of the pictures as the dependent variable found only a statistically significant effect of valence, $F(1, 50) = 966.56$, $p < .001$, η_p^2 [90% CIs] = .95 [.93, .96], indicating that participants rated pictures that had been paired with a negative caption as more negative ($M = 2.77$, $SD = 0.42$) than those that had been paired with a positive caption ($M = 4.95$, $SD = 0.35$). There were no other main effects or interactions.

Vividness/Ease of Image/Sentence Generation and Number of Involuntary Memories

In further unplanned exploratory analyses, there were significant correlations between vividness of negative mental images generated during the picture-word task and number of involuntary memories in the negative imagery block of the VIT, $\tau = .25$, $p = .02$. There were no significant correlations between vividness of positive mental images in the PWT and number of IMs in the positive imagery block of the VIT, $\tau = .18$, $p = .10$. There were no significant correlations between ease of sentence construction during the picture-word task and the number of involuntary memories in the negative, $\tau = .15$, $p = .20$, or positive, $\tau = .13$, $p = .20$, verbal blocks of the VIT.

Discussion

The present study investigated a new experimental paradigm designed to allow testing of causal hypotheses about the impact of involuntary memories (IMs), and in particular the role of mental imagery. Participants generated images or sentences that combined a photo with a caption in a picture-word task (PWT). The experience of involuntary memories of the previously generated mental images

[5] As recognition rates were generally high, we chose to analyse this data in terms of number of incorrect responses rather than number of correct responses, as this mean that the data approximated a Poisson distribution and we could use the Poisson regression. For recall rates, the distribution of correct responses already resembled a Poisson distribution, as recall rates were generally lower, and hence for recall we analysed number of correct responses.

and sentences was then assessed using a vigilance-intrusion task (VIT) and an emotional attentional blink (EAB) task. We also examined voluntary recognition and recall of the picture-word pairs of the PWT. Generating mental images had a greater impact on mood than generating sentences during the PWT. However, we did not find the hypothesised effects of cueing previously-generated images vs. previously-generated sentences on the measures of involuntary memory. Specifically, during the VIT participants reported no more IMs of previously-generated images than previously-generated sentences, and there also appeared to be no differential effect on state mood of triggering imagery vs. verbal IMs. In the EAB task, we did not find the hypothesised effects of cueing imagery vs. verbal IMs, although presentation of the pictures previously combined with negative words led to 'attentional blink', that is, poorer identification of target pictures presented 200 ms later relative to those presented 800 ms later. In contrast to measures of involuntary memory, we did find effects of imagery vs. sentence generation on voluntary memory, in that participants recalled more words previously used for generating images than those used for generating sentences. Finally, in exploratory analyses we found that participants who generated more vivid negative mental images in the PWT reported more involuntary memories in the associated blocks of the VIT. Overall, although the results did not support our specific hypotheses, they showed that the new paradigm could be used to induce IMs, and investigate their impact experimentally, providing a method to start testing the differential causal impact of different kinds of IMs (e.g. imagery vs. verbal) on mood, cognition, and behaviour.

Our results from the VIT indicated that people experienced involuntary memories of the mental images and sentences they had generated in the picture-word task, which supports its potential utility (in conjunction with the PWT) for investigating the impact of different kinds of IMs. Despite our finding that images generated during the PWT were rated as more emotional and led to greater mood change than the sentences generated during the PWT, these previously-generated images were no more likely to return involuntarily during the VIT than the previously-generated sentences. One potential reason for this is that effects of emotion (at encoding) on subsequent involuntary memories may not always be observable at short retention intervals (as in the current study), and may need a longer delay to be observed (e.g. 24 hours or more) (Staugaard & Berntsen, 2014). Another potential reason could be the generally low number of IMs from the PWT recorded during the VIT, with many participants reporting none at all. Some factors that may have reduced the number of memories reported are the task instruction to report all involuntary memories rather than only those related to the picture-word task (Barzykowski & Niedźwieńska, 2016), and the requirement to write a summary of each memory after it occurred, making reporting more demanding (Rasmussen et al., 2015).

The differential effects of valence that we found in the emotional attentional blink (EAB) task are particularly noteworthy, as this potentially indicates that rapid presentation of pictures from the PWT was successful in prompting involuntary retrieval of previously encoded material from memory storage, and that this was possible to detect via an indirect measurement. Indirect measurement of involuntary memory is important as while a key feature of involuntary memory is that it occurs without any plan or intention (Berntsen, 2021), people can mistakenly judge intentionally retrieved, voluntary, memories as having occurred involuntarily due to their ease of retrieval, and thus direct measurement based on self-report may not always be reliable (Sanson et al., 2020). However, as the pictures were not completely neutral, it is also possible that the pattern of results we found simply reflects the valence of the original pictures, or their acquisition of a more positive or negative valence via their pairing with the corresponding word captions in the PWT (i.e. a simple evaluative conditioning effect), rather than any retrieval of the images or sentences themselves. This may help explain the lack of an effect of processing mode in the EAB. In fact, the timeframe of the attentional blink (200 ms) may preclude effects of involuntary retrieval of an episodic memory, which appears to occur over a longer time-frame (Clark et al., 2016). Future studies could investigate including target pictures at a greater range of timeframes after presentation of the distractor, including beyond 800 ms as used as a control period in the current study, to better map out the timeframe of interference caused by presentation of the kind of distractor pictures used in the current study. Future studies could also try to distinguish between whether any interference found is due to the valence intensity of the distractor picture or involuntary retrieval. One possible means to do this would be to use a set of neutral pictures as distractor stimuli, with half of this set used in the PWT at encoding. Via counterbalancing which pictures were presented in the PWT or new during the EAB across participants, it would be possible to test the hypothesis that interference seen during the EAB was due to the earlier presentation in the PWT.

The current study allowed us to investigate whether the new paradigm could be used to contrast the effects of voluntary versus involuntary mental imagery, via examining the effects on mood assessed during the PWT and the VIT. In the PWT we found similar effects on state mood as in previous studies, in that generation of imagery led to greater mood change than generation of sentences (e.g. Holmes et al., 2008; Holmes, Lang, et al., 2009), albeit confounded with counterbalance order effects at a within-subject level. In contrast, we found no differential effect on mood of retrieval of involuntary images vs. sentences on the VIT. However, given that there were also no effects of valence on mood in the VIT this may reflect a lack of sensitivity of the VIT as implemented to detect the impact of IMs on mood rather than a lack of effect of imagery per se. Observational research indicates that participants report IMs as having an impact on mood (del Palacio-Gonzalez & Berntsen, 2020), but in such studies the ratings are made directly after experience of each involuntary memory. In contrast, the effect of IMs on mood change in the VIT was measured more indirectly via state mood ratings made at the end of each block. It may be that there were too few IMs from the PWT to have a detectable effect on mood remaining by the end of a block, given that participants also experienced IMs unrelated to the PWT (see Supplementary Materials). More frequent mood measurement, or manipulations to increase the number of involuntary memories experienced, may be necessary to make the VIT suitable for assessing mood effects.

Consistent with some previous findings (e.g. Blackwell et al., 2020), in exploratory analyses we found that participants who generated more vivid images during the PWT experienced more involuntary memories in the relevant blocks of the VIT, at least for negative imagery. This further highlights the potential importance of imagery vividness when aiming to induce IMs of imagined scenes. However, this result itself cannot tell us whether there is a causal relationship between imagery vividness and subsequent occurrence of IMs, which would require an experimental manipulation of vividness. It is also possible that it is not vividness (i.e. sensory/experiential richness) itself but rather a correlate or consequence of vividness such as emotional intensity that is responsible for any putative effects of vividness observed (see also Bagheri et al., 2023). This would also be useful to investigate further in future research.

In contrast to the results for involuntary memory, we did find an effect of processing mode (imagery vs. verbal) on voluntary recall. That is, when we measured voluntary recall memory of words used in the PWT, we found word captions previously combined with pictures to generate mental imagery were recalled more than those word captions previously combined with pictures to generate sentences. These outcomes could be interpreted as being in line with the picture superiority effect (PST; Paivio, 1971), that is, that stimuli studied as pictures or for which images are generated are better remembered than stimuli studied verbally. One potential explanation for this is the dual-coding theory (Paivio & Csapo, 1973; Paivio, 1991), according to which picture-word pairs combined as images would benefit from both image-based and verbal encoding in memory (although other explanations for the picture superiority effect, such as stimulus distinctiveness, have also been proposed, e.g. Ensor et al., 2019). Alternatively, presentation of pictures as cues for recall testing could result in greater overlap between this cue and the representation in memory for those picture-word pairs encoded as images compared to those encoded as sentences, although in this case we might also have expected to find an effect of processing mode in the VIT. Overall, the different pattern of results for involuntary and voluntary memory highlights the importance of investigating both types of memory in future research, and the potential underlying mechanisms (see also Lau-Zhu et al., 2019).

Interpretation of some of our findings is complicated by the effect of counterbalance order we found for some tasks. For example, the within-subjects effect of a greater impact on mood of imagery than verbal processing in the PWT was only found for participants who completed the imagery condition first, and in fact for this half of the sample the results across other tasks were also more similar to those we had hypothesised than for participants who completed the verbal condition first. One explanation for this could be fatigue: participants could have been more fatigued and had worse concentration when they completed the second processing mode. For participants who completed the imagery condition first, this might have the effect of amplifying the expected imagery vs. verbal effect on emotion (via dampening the effect of the verbal condition), but for participants who completed the verbal condition first the hypothesised greater impact on emotion of imagery would be reduced. The results of the between-group imagery vs. verbal comparison, using only the first experimental condition completed, are consistent with such an explanation, as is the relatively lower vividness ratings for images generated by participants who completed the imagery condition second. An alternative explanation might be that the effect of the counterbalance order in fact reflects imbalances across the participants allocated to the two counterbalance orders. For example, participants who completed the imagery condition first also generated more vivid images on the prospective imagery task (PIT) than those who completed the verbal condition first. However, if participants in the imagery first group also concentrated better on the imagery instructions in the PWT this could also have had a carry-over effect on subsequent performance on the PIT, rather than reflecting pre-existing between-group differences. It may be preferable to carry out such a manipulation as only between-subjects in future, or to adjust the within-subjects design to avoid contamination effects of counterbalance order, e.g. by having a longer break between two processing mode conditions.

It is important to note that our contrast of imagery vs. verbal processing mode was achieved via instructions to the participants, as is common in studies investigating mental imagery. This was reinforced by directed practice examples with feedback from the researcher, and by asking participants a condition-specific question (vividness of image vs. ease of sentence generation) after each trial. However, we did not have any measure of the success of this manipulation other than participants' own ratings, which could be influenced by demand effects. It is plausible that participants in the imagery condition also engaged in verbal processing of the stimuli, and that participants in the verbal condition also engaged in mental imagery. We did not measure participants' engagement in the non-desired processing mode, and this would be useful to do in future studies. Additionally, although we aimed to match the nature of the images and sentences generated in the two conditions by asking participants to generate first-person images and sentences situated in the future and by using practice examples that were matched for content, it is possible that the images and sentences differed in more than their representational format. For example, while the images would necessarily be concrete depictions of a scene or event, the sentences could be constructed to be either very concrete or relatively abstract descriptions. Given research showing the differential effects of concrete vs. abstract processing of emotional material on e.g. mood (Seebauer et al., 2016; Watkins et al., 2008; Werner-Seidler & Moulds, 2012), this could also influence differences found between the two conditions. To investigate this further in future research it could be useful to ask participants to report a selection, or all, of their images and sentences aloud to allow assessment of concreteness/abstractness and other characteristics such as episodic detail. Our exploratory analyses of the type of memories reported in the VIT (whether they involved imagery or were verbal only) also indicates that this did not closely match whether an image or sentence was generated during the PWT (see supplementary materials). This could in part reflect difficulty in engaging in exclusively image- or verbal-based processing during the PWT or the relative rarity of involuntary memories with no imagery component (especially when the original stimulus involved a picture cue). While we would expect those involuntary memories of images generated during the PWT to have a richer, more vivid, image component than those involuntary memoires of sentences that nonetheless had some imagery associated with them, in future it would be useful to assess additional qualities of such experimentally induced involuntary memories (e.g. vividness) to allow further investigation of their nature.

The newly developed paradigm has potential to address a number of potential important theoretical questions. The extent to which different elements of memory (e.g. imagery vs. verbal processing) are stored in the same (Tulving & Thomson, 1973) or separate (Brewin, 2014) systems, and the relationship between voluntary and involuntary memory is a matter of ongoing debate. Some experimental research supports the idea of differentiated memory systems (e.g. Lau-Zhu et al., 2019, 2021), but it has also been argued that the results of such studies, which investigate memories of trauma analogues, cannot be extrapolated to accounts of involuntary memories occurring in daily life (Berntsen, 2021). This new paradigm potentially provides the opportunity to investigate the characteristics of both mildly emotional, 'everyday' involuntary memories and those associated with more intense emotion, and investigate the role of the imagery components of a memory on its later involuntary and voluntary retrieval. It could also be used to investigate the causal effects of different kinds of IMs, by varying the pictures and words used in the picture-word task, e.g. using disorder specific pictures/words. Further, if the paradigm could be used to induce involuntary positive imagery in daily life, for example via having participants providing pictures from their own everyday environment for the PWT, this could also have potential clinical applications for example in the context of depression (Blackwell & Holmes, 2017).

Limitations

One limitation of the current study is that effects of valence found cannot be purely attributed to the valence of the word captions used in the picture-word task. As noted earlier, because almost none of the pictures in the OASIS database are fully neutral, we had to select pictures that had at least a mildly positive or negative valence. To reduce difficulty in generating images and sentences, pictures were then paired with word captions of the same valence when preparing the picture-word stimuli sets. However, this means that pure effects of valence (e.g. in the EAB, recognition task, or picture ratings) may simply reflect the original valence of the pictures used. Valence effects are also confounded with the order of presentation: in the picture-word task negative blocks always preceded positive blocks, in order to maximise the chance of observing mood effects. Interpretation of the effects of processing mode is unaffected, as this was fully counterbalanced (albeit this in itself introducing an order effect, as discussed above), but in future if effects of valence are of primary interest, then it would be preferable to remove these confounds in the design. A further limitation of the study is that the small number of involuntary memories recorded during the VIT made it more difficult to observe their effects (e.g. on mood) or potential modulators of their frequency. As mentioned above, asking participant to report all involuntary memories, regardless of their relevance to the picture-word task and to write a summary of their memory, may lead to participants' reluctance to report the experience of IMs. Increasing the number of involuntary memories recorded may also be possible via improving encoding, for example via repeated generation (or recall testing) of the images and sentences as opposed to a single trial (Blackwell et al., 2020).

Conclusion

This study presents a new paradigm for experimental investigation of the effects of involuntary memories, and in particular the potential role of mental imagery. Future developments and applications of the paradigm can open up a number of opportunities to move beyond observational data and start conducting rigorous tests of the causal role of involuntary memories of different types across their hypothesised important functions in our daily lives.

Additional Information

Supplementary Material

https://osf.io/d9mxe/

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Conflict of Interest

We have no potential conflict of interest to disclose.

Ethical approval

Ethical approval was received from the ethics committee for the Faculty of Psychology, Ruhr University Bochum (Nr. 679).

Data Availability

The data and codebook are also accessible on the same platform via https://osf.io/khqc4/.

Author CRediT Statement

MB and SEB conceived the study. MB, MLW, IFO, IFO, JDJR, JM, and SEB contributed to the study design. IFO, IFO, and JDJR gathered the data, under supervision of MB and SEB. MB analysed the data. MB wrote the first draft of the manuscript, and all authors commented on and approved the final manuscript.

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