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**Why Am I Remembering This Now? Predicting the Occurrence of Involuntary
(Spontaneous) Episodic Memories**

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Abstract

Involuntary episodic memories are memories of events that come to mind spontaneously – that is, with no preceding retrieval attempts. They are common in daily life and observed in a range of clinical disorders in the form of negative, intrusive recollections or flashbacks. However, little is known about their underlying mechanisms. Here we report a series of experiments in which—for the first time—the activation of involuntary memories are controlled and predicted on the basis of manipulations done at encoding. During encoding, participants were presented with pictures of scenes paired with sounds. Both scene and sound could be either unique (derived from a category that was presented only once) or repeated (derived from a category that was presented several times). During retrieval, the participants conducted an attention demanding sound location task employing sounds from the encoding phase. In addition to the sound location task, they were asked to record all memories that might spontaneously arise during this task. Unique sounds generated most involuntary memories, consistent with the notion of cue overload. Repeated sounds rarely generated involuntary memories, but often yielded memories of repeated scenes in a voluntary (strategic) recall condition. Retrieval times were lower for involuntary than for comparable samples of strategically retrieved memories, suggesting less executive functions involved in involuntary recall. Our findings show that it is possible to control the activation of involuntary episodic memories of daily scenes on the basis of well-known mechanisms of associative memory.

Keywords: Involuntary episodic memories, intrusive memories, autobiographical memories

Why am I Remembering This Now? Predicting the Occurrence of Involuntary (Spontaneous) Episodic Memories

I was running in the Botanical Garden, while thinking of something I had just read for my psychology class. It was a beautiful spring day with singing of birds, and not many other people out. I ran per routine – and suddenly got a side stitch (which is unusual for me). I then suddenly remembered a day in Hungary, where I was running with my friend from England. I got a severe side stitch, and, through his years in the military, he had learnt some breathing techniques against side stitches, which he then taught me.

Most people frequently experience involuntary episodic memories – that is, memories of personal experiences that come to mind with no preceding retrieval attempts, as illustrated by the example of the runner (derived from Berntsen, 2001). During the past 10-15 years an increasing number of studies have examined characteristics of such memories (e.g., Ball & Little, 2006; Berntsen, 1996, 2001; Berntsen & Hall, 2004; Kvavilashvili & Mandler, 2004; Mace, 2004; Rubin, Boals & Berntsen, 2008; Schlagman & Kvavilashvili, 2008; for reviews, see Mace, 2007; Berntsen, 2009, 2010). It is now well-documented that everyday involuntary memories are largely emotionally positive and that their occurrence in the great majority of cases is preceded by some cues in the ongoing situation – in terms of some identifiable feature overlap between the ongoing situation and the remembered event (Berntsen, 2009, for review). Still, little is known about the mechanisms underlying their sudden activation. In addition to shedding light on a common everyday memory phenomenon, uncovering such underlying mechanisms has

considerable clinical relevance. Emotionally negative and intrusive involuntary recollections have long been recognized as a key symptom of Posttraumatic Stress Disorder (PTSD, American Psychiatric Association, 2000; Horowitz, 1986). More recently, they are described in relation to a range of other emotional disorders, including depression, social phobia, bipolar disorder, psychosis, and agoraphobia (e.g., Holmes & Bourne, 2008; Steel, Fowler & Holmes, 2005; Williams & Moulds, 2010, for reviews). The fact that intrusive, involuntary memories are observed across different emotional disorders suggests shared underlying mechanisms (e.g., Steel et al., 2005). Knowledge of the mechanisms underlying normal involuntary memory activation may therefore have important implications for our understanding of maladaptive involuntary memories in emotional disorders.

Unlike memories that are retrieved deliberately (i.e., voluntary memories) systematic examinations of involuntary memories have been hampered by the fleeting nature of the phenomenon under study. Most studies have relied on naturalistic diary methods in which participants are asked to record involuntary memories as they occur in daily life (Berntsen, 2009, for a review). A few studies have used an association based strategy for eliciting involuntary autobiographical memories in a laboratory setting (e.g., Mace, 2007; e.g., Schlagman & Kvavilashvili, 2008). While allowing some control of the retrieval phase, such methods do not control the encoding phase. Some studies have instead controlled the encoding phase and left the retrieval phase less restricted, typically by presenting the participants with emotional versus neutral pictorial material during encoding followed by a naturalistic diary procedure for the retrieval phase (e.g., Hall & Berntsen, 2008; Ferree & Cahill, 2009; Holmes, Brewin & Hennessy, 2004; see Holmes

& Bourne, 2008, for a review). Some of these studies have involved procedures that increase or decrease subsequent frequency of intrusive, involuntary memories, for example by presenting trauma-related pictures or by inducing positive versus negative bias in cognitive appraisals (Ehlers, Halligan & Clark, 2005; Lang, Moulds, & Holmes, 2008; Woud et al., in press). In two brain imaging studies (Hall, Gjedde & Kupers, 2008; Kompus, Eichele, Hugdahl & Nyberg, 2011) participants were presented with visual and/or auditory stimuli during an encoding phase, followed by a retrieval phase with verbal references to the presented stimuli and with the instruction to either intentionally retrieve the matching stimuli or conduct a categorization task allowing involuntary memories to occur (also see Addis, Knapp, Roberts, & Schacter, 2011; Ramponi, Barnard, Kherif & Henson, 2011). In spite of this methodological diversity, none of the previous studies have predicted the occurrence of involuntary memories on the basis of manipulations done at encoding. Yet, such manipulation is necessary in order to understand the underlying mechanisms for their activation.

Here we take a first step toward an understanding of this complex question. We report findings from a series of experiments in which both the encoding and the retrieval phase of involuntary recollections are controlled, and in which we predict which memories are most likely to be involuntarily activated in the retrieval phase based on manipulations at the time of encoding. Across the studies, we show that when controlling for other factors, the activation of involuntary episodic memories is due to the combined effects of an encoding-retrieval match and the principle of cue overload (Tulving, 1979; Watkins & Watkins, 1975; Nairne, 2002).

Encoding Specificity and Cue Overload

Many theories invoke the notion of encoding specificity in order to explain the activation of involuntary episodic memories (e.g., Conway, 2005; Moscovitch, 1995; see Berntsen, 2009, for a review). According to this notion, the probability of successfully retrieving a memory increases by increasing overlap between the information present at retrieval (e.g., the cue) and the information stored in memory (e.g., Tulving, 1979).

Although intuitively meaningful, the adherence to the encoding-retrieval match leaves several questions of involuntary episodic memories unresolved. First, assuming that features in the retrieval context fit several past events equally well, why does one of these memories (but not the others) become activated? Second, explanations based on the encoding-retrieval match fail to explain why we are not constantly flooded by involuntary episodic memories. Any moment in our lives seems to include an almost endless number of potential memory cues in terms of features that were also part of our past experiences. When we dwell upon such features in an ongoing situation, we are able to voluntarily generate memories in response to many of them, as demonstrated in experiments conducted by Galton (1907) and replicated and extended by Berntsen and Hall (2004). Thus, if having involuntary autobiographical memories were simply contingent upon an encoding-retrieval match, it seems that we should be flooded by such memories throughout our waking life (Berntsen, 2009).

In order to resolve these issues, the encoding-specificity principle has to be supplemented by the principle of cue overload stating that “The probability of recalling an item declines with the number of items subsumed by its functional retrieval cue” (Watkins & Watkins, 1975, p. 442). In other words, the likelihood of a cue providing access to a given target memory depends on the extent to which this cue is uniquely

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associated with the target. Its strength declines to the extent it is associated with other memories as well (also see the related notion of fan effects described by Anderson, 1983). Thus, if you have had lemon mousse only at one occasion, this occasion is likely to be remembered if you have it again. However, if lemon mousse is a dessert that you have had on a regular basis, having it one more time is less likely to bring to mind a specific memory of any of the previous occasions. Or, to refer to the example in the beginning of the article, if you, as a runner, have had a severe side stitch only once in your past, this event is likely to come to mind the next time you have a side stitch while running. Obviously, the notion of cue-overload implies an informational overlap between the cue and the event, consistent with the encoding specificity principle. However, unlike the latter, it is the uniqueness, not the size, of this overlap that matters (for an excellent conceptual analysis of these problems, see Nairne, 2002).

Building upon both principles, Rubin (1995) introduces the notion of cue-item discriminability. He defines it as “how easily a given cue isolates an item. ... Simply put, a word is likely to be recalled if, on the basis of the cues available at the time, it can be discriminated from all else in memory” (p. 146). In the present context, the notion captures the important idea that in order to spontaneously activate an episodic memory, a cue is needed that is sufficiently distinct to discriminate a past event from alternatives through spreading activation in an associative network. Thus, the cue (or cues) has to be able to activate event-relevant units, or nodes, in the network, and deactivate irrelevant units that would otherwise interfere with the spontaneous construction of the memory. If not, the activation will be too indistinct to form a memory (Berntsen, 2009; Rubin, 1995). In part because such unique cue-item match between a current and a past event occurs

relatively rarely in daily life, we are not constantly flooded by involuntary memories of past events (Berntsen, 2009).

The notion of cue-item discriminability also suggests an explanation for key differences in the characteristics of involuntary and voluntary episodic memories. A number of studies (e.g., Berntsen, 1998; Berntsen & Hall, 2004; Berntsen & Jacobsen, 2008; Johannessen & Berntsen, 2010; Mace, 2006; Schlagman & Kvavilashvili, 2008) have shown that involuntary autobiographical memories more frequently than voluntary (word cued) memories refer to specific episodes – that is, events that took place on a specific day in the past, such as a particular run in the Botanical Garden (Williams, 1996, Williams et al., 2007). Compared to voluntary memories, they therefore refer less frequently to general event representations – that is, memory representations that, instead of representing a specific episode, extract common characteristics of many similar episodes, such as a general representation of going for a run. These differences in the frequency of general events are especially noteworthy, since studies on voluntary recall suggest that the retrieval of discrete episodes requires more effort than retrieving representations of general events (Williams, 1996; Dalgleish et al., 2007; Schlagman & Kvavilashvili, 2008).

However, the enhanced specificity of involuntary memories makes sense when we think of involuntary recall as an associative process governed by the principle of cue-item discriminability. Logically, this principle will favor past events with distinctive features, because such events can more easily be discriminated from alternatives through association. Distinctive features are more likely to be maintained in memories of specific events, whereas general event representations tend to abstract from them, due to the fact

that they focus on conceptual similarities across several events and thus represent a more semantic level of autobiographical knowledge (Conway & Pleydell-Pearce, 2000).

Compared to involuntary recall, representations of general events are more easily accessed through a top-down, voluntary search. Although a top-down search process benefits from cue-item discriminability, the retrieval process is also monitored through schema-based search descriptions.

Involuntary autobiographical memories are not just more specific than their voluntary counterparts. They have also been found to involve shorter retrieval time, when examined in a laboratory setting in response to verbal cues presented during a vigilance task (Schlagman & Kvavilashvili, 2008). The rapid and seemingly effortless retrieval may help to explain why involuntary (rather than voluntary) remembering is especially upsetting in emotional disorders. Because the memory comes to mind rapidly through associative mechanisms there is little room for antecedent emotion regulation (Gross, 2001) or other strategies, such as avoidance, directed at reducing the emotional impact of the recollection. This agrees with the fact that involuntary memories in daily life are accompanied by more emotional impact at the time of retrieval as compared to their voluntary counterparts (e.g., Berntsen & Hall, 2004).

From the Field to the Laboratory

The experiments presented here were designed to mimic the elicitation of involuntary autobiographical memories in real life, while at the same time controlling both encoding and retrieval. The principal aim of all of them was to demonstrate that it is possible to control the activation of involuntary episodic memories by systematically varying the level of cue-item discriminability. First, we use a paired-associate

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methodology because we know from naturalistic studies that involuntary memories usually have identifiable cues in the ongoing situation matching distinctive features of the memory (e.g., Berntsen, 1996, 1998) and because the paired-associate methodology allows us to independently manipulate the similarity between the cues as well as the similarity between the to-be-remembered targets (Crowder, 1976), which is essential in order to systematically vary the level of cue-item discriminability. Second, we use distinct environmental sounds as cues because we know from naturalistic studies that concrete external cues (e.g., objects, locations, sensory impressions) are more common as cues for involuntary memories than are internal states (e.g., thoughts and emotions) and that sounds are especially dominant among cues classified as sensory impressions (see Berntsen, 2009, for a review). Third, we use photographs of common, everyday scenes as memory material, because naturalistic studies have shown that visual imagery is central for autobiographical remembering and for the sense of reliving the past events (Rubin, 2006). Fourth, the content of everyday involuntary memories is relatively mundane in healthy adults. Only quite rarely do people involuntarily recollect highly emotional scenes, or events of central importance to their life story (Berntsen, 1996, 2001). We therefore use neutral or slightly positive scenes as memory material. Fifth, in the retrieval phase of the experiments, we use an attention-demanding sound location task as a cover task for eliciting involuntary memories. Asking people to record task-independent thoughts during a boring, but attention-demanding, parallel signal detection task is a well-established way of studying spontaneous thought processes (e.g., Giambra, 1989; Singer, 1966; Smallwood & Schooler, 2006). This methodology has also been successfully applied to involuntary autobiographical memories (Schlagman & Kvavilashvili, 2008). A

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robust finding from this type of research is that the frequency of spontaneous and task independent thoughts increases if the space between signal presentations in the signal detection task is increased and decreases when the space is diminished (for reviews, see Kane et al., 2007; Singer, 1966; Smallwood & Schooler, 2006). This is consistent with diary studies showing that involuntary memories most frequently arise when attention is diffuse, that is, during boring and/or non-attention demanding tasks (Berntsen, 1998, Berntsen & Jacobsen, 2008; Kvavilashvili & Mandler, 2004; Schlagman, Kvavilashvili & Schulz, 2007). When piloting the present studies, we therefore calibrated the difficulty of the parallel sound detection task so that it would allow spontaneous thoughts to occur while at the same time be sufficiently demanding to keep the subjects engaged in the task.

Overview of the Studies

Because we are here introducing a new paradigm, our design may appear complicated. As a useful analogy, imagine a runner, who on his or her run encounters a number of visual scenes paired with auditory impressions of which many are instances of the same repeated categories (e.g., trees and bird songs) and a few are unique (e.g., a dog and the sound of it barking). Occasionally a unique sound (e.g., the sound of a chain saw) may occur together with a repeated visual scene (e.g., a tree). At other occasions, a repeated sound (e.g., bird songs) occurs together with a unique visual scene (e.g., a person on a bike). The next day, the same person goes running again. In addition to new sounds, the runner encounters the same sounds as he or she paid attention to the day before (e.g., sounds of birds, a dog barking, and the chain saw). Which of these sounds (if any) will involuntarily bring back memories from the first run?

The experiments all have an encoding phase and a retrieval phase. The encoding phase is the same for all participants. The retrieval phase is conducted in either an involuntary or voluntary (between subjects) condition. In the encoding phase, the participants are presented with sounds that are either repeated (i.e., derive from the same category) or unique (i.e., derive from a non-repeated category) coupled with pictures of scenes that are either repeated (i.e., derive from the same category) or unique (i.e., derive from a non-repeated category). This 2 (unique versus repeated sounds) x 2 (unique versus repeated pictures) manipulation yields four systematically varied levels of cue-item discriminability for subsequent involuntary versus voluntary recall, where the previously presented sounds are used as memory cues. Table 1 illustrates the four encoding conditions used in Studies 1 to 3 with the corresponding predictions in each cell for the likelihood of involuntary memories during a subsequent retrieval phase (see also Figure 1).

The predictions presented in Table 1 for the involuntary memories follow basic principles of association, notably the principle of cue-overload. These predictions are largely consistent with predictions formulated by Berntsen (2009) for the activations of involuntary autobiographical memories in daily life. They are also consistent with basic principles of paired-associate learning (e.g., see Bower, 2000, Cowder, 1976, for reviews) as well as classical conditioning (e.g., Rescorla & Hollin, 1982).

The two unique-cue conditions will have an advantage because they both represent a situation with no cue-overload (Watkins & Watkins, 1975) in that a cue (of a particular category) is coupled with only one type of scenes. This advantage will be reduced in the UniqueCue-RepeatedScene condition, because the target scene derives

from a category (e.g., trees) that is repeatedly associated with another type of cue. This reduced probability of involuntary memories in the UniqueCue-RepeatedScene condition may be seen as analogous with the situation of blocking in associative learning – that is, a novel stimulus will not lead to a conditioned response if this conditioned response has already been associated with another (conditioned) stimulus (Rescorla & Hollin, 1982). In our example, a unique sound cue (e.g., the sound of a chain saw presented only once) will be a weaker cue for the target scene (e.g., a tree in a wood) because this type of scene has been repeatedly associated with another type of sound stimuli (e.g., bird songs).

Further, the two repeated cue-conditions will both be less likely to lead to involuntary memories compared to the two unique cue conditions, because they both represent a situation with cue-overload. In the RepeatedCue-RepeatedScene condition many instances of the same type of sound cue (e.g., bird songs) are coupled with many instances of the same type of scene (e.g., a tree in a wood). Hearing the sound cues again during the sound location task is therefore unlikely to trigger involuntary memories of concrete scenes, but may lead to vague, overgeneral representations of the repeated scene category, analogous to overgeneral retrievals in the autobiographical memory literature (e.g., Williams, 1996; Williams et al., 2007). The RepeatedCue-UniqueScene condition is a case of cue overload in that the sound cue (e.g., bird songs) is repeatedly associated with several other scenes, in addition to the target (e.g., a deer). This condition is therefore unlikely to lead to involuntary memories.

The voluntary memories will to some extent be affected by the same associative mechanisms but we expect the effects to be reduced, because the outcomes of voluntary retrieval, in addition to basic associative principles, also reflect the effects of a goal-

directed and top-down search monitored by search descriptions. Overall, we therefore expect a greater proportion of the cues in the voluntary condition to be followed by memories. This is expected for all four conditions in Table 1, but is expected to be especially pronounced for the RepeatedCue-RepeatedScene condition, which would correspond to the larger number of overgeneral memories in voluntary as compared to involuntary recall in naturalistic studies (Berntsen, 2009, for a review).

Finally, we include a recognition task in Studies 1 and 2 in order to demonstrate that the effects observed during involuntary and voluntary recall reflect the accessibility of the encoded target events in response to different cues, and not their availability *per se* (Tulving, 1966). Thus, we expect the majority of the targets in all conditions to be successfully discriminated from foils in a subsequent recognition task. However, this effect is likely to be stronger for pictures of unique (non-repeated) scenes, due to interference effects for the pictures repeating the same category of scenes (Anderson, 1983; Hunt & Worthen, 2006).

Study 1

Method

Participants

A total of 32 participants (28 female, 4 male, mean age 23.19 years, range 19 -44) were recruited through undergraduate courses at the Department of Psychology, Aarhus University.

Design

The experiment consisted of three phases: An encoding phase, a retrieval phase, and a recognition phase; with the retrieval phase to be completed in either a voluntary or

an involuntary format. In the encoding phase, participants were presented with pictures of scenes paired with sounds. Both picture and sound could be either unique (derived from a category that is presented only once) or repeated (derived from a category that was presented several times). This created four types of study trials: one where both sound cue and visual scene were unique (UniqueCue-UniqueScene trials); one where sound cue was unique and scene was repeated (UniqueCue-RepeatedScene trials); one where sound cue was repeated and scene was unique (RepeatedCue-UniqueScene trials); and finally one where both sound and scene were repeated (RepeatedCue-RepeatedScene trials).

Figure 1 shows examples of each type of study trial.

Participants were randomly assigned to one of four versions of the task. In one version, different pictures of trees and different sound clips of bird songs were the repeated stimuli, while pictures of a dog, a car, and a street with their respective sounds were the unique stimuli. In the second version, a street, a car, and trees (and their respective sounds), acted as the unique stimuli while dogs (with their sounds) were the repeated stimuli. In the third and fourth versions, streets and cars were the repeated stimuli, respectively (see Appendix A for an overview). This randomization was employed to control for the content of the pictures and sounds so that only their unique or repeated characteristic would influence the results.

Participants were also randomly assigned to either the involuntary or the voluntary condition. Only the retrieval phase would differ between the two conditions (see *Procedure* below).

Materials

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All phases of the experiment were programmed and run using E-prime 2.0 (Psychology Software Tools, Inc.). Pictures were taken from various sources on the internet and carefully selected to resemble each other (e.g., the dogs were mostly of larger breeds and seen mostly in profile). All pictures were resized to 675x506 pixels. Sounds were a combination of royalty free sound files from the internet as well as from a large library of sounds. All sounds were normalized and additional versions were created of each sound by panning it 75 % to the left and right respectively. All trials were run on a computer with a 19" LCD-monitor set at 1280x1024 resolution, and with an attached serial response box (Psychology Software Tools, Inc.) and headphones. Finally, a questionnaire was constructed to be used in the retrieval phase. It consisted of a space to put in a few keywords in order to describe the scene that came to mind. Below were two questions asking about the clarity and specificity of the image to be rated on 5-point scales. The questionnaire was identical in the involuntary and voluntary conditions.

Procedure

Upon arrival, participants were seated in front of a PC-monitor with headphones and a response box in front of them. Participants were given instructions that were neutral about the task (i.e., "you will now be presented with a number of trials featuring some sounds and some pictures. Please pay close attention to both sounds and pictures"). During the encoding phase, all participants were presented with 40 trials, which consisted of fixed-order picture-sound pairs (in one of the four different versions). Each pair would be presented simultaneously for four seconds, with the picture shown centrally on the monitor and the sound played back to both ears (i.e., centered). The duration of the sounds was four seconds, except for a few (0-3 in each of the four versions) which had a

shorter duration in order to preserve their natural appearance (i.e., the sound of slamming a car door). Twenty-eight of the trials were RepeatedCue-RepeatedScene, four were RepeatedCue-UniqueScene, four UniqueCue-RepeatedScene, and four UniqueCue-UniqueScene. Following each trial, participants rated how exciting the picture was to them on a 5-point scale, 1 being “not at all exciting” and 5 being “very exciting”.

In the retrieval phase, the participants in the involuntary condition completed 128 trials, each consisting of a sound presented either in the left or the right ear, and a bright yellow star presented in either the left or the right side of the screen. The star would be presented 1.5 seconds after the initiation of the sound clip. The sounds were played for the same duration as during encoding or until the participants pressed a button in response to the task. Participants were told to press “1” when the star and the sound were in the same spatial location (e.g., to the right) and “2” if they were in opposite locations. At the same time, they were told to press “3” if they experienced an image of a scene spontaneously appearing in their mind. It was not specified in advance whether the scene should be one previously seen. If participants asked for clarification, they were told, “any image that enters your mind in response to a sound”. Pressing “3” would halt the experiment, giving participants time to fill out the questionnaire, after which they would proceed with the next trial. To prevent a protracted retrieval phase for the involuntary as compared to the voluntary condition, a maximum of 15 images could be recorded in the involuntary condition. If this maximum was reached, the participant would complete the rest of the retrieval phase without recording further memories. Three participants recorded more than 15 memories.

Sixty-four of the 128 sounds were familiar (the same ones as in the encoding phase) and 64 were unfamiliar. Of the 64 familiar sounds, 8 derived from the Unique Cue-UniqueScene, 8 from the uniqueCue-RepeatedScene, and 8 from the RepeatedCue-UniqueScene encoding trials (i.e., the 4 sounds during encoding presented twice, once to each ear). Finally, 40 sounds derived from the RepeatedCue-RepeatedScene encoding trials (i.e., 20 sounds from encoding presented twice, once to each ear).¹ Unfamiliar sounds consisted of 24 repeated sounds (rainfall) and 8 unique sounds (including animal and human sounds) presented once to each ear.

Participants assigned to the voluntary condition would hear 16 familiar sounds (4 from each of the four encoding conditions) presented with the fixation cross. After each sound they were prompted by a screen message to try to remember a scene from the encoding phase to go with that sound and fill out the questionnaire accordingly.

Finally, after completing the retrieval phase, all participants completed a recognition task. This task was the same for all participants. The participants saw 16 trials (4 pictures from each Cue-Scene condition) each one consisting of two scene pictures side by side. One picture was from the encoding phase, while the other was an unfamiliar picture matched closely for content and overall similarity. Participants were asked to indicate the familiar picture with a button press and then rate on a 5-point scale how confident they were that their response was correct.

Upon completion of the three phases, participants were debriefed and given a gift worth approximately 180 DKK (\$32).

Coding

The keyword descriptions written by the participants in response to the sounds that generated memories in the retrieval phase were coded for their correspondence to the scenes presented during encoding. If one or more words described a central component of the relevant scene, it was coded as correct. If the keyword phrases referred to a scene that had been presented together with a different sound during encoding, it was coded as incorrect. If a keyword description contained no clear reference to a picture presented during encoding (but instead, for example, appeared to be autobiographical) it was coded as “other”.²

Thus, following these criteria, we did not expect the participants to correctly remember which of the 28 repeated types of scenes [e.g., trees] they had seen in response to which of the 28 repeated types of sounds [e.g., bird songs], as long as they were able to correctly describe the central component of the scene. A less lenient criterion would have defeated the purpose of the design, since we expected, and found, a markedly reduced level of specificity and recognition accuracy for the repeated scenes (see *Results*).

In the voluntary condition some of the participants recorded more than four repeated scenes in response to the eight repeated cues (because they recorded repeated scenes in stead of unique scenes to the repeated cues). Following the coding criterion that we did not expect the participants to remember exactly which of the repeated scenes (e.g., trees) they had seen together with which of the repeated sounds (e.g., bird songs) these were not coded as errors but were left out of the calculation of percentages in the RepeatedCue-RepeatedScene condition in order not to artificially boost this category. If they were included, and the frequencies consequently normalized by eight instead of by four, the same frequency results as the ones reported above were obtained.³

Two judges independently coded 20% of the keyword phrases and agreed in 96% of the cases (interclass correlation = .91). The remaining keyword phrases were coded by one judge.

Results

We first present the frequencies of involuntary and voluntary memories in the four Cue-Scene conditions. We next analyze the ratings of clarity and specificity of the recalled scenes as a function of Cue-Scene condition and voluntary versus involuntary retrieval. Finally, we present the findings from the recognition test.

The Frequencies of Involuntary and Voluntary Memories as a Function of Cue-Scene Condition

We calculated the relative frequencies (percentages) of memories in each condition by dividing the raw frequencies of memories coded as correct by the number of possible memories (i.e., cues) in each condition (the same method was used in the following studies)⁴. The percentages of involuntary and voluntary memories in the four Cue-Scene conditions are illustrated by Figure 2.

We conducted a 2 (Retrieval: involuntary vs. voluntary) x 2 (Cue: unique versus repeated) x 2 (Scene: unique versus repeated) Analysis of Variance (ANOVA) based on these frequencies calculated for each participant. Cue and Scene were within subjects factors each with two levels. Retrieval was a grouping variable. A main effect was found for involuntary versus voluntary retrieval ($F(1,30)=82.65, p<.0001, \eta_p^2=.73$) for unique versus repeated cues ($F(1,30)=137.11, p<.0001, \eta_p^2=.82$) but not for unique versus repeated scenes ($p>.1$). There was no interaction between cues and retrieval. However, the characteristics of the scenes interacted with involuntary versus voluntary retrieval

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($F(1,30)=28.80, p<.0001, \eta_p^2=.49$) reflecting more repeated scenes in the voluntary than the involuntary condition. There was an interaction between the characteristics of the cues and the characteristics of the scenes ($F(1,30)=159.43, p<.0001, \eta_p^2=.84$), reflecting that the advantage of the unique cues and disadvantage of repeated cues was greater for the unique scenes than for the repeated scenes. Finally, there was a three way interaction reflecting that the cue x scene interaction was more pronounced for voluntary than for involuntary retrieval ($F(1,30)=24.25, p<.0001, \eta_p^2=.44$).

Consistent with our predictions, the UniqueCue-UniqueScene condition yielded most involuntary memories (57.03 % of the cues triggered a memory of a scene, $M=4.56$), followed by the UniqueCue-RepeatedScene (with a 28.13 % retrieval rate, $M=2.25$). The RepeatedCue-RepeatedScene and the RepeatedCue-UniqueScene conditions led to very few involuntary memories (4.01 %, $M=1.56$, and 0.0%, respectively; ($F(3,45)=51.46, p<.0001, \eta_p^2=.77$). Tukey HSD post hoc tests showed that both of the two conditions with unique cues differed significantly from both of the two conditions with repeated cues ($ps<.0001$), whereas the latter did not differ from one another ($p >.8$). These findings follow what would be expected based on the notion of cue overload. In addition, the UniqueCue-UniqueScene differed significantly from the UniqueCue-RepeatedScene condition ($p<.001$).

As also predicted, compared to the involuntary condition, the voluntary retrieval condition generally led to more memories overall. Thus, not surprisingly, a deliberate effort at retrieval is overall more effective than unplanned, involuntary associations. The advantage of the voluntary condition was significant for three of the four Cue-Scene

conditions (all $p < .05$ in Tukey HSD post hoc tests). The RepeatedCue-UniqueScene condition formed an exception in which the relative frequency of voluntary retrieval did not differ significantly from the involuntary counterpart ($p > .8$ in a Tukey HSD post hoc test). A 2 (Retrieval: involuntary vs. voluntary) x 3 (Cue-Scene condition) ANOVA with the RepeatedCue-UniqueScene condition removed showed a significant interaction ($F(2,60) = 5.97, p < .01, \eta_p^2 = .17$), reflecting that the advantage of the voluntary condition was larger for the RepeatedCue-RepeatedScene condition relative to the other two conditions. This relative advantage of the RepeatedCue-RepeatedScene condition in voluntary recall is consistent with the observation of more overgeneral memories among voluntary (word cued) memories as compared to involuntary memories in naturalistic studies (e.g., Berntsen & Hall, 2004). Even if the comparison of the two retrieval conditions was based on the raw frequencies of memories in the RepeatedCue-RepeatedScene condition, a clear advantage of the voluntary condition was seen ($M = 2.94, SD = 1.39$) relative to the involuntary condition ($M = 1.56, SD = 2.00; t(30) = 2.26, p < 0.05$), in spite of the fact that there were ten times more RepeatedCue-RepeatedScene potential retrieval trials in the involuntary than in the voluntary condition (40 versus 4, respectively).

Analyses of errors

Errors consisted of memories coded as incorrect (i.e., scenes retrieved in response to a sound that had been presented with a different scene at encoding) and memories coded as others (i.e., did not refer to a scene seen during encoding). Table 2 shows the distribution of errors for involuntary and voluntary retrieval across the conditions. More

errors were found for involuntary than voluntary retrieval ($t(30)=2.06, p<.05$), whereas there was no significant effect of Cue-Scene condition.

Ratings of Clarity and Specificity

Because very few participants recorded involuntary memories in the two RepeatedCue-conditions, it only made sense to compare ratings of clarity and specificity across the two remaining Cue-Scene conditions. We therefore conducted a 2 (involuntary vs. voluntary) x 2 (UniqueCue-UniqueScene vs UniqueCue-RepeatedScene) ANOVA for each of the two variables (based on means calculated for each participant). The results are shown in Table 3. For both specificity and clarity ratings a main effect was seen for the UniqueCue-UniqueScene vs UniqueCue-RepeatedScene distinction, reflecting markedly higher scores in the unique scene condition as compared to the repeated scene condition, see Table 3. No other significant effects were found.

With one exception, all participants in the voluntary condition (unlike the involuntary condition) had recorded memories also in the RepeatedCue-RepeatedScene condition. Therefore it made sense to compare level of clarity and specificity across all three conditions in the voluntary group only. Repeated measures ANOVA with three levels (UniqueCue-UniqueScene; UniqueCue-RepeatedScene; RepeatedCue-RepeatedScene) yielded significant effects for both clarity ($F(2,28) = 28.88, p<.0001, \eta_p^2 = 0.67$) and specificity ($F(2,28) = 40.89, p<.0001, \eta_p^2 = 0.74$). Tukey posthoc analyses showed that for clarity, the UniqueCue-UniqueScene was higher than the other two conditions ($ps<.0001$), which did not differ from one another ($ps>.6$). For specificity, all three conditions differed from one another ($ps<.05$), with the UniqueCue-

UniqueScene showing the highest level of specificity and the RepeatedCue-

RepeatedScene showing the lowest level.

Recognition

The means from the recognition task are presented in Table 4. The main finding was a clear advantage of the two unique scene conditions over the two repeated scene conditions. A 2 (Retrieval: involuntary vs. voluntary) x 2 (Cue: unique versus repeated) x 2 (Scene: unique versus repeated) yielded a significant main effect of Scene for *Accuracy* ($F(1,30)=24.45, p<.0001, \eta_p^2 = 0.45$), *Confidence* ($F(1,30)=119.18, p<.0001, \eta_p^2 = 0.80$) and *Reaction time* ($F(1,30)=66.19, p<.0001, \eta_p^2 = 0.69$). For all three variables this effect reflected a significant advantage of the two unique scene conditions over the repeated ones (all $ps<.05$). No main effects were seen of the preceding allocation to involuntary versus voluntary retrieval (all $ps>.3$). A main effect of Cue was seen for *Confidence* ($F(1,30)=37.36, p<.0001, \eta_p^2 = 0.55$) reflecting higher confidence ratings for scenes that had previously been associated with repeated cued. This effect was qualified by a Cue x Retrieval interaction ($F(1,30)=18.42, p<.001, \eta_p^2 = 0.38$), as well as by a Cue x Scene interaction ($F(1,30)=31.44, p<.001, \eta_p^2 = 0.51$). For *Reaction time*, a significant Cue x Retrieval interaction was seen ($F(1,30)=5.94, p<.05, \eta_p^2 = 0.317$).

Summary and Discussion

The most important finding from Study 1 was the demonstration that it is possible to systematically manipulate and predict the activation of involuntary episodic memories, on the basis of well-known mechanisms of associative memory. This new experimental paradigm is an important break-through in the research on involuntary episodic

memories, because it allows for much more controlled investigations of this intriguing phenomenon than what has been possible in the past.

Overall the findings showed that both types of recall were enhanced in conditions with unique relative to repeated cues. At a more detailed level, Study 1 showed that involuntary and voluntary recall were both enhanced in the UniqueCue-UniqueScene condition and dramatically reduced in the RepeatedCue-UniqueScene condition. The UniqueCue-RepeatedScene condition yielded an intermediate retrieval rate, consistent with the notion of blocking: although the cue was unique, the target scene had been repeatedly associated with another type of sound cue, thus reducing the effect of the unique cue. Also, the remembered scenes in this condition were rated less clear and less specific than the remembered scenes in the UniqueCue-UniqueScene condition, presumably due to the fact that the former scenes belonged to a category of scenes that had been repeated during encoding.

The two retrieval conditions differed with regard to the RepeatedCue-RepeatedScene condition. Here the voluntary condition yielded a high retrieval rate, while few memories were recorded in the involuntary condition. Further analyses showed that the memories in the RepeatedCue-RepeatedScene condition as expected were rated lower on specificity than memories in any of the other Cue-Scene conditions. This makes them comparable to the overgeneral memories reported in the autobiographical memory literature, which likewise have been found to be more frequent for voluntary than for involuntary autobiographical recall (e.g., Berntsen & Hall, 2004; Schlagman & Kvavilashvili, 2008). This is most likely due to a schema-driven, top-down search

strategy favoring such non-episodic information relative to what is the case for involuntary, associative recall (Berntsen, 2009, 2010).

Findings from the recognition test indicate that the systematic effects of Cue-Scene conditions in the retrieval phase reflected the accessibility of the target scenes, given the cues, and not the availability of the memories *per se* (Tulving, 1966). It is especially noteworthy that the RepeatedCue-UniqueScene condition that yielded no involuntary recollections and very few voluntary ones, nonetheless showed near-perfect recognition rates, with accuracy, reaction times and confidence ratings at the same level as the UniqueCue-UniqueScene condition. Further, consistent with the low subjective ratings of clarity and specificity for the repeated scenes in the recall phase, the repeated scenes were recognized less accurately, with less confidence and with longer latencies than the unique scenes.

In summary, the main findings can be described in terms of two theoretical notions. First we found more memories in response to unique than repeated cues, which is consistent with the notion of cue overload. Second, more voluntary memories were recorded in response to repeated cues coupled with repeated scenes. Because these memories were rated lower on specificity and clarity and were less well recognized than the unique scenes, they are comparable to overgeneral (non-specific) memories as observed in naturalistic studies.

In Study 1, participants in the voluntary condition were reminded after each sound cue that they were to retrieve a memory, whereas the sounds were played continuously in the involuntary condition. This explicit instruction in the voluntary condition served to ensure that the voluntary memories clearly reflected a goal-directed and planned search.

However, at the same time, this procedural difference between the two conditions rendered comparisons of retrieval times meaningless. In order to address this issue, Study 2 was conducted.

Study 2

Study 2 was undertaken to examine if the findings from Study 1 would replicate, when the sound cues for the voluntary retrieval task were presented continuously (i.e., with no intermediate retrieval instruction after each sound) as in the involuntary condition. This allowed us to obtain comparable retrieval time measures for each condition. Based on the claim that involuntary retrieval requires little executive functions as compared to voluntary retrieval, we should expect shorter retrieval times in the former as compared to the latter condition. This would be consistent with findings on involuntary versus voluntary autobiographical memories elicited in response to verbal cues in a laboratory setting (Schlagman & Kvavilashvili, 2008), while at the same time (unlike previous work) keeping the nature of the cueing constant between the two retrieval conditions.

Method

Participants

A total of 40 participants (8 male, 32 female, mean age 21.78 years, range 19-30) were recruited through undergraduate courses at the Department of Psychology, Aarhus University.

Design, Material, and Procedure

The design, material and procedure were similar to Study 1, except that participants in the voluntary condition were not given onscreen prompts to retrieve a memory. Instead they were asked to press 1 if they recalled a picture to a sound, or 2, if

they were unable to recall a picture. Pressing 1 would pause the task, giving them time to fill out the questionnaire. Also, the maximum possible images to be recorded in the involuntary condition were increased to 16 so that it would be the same maximum number as in the voluntary condition. Five participants had more than 16 involuntary memories.

In the involuntary condition, the 1.5 second delay between the onset of the sound cue and the onset of the visual target (the star) was added to each participant's retrieval time. In the voluntary condition, retrieval time was measured simply from the onset of the sound cue. Also, in the voluntary condition, a few participants would forget to indicate having had a memory before recording it in the questionnaire. This would artificially increase their retrieval times. Such mistakes could be readily identified in the data output file and were removed prior to analysis (4.5% of the total number of memories recorded). The key word phrases recorded by the participants were coded in the same way as in Experiment 1 (interrater agreement = 97% ; intraclass correlation = .90).

Results

The findings from Study 2 replicated the findings from Study 1. We first present findings regarding frequencies of involuntary and voluntary memories in the four Cue-Scene conditions, then findings on retrieval time and subjective ratings of clarity and specificity. Finally, we present findings from the recognition task.

Frequencies of Involuntary and Voluntary Memories as a Function of Cue-Scene conditions

The percentages of involuntary and voluntary memories in the four Cue-Scene conditions were calculated as in Study 1 and are illustrated by Figure 3. We conducted a

2 (Retrieval: involuntary vs. voluntary) x 2 (Cues: unique versus repeated) x 2 (Scenes: unique versus repeated) ANOVA with these frequencies as the dependent variable. As in Study 1, the analysis showed a main effect for involuntary versus voluntary retrieval ($F(1,38)=84.29, p<.0001, \eta_p^2=.69$) and for unique versus repeated cues ($F(1,38)=87.30, p<.0001, \eta_p^2=.70$). A modest (but significant) main effect for unique versus repeated scenes was also found ($F(1,38)=5.37, p<.05, \eta_p^2=.12$). There was no interaction between cues and retrieval. However, as in Study 1, the characteristics of the scenes interacted with involuntary versus voluntary retrieval ($F(1,38)=24.06, p<.0001, \eta_p^2=.39$) reflecting more repeated scenes in the voluntary than the involuntary condition. There was an interaction between the unique versus repeated characteristics of the cues and the unique versus repeated characteristics of the scenes ($F(1,38)=78.59, p<.0001, \eta_p^2=.67$), again reflecting that the advantage of the unique cues and disadvantage of repeated cues was greater for the unique scenes than for the repeated scenes. Finally, there was a three way interaction reflecting that the cue x scene interaction was more pronounced for voluntary than for involuntary retrieval ($F(1,38)=24.77, p<.0001, \eta_p^2=.39$).

Consistent with Study 1, the UniqueCue-UniqueScene condition yielded most involuntary memories (53.75 % of the cues triggered a memory, $M=4.30$). The UniqueCue-RepeatedScene condition showed an intermediate position (with a 33.75 % retrieval rate; $M=2.70$), whereas the RepeatedCue-RepeatedScene and the RepeatedCue-UniqueScene conditions led to few involuntary memories (4.50% and 0.63%, respectively; $M=1.80$ and $M=0.05$, respectively). The means were also numerically quite similar to Study 1 (cf. Figures 2 and 3; $F(3,57)=43.54, p<.0001, \eta_p^2=.70$). As in Study 1,

and consistent with the notion of cue overload, Tukey HSD post hoc tests showed that both of the two conditions with unique cues differed significantly from both of the two conditions with repeated cues ($p < .001$), whereas the latter did not differ from one another ($p > .8$). In addition, the UniqueCue-UniqueScene differed significantly from the UniqueCue-RepeatedScene condition ($p < .01$).

Compared to the involuntary condition, the voluntary retrieval condition yielded more memories in all cue-scene conditions (all $p < .01$ in Tukey HSD post hoc tests), again with the exception of the RepeatedCue-UniqueScene condition ($p > .9$ in a Tukey HSD post hoc test), which was at the bottom for both conditions. However, this condition was only significantly lower than the RepeatedCue-RepeatedScene condition for voluntary retrieval ($p < .001$). This relative advantage of the RepeatedCue-RepeatedScene condition in voluntary recall also replicated findings in Study 1. As in Study 1, a 2 (Retrieval: involuntary vs. voluntary) x 3 (Cue-Scene condition) ANOVA with the RepeatedCue-UniqueScene condition removed showed a significant interaction ($F(2,76) = 5.95, p < .01, \eta_p^2 = .14$), reflecting that the advantage of the voluntary condition was larger for the RepeatedCue-RepeatedScene condition relative to the other two conditions.

Analyses of errors

As shown in Table 2, the cases with errors are mostly found in the UniqueCue-RepeatedScene for both voluntary and involuntary retrieval. A 2 (involuntary vs. voluntary) x 2 (UniqueCue-UniqueScene vs. UniqueCue-RepeatedScene) mixed ANOVA on the mean percentage of errors, showed a significant effect of unique vs. repeated cues ($F(1,36) = 9.62, p < .01$) and no effects of retrieval.

Retrieval Times and Ratings of Clarity and Specificity

Because of the few involuntary memory records in the two repeated cue conditions, the analyses for clarity, specificity and retrieval times are based on the records in the two unique cue conditions (UniqueCue-UniqueScene; UniqueCue-RepeatedScene). A series of 2 (involuntary vs. voluntary) x 2 (UniqueCue-UniqueScene vs. UniqueCue-RepeatedScene) mixed ANOVAs were conducted with clarity, specificity and retrieval time as the dependent variables. The results are presented in Table 3. For retrieval time, significant effects were seen for both the between and within subjects factors. This reflected shorter retrieval times in the involuntary compared to the voluntary condition, and in the UniqueCue-UniqueScene compared to the UniqueCue-RepeatedScene condition (see Table 3). For both specificity and clarity ratings, a main effect was seen for the UniqueCue-UniqueScene vs. UniqueCue-RepeatedScene distinction, which reflected markedly higher scores in the unique scene condition as compared to the repeated scene condition.

With the exception of three participants, all participants in the voluntary condition recorded memories in three Cue-Scene conditions (UniqueCue-UniqueScene; UniqueCue-RepeatedScene; RepeatedCue-RepeatedScene). It therefore was meaningful to compare level of clarity, specificity and retrieval time across these three conditions in the voluntary group only. We thus conducted a series of repeated measures ANOVAs with three levels (corresponding to the three Cue-Scene conditions) and with level of clarity, specificity and retrieval time as dependent variables. A significant effect was obtained for both clarity ($F(2,32) = 17.04, p < .0001, \eta_p^2 = 0.52$) and specificity ($F(2,32) = 26.98, p < .0001, \eta_p^2 = 0.63$), but not for retrieval time ($p > .06$). Tukey post hoc

analyses showed that for clarity, the UniqueCue-UniqueScene differed from the other two conditions ($ps < .001$), which did not differ from one another ($ps > .7$). For specificity all three conditions differed from one another ($ps < .05$), with the UniqueCue-UniqueScene showing the highest level of specificity and the RepeatedCue-RepeatedScene showing the lowest level. These findings are similar to Study 1.

Recognition

Results from the recognition task are presented in Table 4.

2 (Retrieval: involuntary vs. voluntary) x 2 (Cue: unique versus repeated) x 2 (Scene: unique versus repeated) yielded a significant main effect of Scene for *Accuracy* ($F(1,38)=22.52, p < .0001, \eta_p^2 = 0.37$), *Confidence* ($F(1,38)=110.46, p < .0001, \eta_p^2 = 0.74$) and *Reaction time* ($F(1,38)=56.99, p < .0001, \eta_p^2 = 0.60$). For all three variables this effect reflected a significant advantage of the unique scene conditions over the repeated ones. No other significant effects were observed for the variables *Accuracy* and *Reaction Time*. The group who had conducted voluntary retrieval in the preceding retrieval task had higher *Confidence* ratings in the recognition task ($F(1,38)=5.32, p < .05, \eta_p^2 = 0.26$). A main effect of Cue was seen only for *Confidence* ($F(1,38)=13.49, p < .001, \eta_p^2 = 0.26$) reflecting higher confidence ratings for scenes that had previously been associated with repeated cues. This effect was qualified by a Cue x Scene interaction ($F(1,30)=31.44, p < .001, \eta_p^2 = 0.51$) reflecting that this advantage was greater for repeated scenes. In short, as in Study 1, the main finding of the recognition task was a clear advantage of the two unique scene conditions over the two repeated scene conditions, although *Confidence* ratings showed a more complex picture

Summary and Discussion

In Study 2 we changed the procedure for the recording of the voluntary memories to be similar to the recording of the involuntary memories, which enabled us to obtain comparable measures of retrieval time in the two conditions. In spite of these changes, Study 2 formed a close replication of Study 1. This shows that our new procedure for manipulating and predicting the retrieval of involuntary episodic memories yields robust results.

Study 2 extended findings from Study 1 by showing significantly shorter retrieval times for involuntary than for voluntary memories. This supports the thesis that involuntary recollection is an automatic process involving little executive control as compared to voluntary recall. We also found a main effect for cueing. This reflected shorter retrieval times in the UniqueCue-UniqueScene condition as compared to the UniqueCue-RepeatedScene condition, suggesting easier access to the former than to the latter, irrespective of retrieval form.

Findings on the recognition task also replicated the main findings from Study 1 by showing an advantage of the two unique scene conditions. The fact that voluntary recall and repeated cues were associated with enhanced confidence ratings in the subsequent recognition task, may reflect effects of rehearsal.

Although Studies 1 and 2 yielded highly consistent results, it might be objected that the key difference between the involuntary versus voluntary retrieval in these experiments had to do with a competing task (i.e., the sound location task) being carried out in the involuntary condition but not in the voluntary condition. As a consequence, voluntary recall accessed more memories overall and in particular in the RepeatedCue-

RepeatedScene condition. The reason would simply be, following this explanation, that more cognitive resources were available in the voluntary condition because there was no competing task. This objection agrees poorly with the fact that retrieval times were lower in the involuntary condition, suggesting that, rather than being easier, the voluntary recall task was in fact more cognitively demanding. It should also be noted that in real life situations, as examined in diary studies, people typically have involuntary memories while they are doing other things, whereas voluntary recall is studied by asking people to search for a memory in a goal-directed manner, for example in response to cue words (Berntsen, 2009, for a review). Thus, the paradigm used in Studies 1 and 2 matches previous naturalistic work. Nonetheless, in Study 3 we included a parallel task in the voluntary condition in order to rule out this possible, alternative explanation.

Study 3

Methods

Participants

A total of 32 participants (14 male, 18 female, mean age 25.69 years, range 19-33) were recruited through advertisements at Aarhus University.

Design, Material, and Procedure

The design, material, and procedure were overall similar to the ones employed in Study 2, but differed in the following three ways. First, the voluntary condition also included a parallel attention task that was identical to the sound location task in the involuntary condition. To reiterate, the task was to compare the location of the sound cue (left or right ear) to the location of a bright star positioned left or right on the monitor. Participants were asked to press “1” if sound and star were in the same location and “2” if

they were in opposite locations. At the same time, participants in the voluntary condition were told to retrieve the scene corresponding to the sound. In order to render the voluntary condition analogous to the involuntary condition, the instruction was simply to retrieve the relevant memory while doing the sound location task. When they retrieved a memory of a scene, they were asked to press “3”, or alternatively press “4”, if they were unable to retrieve a scene. Pressing “3” would pause the task, giving them time to fill out the questionnaire. Second, the possible amount of memories that participants could record in the involuntary condition was doubled to 32 (one participant recorded more than 32 involuntary memories). We did so to make sure that the limits used in the previous two studies had not artificially reduced the number of recorded involuntary memories. However, this adjustment did not increase the frequency. Third, retrieval time was measured from the onset of the sound cue in both conditions, thus allowing participants to retrieve memories within the first 1500 milliseconds from the onset of the sound cue. This adjustment did not affect the results, since very few memories were retrieved within 1500 milliseconds.

The key word phrases recorded by the participants in response to the memories were coded in the same way as in Experiment 1 (interrater agreement = 98% ; intraclass correlation = .96). Finally, to simplify, the recognition phase of Studies 1 and 2 was omitted from Study 3 because it was not relevant to the focus of the experiment.

Results

The percentages of involuntary and voluntary memories in the four Cue-Scene conditions are illustrated by Figure 4. As in the previous studies, we conducted a 2 (Retrieval: involuntary vs. voluntary) x 2 (Cues: unique versus repeated) x 2 (Scenes:

unique versus repeated) ANOVA based on these frequencies, again showing a main effect for involuntary versus voluntary retrieval ($F(1,30)=39.03, p<.0001, \eta_p^2=.73$) for unique versus repeated cues ($F(1,30)=148.66, p<.0001, \eta_p^2=.83$) but not for unique versus repeated scenes ($p>.3$). Again, there was no interaction between cues and retrieval, but characteristics of the scenes interacted with involuntary versus voluntary retrieval ($F(1,30)=11.82, p<.01, \eta_p^2=.28$) reflecting more repeated scenes in the voluntary than the involuntary condition. There was an interaction between the characteristics of the cues and the characteristics of the scenes ($F(1,30)=220.09, p<.0001, \eta_p^2=.88$), reflecting that the disadvantage of repeated cues and advantage of the unique cues was considerably greater for the unique scenes than for the repeated scenes. Finally, there was a three way interaction reflecting that the cue x scene interaction was more pronounced for voluntary than for involuntary retrieval ($F(1,30)=57.70, p<.0001, \eta_p^2=.68$).

As Figure 4 illustrates, the distribution of the involuntary memories across the four cue categories was very similar to ones observed in the previous two studies. Again the UniqueCue-UniqueScene condition yielded most involuntary memories (57.81%; $M=4.62$), followed by the UniqueCue-RepeatedScene condition (32.03%; $M=2.56$), whereas the RepeatedCue-RepeatedScene (8.28%; $M=3.31$) and the RepeatedCue-UniqueScene (0.78%; $M=0.06$) conditions led to very few involuntary memories relative to the number of cues ($F(3,45)=34.83, p<.0001, \eta_p^2=.70$). As in Studies 1 and 2, and consistent with the notion of cue overload, Tukey HSD post hoc tests confirmed that both of the two conditions with unique cues differed significantly from both of the two conditions with repeated cues ($ps<.0001$), whereas the latter did not differ from one

another ($p > .6$). In addition, the UniqueCue-UniqueScene differed significantly from the UniqueCue-RepeatedScene condition ($p < .001$).

Importantly, although a parallel sound location task was added to the voluntary recall condition, this did not significantly impact the frequencies of the recorded voluntary memories in any of the four Cue-Scene conditions relative to the frequencies seen in Studies 1 and 2 (all $ps > .08$). Consistent with Studies 1 and 2, the voluntary retrieval condition generally yielded more memories in all Cue-Scene conditions (all $ps < .05$ in Tukey HSD post hoc tests), again with the exception of the RepeatedCue-UniqueScene condition ($p = 1$ in a Tukey HSD post hoc test), which was at the bottom for both types of retrieval. However, as in the previous two studies it was only significantly lower than the RepeatedCue-RepeatedScene condition for voluntary retrieval ($p < .001$). As in Studies 1 and 2, a 2 (Retrieval: involuntary vs. voluntary) \times 3 (Cue-Scene condition) ANOVA with the RepeatedCue-UniqueScene condition removed showed a significant interaction ($F(2,60) = 7.18, p < .01, \eta_p^2 = .19$), reflecting that the advantage of the voluntary condition was larger for the RepeatedCue-RepeatedScene condition relative to the other two conditions.

Analyses of errors

Few errors were identified, see Table 2. As in Study 2 they tended to be most frequent in the UniqueCue-RepeatedScene condition. Although numerically more errors were reported for involuntary ($M = .56, SD = .99$) than voluntary retrieval ($M = .13, SD = .34$) this difference was not significant ($t(30) = 1.71, p > .09$).

Retrieval Times and Ratings of Clarity and Specificity

As in Studies 1 and 2, the analyses for clarity, specificity and retrieval times were based on the records in the two unique cue conditions only, because of the few involuntary memory records in the two repeated cue conditions. A series of 2 (involuntary vs. voluntary) x 2 (UniqueCue-UniqueScene vs. UniqueCue-RepeatedScene) mixed ANOVAs were conducted with clarity, specificity and retrieval time as the dependent variables. The results are presented in Table 3. For retrieval time, a significant effect was seen for involuntary vs. voluntary retrieval. This reflected markedly shorter retrieval times in the involuntary compared to the voluntary condition. This effect was also seen in Study 2, but is more pronounced in the present study (cf. Table 3). A comparison of retrieval time for the voluntary memories across the two studies showed that the retrieval time in the voluntary condition was markedly extended in the present study relative to Study 2 ($F(1,33)=19.60, p<.0001, \eta_p^2=.37$; see Table 3 for a comparison of the means). For both specificity and clarity ratings a main effect was seen for the UniqueCue-UniqueScene vs. UniqueCue-RepeatedScene factor, which reflected higher scores in the unique scene condition as compared to the repeated scene condition.

With the exception of one participant, all participants in the voluntary condition recorded memories in three Cue-Scene conditions (UniqueCue-UniqueScene; UniqueCue-RepeatedScene; RepeatedCue-RepeatedScene). We therefore compared level of clarity, specificity and retrieval time across these three conditions in the voluntary group only. We conducted a series of repeated measures ANOVAs with three levels (corresponding to the three Cue-Scene conditions) and with level of clarity, specificity and retrieval time as dependent variables. A significant effect was obtained for both clarity ($F(2,28) = 55.76, p<.0001, \eta_p^2 = 0.80$) and specificity ($F(2,28) = 40.18, p<.0001,$

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$\eta_p^2 = 0.74$), but not for retrieval time ($p > .06$). Tukey posthoc analyses showed that for clarity, the UniqueCue-UniqueScene differed from the other two conditions ($ps < .0001$), which did not differ from one another ($ps > .2$). For specificity all three conditions differed from one another ($ps < .01$), with the UniqueCue-UniqueScene showing the highest level of specificity and the RepeatedCue-RepeatedScene showing the lowest level. These findings are similar to Studies 1 and 2.

Summary and Discussion

The voluntary condition in Study 3 involved a parallel sound location task in order to make it comparable to the dual task characteristics of involuntary recall condition in Studies 1 and 2. In spite of this change, the frequency distribution of the involuntary and voluntary memories across the four Cue-Scene conditions closely replicated the ones observed in Studies 1 and 2. However, adding the parallel sound location task to the voluntary recall condition in the present study dramatically increased the retrieval time for voluntary memories relative to the retrieval time for the involuntary memories, and relative to the retrieval time for the voluntary memories without the parallel task in Study 2. This suggests that voluntary recall, more so than involuntary recall, involves cognitive and/or executive processes that are impeded by an attention-demanding parallel task.

Studies 1 - 3 showed a systematic recall advantage of the two conditions where the cue was unique relative to the two conditions in which the cue derived from a repeated category of sounds. This is consistent with the idea that cue overload is an important mechanism for the activation of involuntary autobiographical memories. Alternatively it might be suggested that the conditions with unique cues were

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characterized by a higher degree of natural relatedness than the other conditions and that this accounts for the findings. For example, it might be argued that bird songs coupled with trees form a more natural association than bird songs coupled with a golf player on the golf field. Through Studies 1-3 we attempted to control for this possibility by using four different versions of the experiment and by alternating which sounds and scenes pairings were unique versus repeated across these four versions (see Appendix A). However, in order to more fully control for this potential problem, a fourth experiment was conducted in which the sound and scene pairings were made arbitrary.

Study 4

The purpose of Study 4 was to control for the possibility that the findings in Studies 1 - 3 reflected an enhanced natural relatedness between the sounds and scenes in the unique cue conditions relative to the repeated cue conditions. We therefore changed the material for Study 4 so that the sound and scenes were combined in ways that were as arbitrary as possible across all four Cue-Scene conditions in order to rule out such possible effects. Further, we constructed four different versions of such pairings (see Appendix B). Because of the arbitrary relations between cue and scene, we expected the overall retrieval rate to be reduced in the present study as compared to Studies 1- 3. Still, we expected to replicate the main findings from the previous studies – that is, we expected to find an advantage of the unique cues relative to repeated cues, consistent with the notion of cue overload. We also expected an interaction between involuntary versus voluntary retrieval and Cue-Scene conditions reflecting easier voluntary than involuntary access to repeated scenes, consistent with the notion of overgeneral memories, and we expected shorter retrieval times for involuntary relative to voluntary memories.

Participants

Thirty-two participants (27 females, mean age = 23.81 years; $SD=2.90$) were recruited from the student population at Aarhus University and randomly assigned to the involuntary and voluntary retrieval conditions.

Material

We used the same scenes and sounds as in the previous three studies but the sound-scene pairings were constructed in ways that minimized natural relatedness across all four Cue-Scene conditions⁵. We created four different versions. The pairings are shown in Appendix B.

Design and Procedure

The design and procedure were overall similar to the ones employed in Study 2, except that the possible amount of memories that participants could record in the involuntary condition was 32 (as in Study 3). Reaction time was measured in the same way as in Study 3.

The key word phrases recorded by the participants in response to the memories were coded in the same way as in Experiments 1-3 (interrater agreement = 94.74% ; intraclass correlation = .98).

Results

We first present analyses on the frequencies of involuntary and voluntary memories across the four Cue-Scene conditions, next findings regarding memory characteristics.

The percentages of involuntary and voluntary memories in the four Cue-Scene conditions were calculated in the same way as in the previous three studies. We

conducted a 2 (Retrieval: involuntary vs. voluntary) x 2 (Cues: unique versus repeated) x 2 (Scenes: unique versus repeated) ANOVA with these relative frequencies as the dependent variables (see Figure 5). As in Studies 1-3, this analysis showed a main effect for involuntary versus voluntary retrieval ($F(1,30)=98.72, p<.0001, \eta_p^2=.76$) which reflected that more voluntary than involuntary memories were recorded. Again a main effect was found for unique versus repeated cues ($F(1,30)=5.95, p<.05, \eta_p^2=.87$), reflecting more memories in response to unique than repeated cues. As in Study 2, we also found a main effect for unique versus repeated scenes ($F(1,30)=42.23, p<.0001, \eta_p^2=.58$). Consistent with Studies 1 - 3, there was no interaction between cues and retrieval, but the unique versus repeated characteristics of the scenes interacted with involuntary versus voluntary retrieval ($F(1,30)=57.15, p<.0001, \eta_p^2=.66$), again reflecting more repeated scenes in the voluntary than the involuntary condition. Also consistent with Studies 1 to 3, there was an interaction between the characteristics of the cues and the characteristics of the scenes ($F(1,30)=33.51, p<.0001, \eta_p^2=.53$), reflecting that the disadvantage of the repeated cues was greater for the unique scenes than for the repeated scenes. Finally, we also replicated the three way interaction found in Studies 1 - 3, which reflected that the cue x scene interaction was more pronounced for voluntary than for involuntary retrieval ($F(1,30)=24.15, p<.0001, \eta_p^2=.45$).

The distribution of the involuntary memories across the four Cue-Scene conditions was similar to the ones observed in the previous three studies. Again the UniqueCue-UniqueScene condition yielded most involuntary memories (24.22%; $M=1.94$), followed by the UniqueCue-RepeatedScene condition (17.97%; $M=1.44$),

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whereas the RepeatedCue-RepeatedScene (4.69%; $M=1.88$) and the RepeatedCue-UniqueScene (4.69%; $M=0.38$) conditions led to fewest involuntary memories relative to the number of cues ($F(3,45)=7.41, p<.01, \eta_p^2=.33$). Tukey HSD posthoc analyses showed that the UniqueCue-UniqueScene condition differed significantly from both of the two conditions with repeated cues ($ps<.01$), and the UniqueCue-RepeatedScene condition showed trends in the same direction ($ps<.06$). No other differences were significant ($ps>.2$). The advantage of the two conditions with unique cues was significant ($F(1,15)=11.39, p<.01, \eta_p^2=.43$) and is consistent with what should be expected on the basis of the notion of cue overload.

Consistent with Studies 1 - 3, the voluntary retrieval condition generally yielded more memories in all Cue-Scene conditions (all $ps<.05$ in Tukey HSD post hoc tests), again with the exception of the RepeatedCue-UniqueScene condition ($p=1$ in a Tukey HSD post hoc test), which was at the bottom for both conditions. However, as in the previous two studies it was only significantly lower than the RepeatedCue-RepeatedScene condition for voluntary retrieval ($p<.001$). As in Studies 1 - 3, a 2 (Retrieval: involuntary vs. voluntary) x 3 (Cue-Scene condition) ANOVA with the RepeatedCue-UniqueScene condition removed still showed a significant interaction ($F(2,60)=17.23, p<.0001, \eta_p^2=.36$), reflecting that the advantage of the voluntary condition was larger for the RepeatedCue-RepeatedScene condition relative to the other two conditions.

Analyses of errors

The number of errors was higher in the present study relative to Studies 1-3 (see Table 2). This is not surprising given the randomness of the associations. As shown in Table 2, for both involuntary and voluntary retrieval most errors were found in the two conditions with unique cues. A 2 (involuntary vs. voluntary) x 2 (UniqueCue-UniqueScene vs. UniqueCue-RepeatedScene) mixed ANOVA on the mean percentage of errors, showed that these two conditions did not differ significantly ($F(1, 24)=1.57$, $p>.1$), whereas more errors tended to be seen for involuntary relative to voluntary retrieval ($F(1,24)=4.07$, $p=.05$).

Retrieval Times and Ratings of Clarity and Specificity

As in Studies 1 -3, the analyses for clarity, specificity and retrieval times were based on the records in the two unique cue conditions only, because of the few involuntary memory records in the two repeated cue conditions. A series of 2 (involuntary vs. voluntary) x 2 (UniqueCue-UniqueScene vs. UniqueCue-RepeatedScene) mixed ANOVAs were conducted with clarity, specificity and retrieval time as the dependent variables. The results are presented in Table 3. For retrieval time, a significant effect was seen for involuntary vs. voluntary retrieval, which reflected shorter retrieval times in the involuntary compared to the voluntary condition, consistent with Studies 2 and 3. For both specificity and clarity ratings a main effect was seen for the UniqueCue-UniqueScene vs. UniqueCue-RepeatedScene factor with higher scores in the unique scene condition as compared to the repeated scene condition, which replicates Studies 1-3.

With the exception of two participants, all participants in the voluntary condition recorded memories in three Cue-Scene conditions (UniqueCue-UniqueScene;

UniqueCue-RepeatedScene; RepeatedCue-RepeatedScene). We therefore compared level of clarity, specificity and retrieval time across these three conditions in the voluntary group only. We conducted a series of repeated measures ANOVAs with three levels (corresponding to the three Cue-Scene conditions) and with level of clarity, specificity and retrieval time as dependent variables. A significant effect was obtained for both clarity ($F(2,26) = 15.30, p < .0001, \eta_p^2 = 0.54$) and specificity ($F(2,26) = 26.38, p < .0001, \eta_p^2 = 0.67$), but not for retrieval time ($p > .07$). Tukey HSD posthoc tests showed that the UniqueCue-UniqueScene scored higher than the two repeated scene conditions on clarity and specificity, ($ps < .01$), whereas the two repeated scene conditions did not differ from one another ($ps > .3$).

Summary and Discussion

The frequency of involuntary memories was reduced relative to the previous three studies. This was expected given the arbitrary, and thus weaker, associations overall between cues and scenes. Nonetheless, the present study replicated the main findings from the previous three studies. First, we found an advantage of unique relative to repeated cues, consistent with the notion of cue overload. Second, we found an overgeneral memory effect for voluntary retrieval in terms of more memories of repeated scenes (in response to repeated cues), which were rated as less specific and less clear than the memories of unique scenes. Third, the retrieval time for voluntary memories was longer than for the involuntary memories. This effect was even more pronounced in the present study than in Study 2, which is likely to reflect a prolonged strategic search process due to the arbitrariness of the cue-scene connections.

In contrast to Studies 1-3, the UniqueCue-UniqueScene condition did not yield significantly more memories than UniqueCue-RepeatedScene condition (although a numerical difference was found in the expected direction). This may largely be due to the greater error rate for the former than for the latter condition in the present study (cf. Table 2), which most likely reflected the fact that more different response options were available for the unique scenes (in UniqueCue-UniqueScene condition) than for the repeated scenes (in UniqueCue-RepeatedScene condition).

General Discussion

We have demonstrated that it is possible to systematically manipulate and predict the retrieval of involuntary episodic memories on the basis of well-known mechanisms of associative memory, notably the principle of cue-overload. We have thereby introduced a new experimental paradigm, which allows for more controlled investigations of involuntary episodic memories than what has been possible in the past. Across 4 studies we have found (1) more involuntary memories in response to unique than repeated cues, consistent with the notion of cue overload, (2) more voluntary memories of repeated scenes, analogous with the notion of overgeneral memories in naturalistic studies, and (3) shorter retrieval time for involuntary than for voluntary memories, consistent with the idea that the former requires less executive functions.

Our finding that involuntary memories have shorter retrieval times than their voluntary counterparts and that this effect increased markedly when a parallel task was added to the voluntary condition in Study 3, suggests that involuntary memories come to mind through processes that requires less monitoring and thus less executive control than what is the case for voluntary recall. Although the instructions for the involuntary and

voluntary conditions were similar, it is likely that such enhanced demands for executive control led participants in the voluntary condition to conduct the sound location task and the recall task sequentially, resulting in markedly extended retrieval times relative to the involuntary condition. It is noteworthy that even when no parallel task was added to the voluntary condition (Studies 2 and 4), retrieval times were significantly longer for voluntary relative to involuntary recall.

Schlagman and Kvavilashvili (2008) also found shorter retrieval times for involuntary as compared to voluntary autobiographical memories recalled in response to verbal cues. However, in their pioneering work it was not clear whether this effect was due to the fact that the involuntary memories came to mind in response to a self-elicited subset of the verbal cues (i.e., the phrases that triggered the memories for each participant in question), whereas voluntary memories were retrieved in response to a randomly generated subset of the cues. In contrast, the present work demonstrated shorter retrieval time for involuntary memories under similar cueing conditions (i.e., across the two conditions with unique sound cues) for both involuntary and voluntary recall. This suggests that the shorter retrieval times for involuntary recall reflect underlying memory mechanisms and not simply more efficient cues.

The demonstration of this rapid retrieval of involuntary (relative to voluntary) memories has implications for the understanding of intrusive involuntary memories in emotional disorders and their ability to trigger strong and uncontrollable emotional reactions, such as in flashbacks in PTSD (American Psychiatric Association, 2000) as well as similar maladaptive reactions to intrusive memories and images in other disorders (Holmes & Mathews, 2010, for review). Strong emotional reactions in response to

intrusive memories may in part reflect that the uncontrollable onset of involuntary remembering leaves little or no room for antecedent emotion regulation and/or avoidance (Berntsen, 2009). The present experimental paradigm may be extended to examine risk factors for intrusive involuntary memories in different clinical disorders, for example by using emotional instead of neutral scenes and/or scenes addressing key themes of specific emotional disorders.

The distribution of the involuntary memories across the four Cue-Scene conditions can largely be accounted for in terms of the notion of cue-overload, according to which the likelihood of a cue providing access to a given target memory depends on the extent to which this cue is uniquely associated with the target. Its strength as a cue declines to the extent it is associated with other memories as well (Watkins & Watkins, 1975). Following this principle, we should expect the two unique-cue conditions to show an advantage over the repeated cue conditions, consistent with our findings. Across all studies we found that involuntary retrievals were most frequent in the two conditions with unique cues, whereas they were rare in the two conditions with repeated cues. Study 4 showed that the advantage of the unique cues relative to the repeated cues were not due to increased natural relatedness, since the same effects were seen when the connections between the cues and the targets were made arbitrary.

The recognition task included in Studies 1 and 2, on the other hand, showed an advantage of the two unique *scene* conditions compared to the repeated ones (irrespective of whether the *cues* in the preceding recall phase were repeated or unique). This indicates that the sparseness of memories in the two RepeatedCue conditions reflected cue

dependent forgetting (Tulving, 1966) and not the availability of the remembered scenes *per se*.

The frequency distribution of the voluntary memories differed in more respects from the one of the involuntary memories. First, voluntary recall yielded more memories overall, showing that voluntary recall overcomes some of the associative mechanisms that lead to loss of information for involuntary recall. This is consistent with the view that it is a major evolutionary advantage to be able to control and monitor retrieval in a deliberate and goal-directed fashion rather than having to rely solely on involuntary, associative recall (Donald, 1991). Second, the relative advantage of the voluntary mode was especially pronounced for the RepeatedCue-RepeatedScene condition, where voluntary recall yielded a high memory rate in contrast to involuntary recall. At the same time, the remembered scenes were rated low on specificity and clarity, making them comparable to the overgeneral autobiographical memories (e.g., Williams et al., 2007), which have consistently been found to be more common for voluntary recall (Berntsen, 1998; Berntsen & Hall, 2004; Berntsen & Jacobsen, 2008; Schlagman & Kvavilashvili, 2008). Third, the advantage of voluntary recall was absent for the RepeatedCue-UniqueScene condition where both types of recall were very low. This suggests that something in addition to cue-overload may be operating for this condition, at least for voluntary recall. Essentially, this finding shows that when a certain type of stimuli (A_s) is repeatedly associated with a certain type of targets (B_s ; e.g., A_1-B_1 , A_2-B_2 , A_3-B_3), it will be a poor cue for a different target with which it has been encountered only once ($A-D$), even when the person is deliberately trying to remember. Similar effects have been observed in verbal learning experiments (with voluntary recall) based on the paired-

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associate methodology. It has been variously designated as occlusion, resource diffusion, associative decrement or inhibition (see Anderson & Spellman, 1995, for a review) and may also be related to retrieval induced forgetting (Anderson, Bjork & Bjork, 1993).

This effect calls for more research, because in everyday life a repeated cue (i.e., a cue associated with many events) seems nonetheless capable of bringing particularly distinctive and/or emotional scenes to mind. This may be especially pronounced in relation to highly emotional events. For example, returning from deployment in Afghanistan, a Danish soldier reported recurrent involuntary memories of an event in which he had removed the bodies of children killed in an explosion. The memory of this distinctive event frequently came to mind in response to a common environmental feature (i.e., a repeated cue): the smell of grilled meat (see Ehlers, Hackman & Michael, 2004, for similar observations). Following such observations, we would expect that it would be possible to significantly increase the frequencies of memories reported in the RepeatedCue-UniqueScene condition by replacing the neutral scenes in this condition with highly emotional ones. This is a question for future work.

To which extent can these findings be generalised to real world observations on involuntary episodic/autobiographical memories? First, when developing the present paradigm we followed the lead from the early ethologists (Tinbergen, 1963) and designed our experiments on the basis of what we know from two decades of research on involuntary autobiographical memories in naturalistic settings, in order to ensure ecological validity (Neisser, 1982). Second, the advantage of the unique cues is consistent with naturalistic observations on involuntary autobiographical memories and predictions from naturalistic studies (see Berntsen, 2009, for a review). Third, in the

present studies we replicate a robust finding from the naturalistic studies in terms of voluntary recall accessing overgeneral (non-specific) memories more frequently than involuntary recall (e.g., Berntsen & Hall, 2004; see Berntsen, 2009, for a review). Fourth, the involuntary memories recorded in the present studies had shorter retrieval times than their voluntary counterparts. This is consistent with previous work with personally experienced events recalled involuntarily (versus voluntarily) in a laboratory setting (Schlagman & Kvavilashvili, 2008). Fifth, asking people to record spontaneous thoughts during a parallel signal detection task is a well-established way of studying spontaneous thought processes, going back to at least the sixties (Berntsen, 2009, for review). This type of methodology has also been successfully applied to real life, involuntary autobiographical memories in the past (Schlagman & Kvavilashvili, 2008).

Thus, we believe the present findings have external validity. The alternative position that real life involuntary memories form a special category whose mechanisms defy experimental control appears untenable. At the same time, there are important differences between the present work and real life conditions for involuntary recollections, which should be acknowledged. Clearly, in everyday life not all events are equally important, not all are encountered at the same time, and some are likely to be a lot more rehearsed (thought and talked about) than others. Therefore everyday involuntary recollections are bound to show more variability with regard to their activation than what we have demonstrated in the present studies (e.g., Roediger, 2008). In the present experiments, we have concentrated on manipulating the cue strength. For the sake of experimental control we kept the “history” of the target scenes similar. Thus, all sound and scene pairs were encoded roughly at the same time during the same

encoding phase, and shortly before the retrieval phase. Compared to real life research this means that we have here mostly concentrated on what Berntsen (2007, 2009) calls *the immediate situation* (that is, that specific moment in which an involuntary memory comes to mind) and ignored the influence of what she calls the *overall life situation*, which is the individual's current appraisal of his or her recent past and close future, such as current concerns, unfinished personal business and recent stirring events (Berntsen, 2009). In addition to cues in the immediate situation, the overall life situation may influence memory by rendering certain classes of past events more accessible through priming (Mace, 2005) and/or by biasing attention towards certain types of cues (Johannessen & Berntsen, 2010). For example, a person who has recently suffered a personal loss may be more inclined to pay attention to potential cues that can be related to this loss and therefore have more loss-related involuntary memories. This intricate interplay between attention, motivational factors and the strength of the immediate cues is an important topic for future research, which may be addressed through extensions of the present experimental paradigm.

The present series of studies represents an important breakthrough in research on involuntary episodic memories by showing that it is possible to systematically manipulate their occurrence through simple laboratory techniques, that their activation can be predicted by well-known mechanisms of associative memory and that their retrieval pace is less affected by a parallel task than is voluntary recall. The findings suggest that the two types of recall are governed by different underlying mechanisms, which has critical implications for our understanding of involuntary memories in daily life as well as for our understanding of intrusive involuntary memories in emotional disorders.

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Author note

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Footnotes

1. Due to a clerical error, one of the sounds deriving from the RepeatedCue-RepeatedScene condition was presented only to the left ear, for which reason the total number of cues in this condition was 39.

2. Involuntary memories were occasionally retrieved to filler sounds – i.e., the sounds that were presented only during retrieval as part of the sound location task employed in this condition (Ns for Study 1 = 26, Study 2 = 32, Study 3 = 60, Study 4 = 81). Because they could only be present in the involuntary condition and could not be categorized in terms of Cue-Event conditions, they were not further analyzed.

3. The same strategy was used in Studies 2, 3, and 4.

4. The relative distribution of memories across the four categories, and their characteristics did not interact with whether the cue was presented first or second in the involuntary condition.

5. Some of the sounds designated as unfamiliar in Studies 1-3 were used as familiar sounds, and vice versa, in Study 4, in order to ensure sufficiently arbitrary connections.

Table 1

An Overview of the Cue-Scene Conditions and Predictions of Involuntary Memory

Frequency

Cues	Pictures of Scenes	
	Unique Scenes	Repeated Scenes
Unique sound cue	No cue-overload. High level of cue-item discriminability. High probability of involuntary memories in response to the cues.	No cue-overload but reduced level of cue-item discriminability because of blocking (the target is repeatedly associated with another cue) . Reduced probability of involuntary memories in response to the cues .
Repeated sound cue	Cue-overload. Thus, little cue-item discriminability. Markedly reduced probability of involuntary memories.	Cue-overload. Little cue-item discriminability in relation to particular instances. The repetitive cue may bring to mind a general (non-specific) representation of the repeated target picture (a case of overgeneral retrieval) .

Table 2

Errors for Involuntary and Voluntary Retrieval Across the four Cue-Scene Conditions (Percentages Calculated Based on the Total Number of Memories in Each Condition)

	UniCue-UniScene				UniCue-RepScene				RepCue-UniScene				RepCue-RepScene			
	Involuntary		Voluntary		Involuntary		Voluntary		Involuntary		Voluntary		Involuntary		Voluntary	
	Sum	%	Sum	%	Sum	%	Sum	%	Sum	%	Sum	%	Sum	%	Sum	%
Study 1	4	5.2	0	--	2	5.3	0	--	0	--	0	--	3	10.7	0	--
Study 2	1	1.2	1	1.4	7	11.5	8	12.3	0	--	1	11.1	0	--	0	--
Study 3	0	--	0	--	5	10.9	2	5.0	0	--	0	--	4	7.0	0	--
Study 4	15	32.6	8	21.1	7	23.3	4	11.1	0	--	2	33.3	2	6.3	0	--

Table 3

Means and Standard Deviations for Specificity, Clarity and Retrieval Time for Involuntary versus Voluntary Recall in the UniqueCue-UniqueScene versus UniqueCue-RepeatedScene conditions.

Variables	UniCue-UniScene				UniCue-RepScene				Main effects				Interaction		
	Involuntary		Voluntary		Involuntary		Voluntary		Cueing		Inv/Vol		Cueing/Inv-vol		
	M	SD	M	SD	M	SD	M	SD	F	η_p^2	F	η_p^2	F	η_p^2	
<u>Study 1</u>															
Specificity	4.70	0.42	4.93	0.12	3.06	1.31	3.12	0.92	78.53***	0.73	0.41	0.01	0.21	0.01	
Clarity	4.34	0.52	4.59	0.50	2.80	1.11	3.15	0.78	92.99***	0.77	1.67	0.06	0.08	0.00	
<u>Study 2</u>															
Specificity	4.82	0.31	4.69	0.71	2.94	0.94	3.03	1.01	74.80***	0.68	0.02	0.00	0.28	0.01	
Clarity	4.40	0.69	4.39	0.75	2.64	0.63	3.03	0.71	89.52***	0.72	1.48	0.04	1.47	0.04	
RT. ms	4955	1719	6108	2590	5264	2245	8303	4877	6.44*	0.16	5.13*	0.13	3.66	0.09	
<u>Study 3</u>															
Specificity	4.78	0.34	4.62	0.41	3.41	1.31	3.18	0.83	49.59***	0.66	0.73	0.03	0.02	0.00	
Clarity	4.53	0.37	4.36	0.40	2.92	0.99	2.62	0.71	102.41***	0.80	1.53	0.06	0.17	0.01	
RT. ms	5171	5006	17119	9078	4327	3121	15660	9402	0.97	0.04	21.19***	0.45	0.07	0.00	
<u>Study 4</u>															
Specificity	4.23	0.87	4.66	0.53	2.85	1.31	2.34	0.43	43.65***	0.66	0.03	0.00	2.77	0.11	
Clarity	3.95	0.93	4.53	0.53	2.39	0.89	2.37	0.89	61.16***	0.74	1.41	0.06	1.60	0.07	
RT. Ms	4141	2142	19603	29120	4612	2104	11449	5916	00.53	0.02	5.57*	0.20	0.67	0.03	

Note: For Study 1 N = 30 (i.e., 14 in the involuntary and 16 in the voluntary condition, who retrieved memories in the two conditions). For Study 2 N = 37 (17 in the involuntary and 20 in the voluntary condition, who retrieved memories in the two conditions). For Study 3 N = 28 (13 in the involuntary and 15 in the voluntary condition, who retrieved memories in the two conditions). For Study 4 N = 24 (9 in the involuntary and 15 in the voluntary condition) *p<.05, ***p<.0001

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Table 4
Accuracy, Confidence, and Retrieval Time for the Recognition Task in Studies 1 and 2

Variables	UniCue-UniScene				UniCue-RepScene				RepCue-UniScene				RepCue-RepScene			
	Involuntary		Voluntary		Involuntary		Voluntary		Involuntary		Voluntary		Involuntary		Voluntary	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>												
<u>Study 1</u>																
Accuracy	1.00	0.00	1.00	0.00	0.88	0.15	0.91	0.13	1.00	0.00	0.98	0.06	0.89	1.16	0.89	1.16
Confidence	4.78	0.46	4.94	0.14	2.61	0.78	3.38	1.12	4.84	0.30	4.73	0.64	3.80	0.52	3.80	1.01
RT ms.	3397	1966	2909	0879	5707	1747	4662	1811	2621	0668	2630	0850	4838	1336	5151	2013
<u>Study 2</u>																
Accuracy	1.00	0.00	0.99	0.06	0.85	0.22	0.84	0.23	1.00	0.00	0.99	0.06	0.84	0.20	0.95	0.13
Confidence	4.69	0.39	4.80	0.26	2.79	1.15	3.35	1.02	4.60	0.51	4.81	0.39	3.56	0.79	3.99	0.63
RT ms.	2900	1026	3303	2593	4491	2271	4233	1745	2482	0764	2534	1567	4893	1645	4274	1808

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Figure 1. An illustration of the four conditions of the design used in the Experiments.

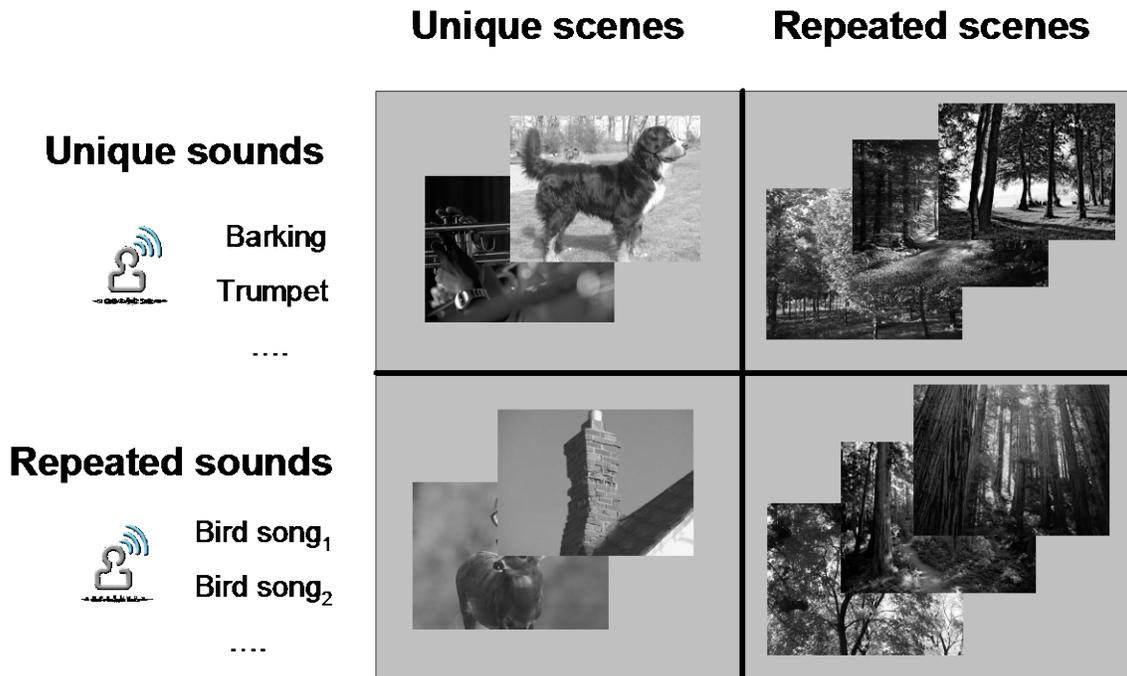


Figure 2. The frequency of involuntary and voluntary retrievals across the four Cue-Scene conditions in Experiment 1: UU=UniqueCue-UniqueScene; UR=UniqueCue-RepeatedScene; RR=RepeatedCue-RepeatedScene; RU=RepeatedCue-UniqueScene. Vertical bars denote 0.95 confidence intervals.

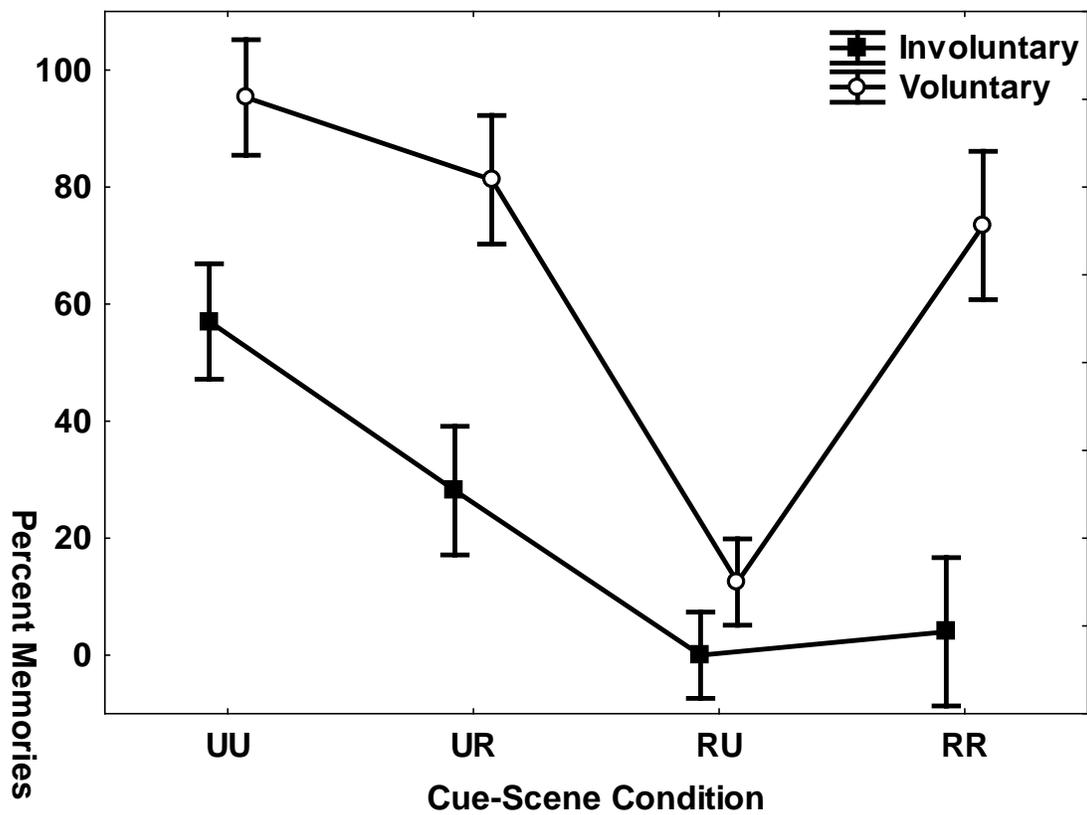


Figure 3. The frequency of involuntary and voluntary retrievals across the four Cue-Scene conditions in Experiment 2. UU=UniqueCue-UniqueScene; UR=UniqueCue-RepeatedScene; RR=RepeatedCue-RepeatedScene; RU=RepeatedCue-UniqueScene. Vertical bars denote 0.95 confidence intervals.

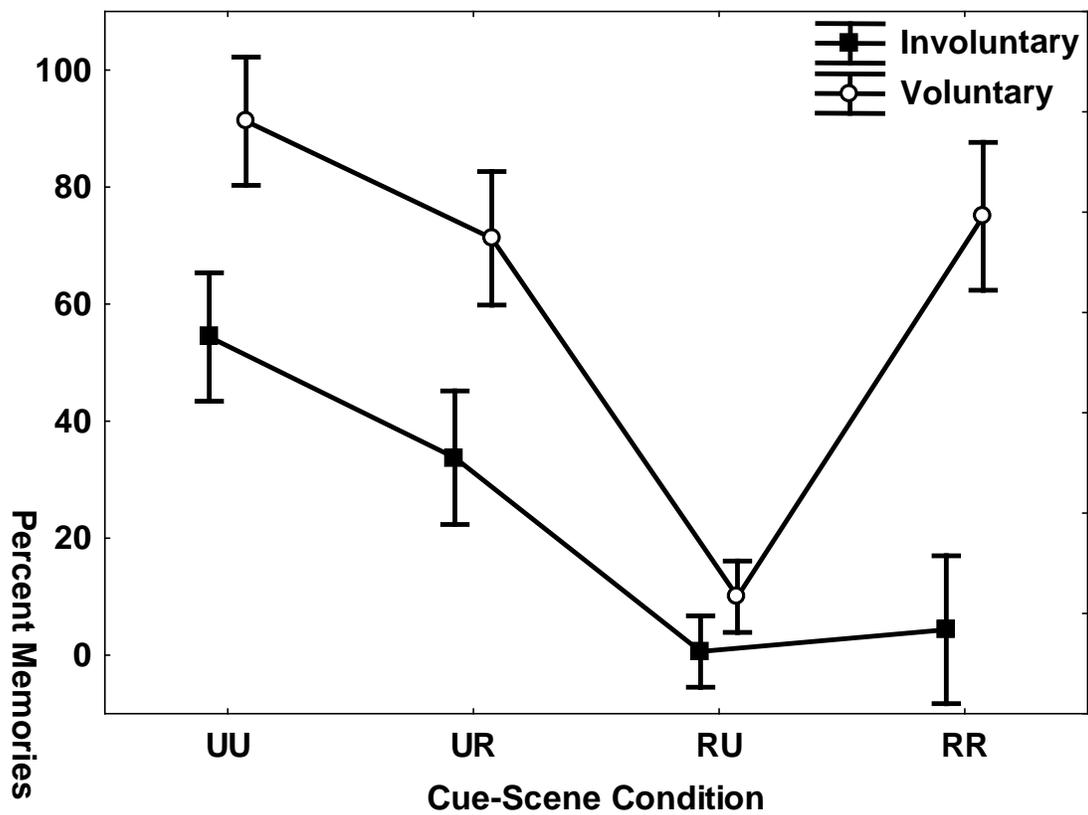


Figure 4. The frequency of involuntary and voluntary retrievals across the four Cue-Scene conditions in Experiment 3. UU=UniqueCue-UniqueScene; UR=UniqueCue-RepeatedScene; RR=RepeatedCue-RepeatedScene; RU=RepeatedCue-UniqueScene. Vertical bars denote 0.95 confidence intervals.

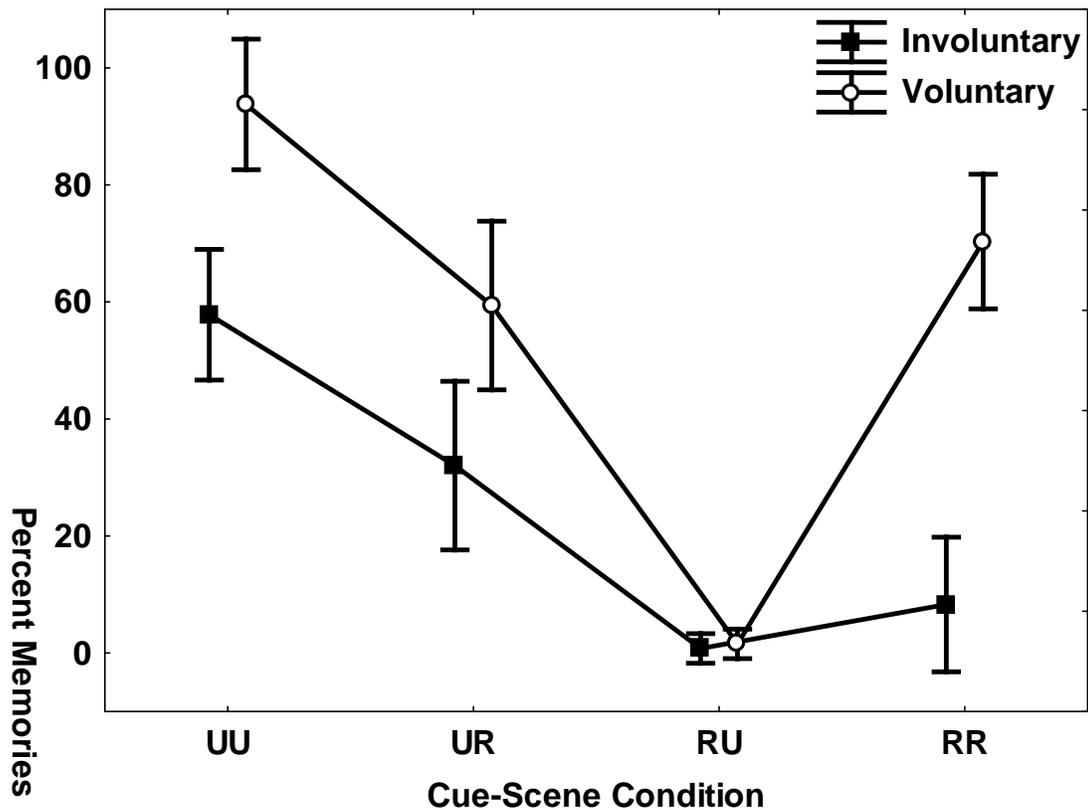
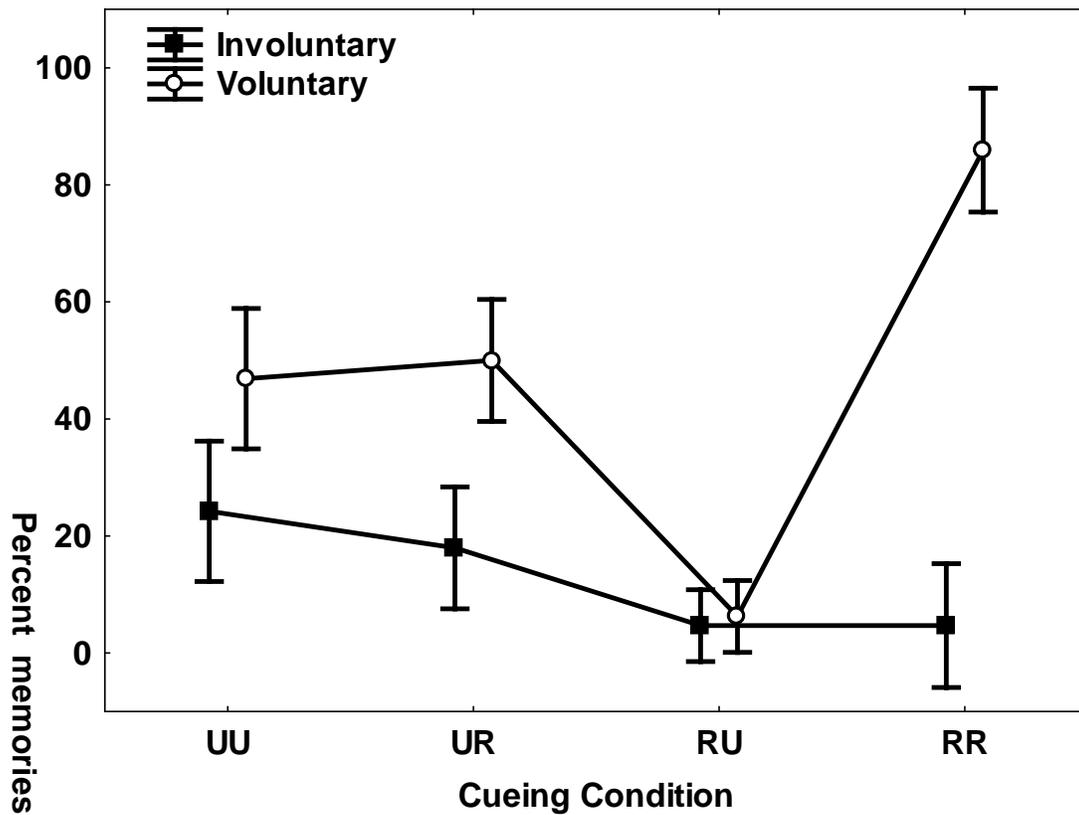


Figure 5. The frequency of involuntary and voluntary retrievals across the four Cue-Scene conditions in Experiment 4. UU=UniqueCue-UniqueScene; UR=UniqueCue-RepeatedScene; RR=RepeatedCue-RepeatedScene; RU=RepeatedCue-UniqueScene. Vertical bars denote 0.95 confidence intervals.



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Appendix A: The four versions of the task used in Studies 1-3

Cue	Scene	<u>Version 1:</u>		<u>Version 2:</u>		<u>Version 3:</u>		<u>Version 4:</u>	
		Sound	Scene	Sound	Scene	Sound	Scene	Sound	Scene
Unique	Unique	car drives by1	car1	song birds 1	trees1	song birds 1	trees1	Song birds1	trees1
Unique	Unique	walk&talk1	street1	walk&talk1	street1	walk&talk1.	street1	barking1	dog1
Unique	Unique	barking1	dog1	barking1	dog1	car drives 1	car1	car drives 1	car1
Unique	Unique	trumpet	Trumpeter	Trumpet	trumpeter	trumpet	trumpeter	trumpet	trumpeter
Unique	Repeated	chainsaw	trees29	car alarm	car29	whimper	dog29	shout	street29
Unique	Repeated	birds fleeing	trees30	Honk	car30	panting	dog30	music	street30
Unique	Repeated	cuckoo	trees31	Brakes	car31	howl	dog31	bicycle bell	street31
Unique	Repeated	crow scream	trees32	Doorslam	car32	lapping	dog32	siren	street32
Repeated	Unique	song birds 13	chimney	car drivesby13	engine	barking13	collar	walk&talk13	graffiti
Repeated	Unique	song birds 14	bicycles	car drives by14	gasstation	barking14	dog basket	walk&talk 14	roadsign
Repeated	Unique	song birds 15	deer	car drives by15	windshield	barking15	fleeing cat	walk&talk 15	subway entr.
Repeated	Unique	song birds 16	Golfplayer	car drives by16	stoplight	barking16	dog food	walk&talk 16	musician
Repeated	Repeated	song birds 1	trees1	car drives by1	car1	barking1	dog1	walk&talk 1	street1
Repeated	Repeated	song birds 2	trees2	car drives by2	car2	barking2	dog2	walk&talk 2	street2
Repeated	Repeated	song birds 3	trees3	car drives by3	car3	barking3	dog3	walk&talk 3	street3
Repeated	Repeated	song birds 4	trees4	car drives by4	car4	barking4	dog4	walk&talk 4	street4
...
Repeated	Repeated	song birds28	trees28	car drives by28	car28	barking28	dog28	walk&talk 28	street28

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Appendix B: The four versions of the task used in Study 4

Cue	Scene	<u>Version 1:</u> Sound	Scene	<u>Version 2:</u> Sound	Scene	<u>Version 3:</u> Sound	Scene	<u>Version 4:</u> Sound	Scene
Unique	Unique	heartbeat	subway entrance	camera	dog1	music	trees1	shout	deer
Unique	Unique	sigh	gasstation	heartbeat	street1	bell	street1	music	trees1
Unique	Unique	chainsaw	dog1	sigh	trumpeter	camera	chimney	bell	car1
Unique	Unique	shout	trumpeter	chainsaw	gasstation	phone ringing	subway entrance	camera	trumpeter
Unique	Repeated	phone ringing	trees29	shout	car29	sigh	dog29	phone ringing	street29
Unique	Repeated	bell	trees30	phone ringing	car30	heartbeat	dog30	sigh	street30
Unique	Repeated	music	trees31	bell	car31	chainsaw	dog31	heartbeat	street31
Unique	Repeated	camera	trees32	music	car32	shout	dog32	chainsaw	street32
Repeated	Unique	car drives by13	chimney	bird song13	engine	rain13	deer	barking13	graffiti
Repeated	Unique	car drives by14	bicycles	bird song14	deer	rain14	dog basket	barking14	golfer
Repeated	Unique	car drives by15	collar	bird song15	golfer	rain15	musician	barking15	engine
Repeated	Unique	car drives by16	deer	bird song16	Subway-entr	rain16	trumpeter	barking16	gasstation
Repeated	Repeated	car drives by1	trees1	bird song1	car1	rain1	dog1	barking1	street1
Repeated	Repeated	car drives by2	trees2	bird song2	car2	rain2	dog2	barking2	street2
Repeated	Repeated	car drives by3	trees3	bird song3	car3	rain3	dog3	barking3	street3
Repeated	Repeated	car drives by4	trees4	bird song4	car4	rain4	dog4	barking4	street4
...
Repeated	Repeated	car drives by28	trees28	bird song28	car28	rain28	dog28	barking28	street28