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Why aren't we flooded by involuntary autobiographical memories?

Few cues are more effective than many

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Abstract

Recent research on involuntary autobiographical memories (IAMs) has shown that these memories can be elicited and studied in the laboratory under controlled conditions. Employing a modified version of a vigilance task developed by Schlagman and Kvavilashvili (2008) to elicit IAMs, we investigated the effects of varying the frequency of external cues on the number of IAMs reported. During the vigilance task, participants had to detect an occasional target stimulus (vertical lines) in a constant stream of non-target stimuli (horizontal lines). Participants had to interrupt the task whenever they became aware of any task-unrelated mental contents and to report them. In addition to line patterns, participants were exposed to verbal cues and their frequency was experimentally manipulated in three conditions (frequent cues vs. infrequent cues vs. infrequent cues plus arithmetic operations). We found that, compared to infrequent cues, both conditions with frequent cues and infrequent cues plus arithmetic operations decreased the number of IAMs reported. The comparison between the three experimental conditions suggests that this reduction was due to the greater cognitive load in conditions of frequent cues and infrequent cue plus arithmetic operations. Possible mechanisms involved in this effect and their implications for research on IAMs are discussed.

Key words: Involuntary memories, autobiographical memory, cognitive load, mind wandering.

Introduction

For a long time mainstream research on autobiographical memory has been focused on the investigation of deliberately retrieved memories of personal events, intentionally generated in response to specific cues provided by the experimenter (for a review see Conway & Pleydell-Pearce 2000). However, our autobiographical memory is not just driven by our decision and commitment to remember. Autobiographical memories might also come to mind involuntarily and spontaneously, with no preceding conscious attempt at retrieval (Berntsen 2009, 2010; Mace 2007).

Up until recently, the most common approach for studying involuntary autobiographical memories (IAMs) has been the naturalistic diary method in which individuals are asked to keep a diary of IAMs they experience in everyday life (e.g., Berntsen 1996; Berntsen & Hall 2004; Mace 2004). These studies have revealed that IAMs are more likely when one is engaged in undemanding activities that require little attention and concentration (e.g., during relaxation and routine activities) (Berntsen & Hall 2004; Kvavilashvili & Mandler 2004) and that in the large majority of cases (80% or more) they are elicited by easily identifiable external (environmental) cues, generally related to prominent, possibly thematic, aspects of the remembered experiences (e.g., Berntsen 1996; Berntsen & Hall 2004; Mace 2004).

The fact that involuntary memories can be elicited by external cues allowed for designing laboratory procedures to investigate the phenomenon of IAMs under well-controlled conditions (Berntsen, Staugaard, & Sorensen 2013; Mazzoni, Vannucci, & Batool 2014; Schlagman & Kvavilashvili 2008; Vannucci, Batool, Pelagatti & Mazzoni 2014). These procedures have simulated the conditions that in more naturalistic diary studies have been shown to facilitate the production of IAMs, such as

being engaged in undemanding cognitive tasks and being exposed to cues that can potentially trigger IAMs. In one of the most successful paradigms, developed by Schlagman and Kvavilashvili (2008), participants are exposed to a long sequence of trials of mostly horizontal lines and have to detect an occasional target (vertical lines) while being simultaneously exposed to irrelevant cue-phrases, presented in the middle of the screen (e.g., 'relaxing on a beach' or 'crossing the street'). Participants are instructed to stop the procedure whenever they experience IAMs, to record basic details about the memory (i.e., memory description, triggers, concentration rating) and then resume the vigilance task. After completion of the task, participants are given a detailed questionnaire concerning the IAMs they recorded earlier. This procedure produces a fair amount of IAMs, the majority of which (85% in the original study) are reported as being triggered by the word-cues on the screen.

The laboratory procedure for investigating IAMs can be used to investigate a pervasive problem in theorizing on involuntary memories, namely *why*, given the constant flow of external stimulation that can potentially trigger IAMs, we are not constantly flooded by them. We are after all immersed in an environment rich with a multitude of potential cues, and engaged relatively often in routine monotonous daily activities. Yet the daily rate of occurrence of IAMs, as indicated by diary studies (cf. Berntsen 2009), can hardly be described as a flood. What then are the factors limiting the incidence of IAMs? The present study aimed to address this issue by investigating the role of frequency of environmental cues and cognitive load imposed when these cues are presented.

In the experiment reported here we employed a modified version of the Schlagman and Kvavilashvili (2008) procedure, already successfully used to investigate IAMs (Mazzoni et al. 2014; Vannucci et al. 2014). The slight but important

modification consists of two elements. First, participants are not informed that one of the aims is to study involuntary memories, and they are asked to report whatever comes to mind, things about the past, plans, intentions for the future, etc., as long as these contents are not task-related. This makes the task more akin to a mind wandering task (Schooler et al. 2011). Second, participants are asked to categorize their mental contents as memories vs. non memories (generically called thoughts) only at the end of the report. Within this modified IAM task we focused on the issue of cue frequency, namely the number of cues presented in a specific amount of time, that we hypothesized could be related to the number of IAMs. In particular, we tested three hypotheses – the volume hypothesis, the cognitive load hypothesis, and the interference hypothesis – that could potentially account for the relative scarcity of IAMs.

The *volume hypothesis* states that presenting participants with more cues, which could potentially serve as triggers, will lead to more IAMs. Currently, involuntary retrieval is thought to occur only when there is a sufficient match between elements of the cue and central features or themes of the retrieved memory (e.g. Ball, Mace, & Corona 2007; Berntsen & Hall 2004). In a related vein, recent theorizing on IAMs stresses that only a subset of cues encountered in the environment has the potency to trigger involuntary memories. For example, referring to the cue overload hypothesis, Berntsen et al. (2013) showed that only cues that uniquely point to a single memory, at the exclusion of other memory records, are capable to produce cue-memory matches strong enough to elicit IAMs (see also Rubin 1995). These observations suggest that the main bottleneck for IAMs might simply be the lack of memory relevant cues in the environment. Thus, increasing the volume of cues in

the Schlagman and Kvavilashvili (2008) procedure may result in more unique cue-memory matches and thus more IAMs.

By contrast, the *cognitive load hypothesis* states that more cues could potentially lead to fewer instances of IAMs by imposing a greater cognitive load. Several studies have shown that IAMs are more likely to occur when the individual is in a diffuse state of attention, as for example during boring and/or undemanding activities that require little attention (e.g., Berntsen 1998; Berntsen & Hall 2004; Kvavilashvili & Mandler 2004). Previous studies have also found that external distractors irrelevant to the task, might capture attention and therefore disrupt task performance (Forster & Lavie 2008a, 2008b). Also, an increase in cognitive demands was found to be associated with a reduction of task-irrelevant thoughts (McKiernan et al. 2006). According to these findings the analysis of the constant stream of environmental cues might tax the cognitive system in a way that precludes memory retrieval. Another possibility, suggested by recent findings in the literature on mind-wandering, is that cognitive load may decrease the amount of attention and awareness about mental contents, and thus decreases the likelihood to notice existing mental contents, including IAMs (for a review, Schooler, Smallwood, Christoff, Handy, Reichle, & Sayette, 2011).

Finally, the *memory interference hypothesis* states that more cues can lead to fewer IAMs by creating memory interference at retrieval, interfering with the process of forming or reporting IAMs. Although Schlagman and Kvavilashvili (2008) showed that involuntary memories were retrieved faster than voluntary memories, their formation and reporting still took on average 4-5 seconds. Therefore, increasing the cue frequency in the IAM task means that the process of forming a new memory may not always be accomplished before the next external cue is presented.

Because the newly presented cue is likely to match memory records that are different from the one triggered by the previous cue, it can interfere with the process of forming the mental representation of the involuntary memory that would have been potentially triggered by the previous cue. Thus, increasing the frequency can potentially interfere with forming IAMs, reducing the overall number of reported memories. At the same time, different cues are likely to activate different episodic nodes in memory and stimulate the network in parallel. This stimulation might create competition among stimulated targets and ultimately trigger interference at retrieval.

The present study was designed to assess the effects of changing the cue frequency in the IAM task with respect to the three hypotheses described above. We included three conditions in our study. In the “frequent cues” condition 300 cue-phrases were presented over 450 trials (2/3), while in the “infrequent cues” condition, participants were presented with 90 word-cues over 450 trials (1/5) of the vigilance task. The comparison between the two conditions allows for testing the volume hypothesis, which specifically predicts more IAMs in the frequent than in the infrequent cues condition.

To distinguish between the cognitive load and the memory interference hypotheses, participants in the third “infrequent cues plus math” condition were exposed to 90 cue-phrases, as in the infrequent cues condition. However, on further 210 of the 450 trials, for a total of 300 trials, these participants were exposed to simple arithmetic operations (e.g., 3 + 8 = 11). According to the cognitive load hypothesis, if participants read these formulas (and perhaps covertly check the validity of the provided solution) just as they read irrelevant verbal cues in the IAM task, the formulas should increase the cognitive load as would the additional verbal cues in the frequent cues condition, compared to the infrequent cues condition in which only 90

cue-phrases are presented. However, because particular formulas are very unlikely to match any records in participants' memory, they should not create memory interference. Thus, the cognitive load hypothesis predicts that the number of IAMs should be lower in the frequent cues and in the infrequent cues plus math conditions (both with higher cognitive load), compared to the infrequent cues condition (with lower cognitive load). By contrast, the memory interference hypothesis predicts an increased rate of IAMs in both the infrequent cues and infrequent cues plus math conditions, which are characterized by a low frequency of verbal cues (low memory interference) compared to the frequent cues condition (high memory interference).

In the present study, the focus was on quantitative measures of IAMs (number of involuntary memories and number of involuntary memories triggered by the cues, retrieval times). However qualitative (phenomenological characteristics) aspects of the retrieval of IAMs were analyzed for exploratory purposes.

Materials and Methods

Participants. Seventy two undergraduate students from the University of Florence (48 females, age range 18-33, M = 21.8 years) were randomly assigned to one of the three conditions, frequent cues (n = 24), infrequent cues (n = 24) or infrequent cues plus math (n = 24) conditions. Their first language was Italian, and they had normal or corrected-to-normal vision. Age differences among the conditions were not significant (F <1).

Materials. Vigilance task. The same vigilance task was used as in Vannucci et al. (2014, experimental condition "No IAM instructions/Self-interruption"). The task consisted of 450 trials, each remaining on the screen for 1.5 sec. Each showed a card depicting either a pattern of black horizontal (non-target stimuli) or black vertical lines

(target stimuli). Target stimuli appeared randomly on 9 trials of the task. Not all participants got target slides on exactly the same trials. As in previous studies (e.g. Schlagman & Kvavilashvili, 2008) the target slides were presented pseudo-randomly, that is every 40-60 trials (not fixed interval), in order to ensure that they occurred at long and irregular intervals. When either a cue word or a formula was included in a given trial, it was presented in size 18 Arial and placed in the middle of the card.

The word-phrases that served as cues were selected from the pool of 800 phrases used by Schlagman and Kvavilashvili (2008) and adapted to the Italian sample. Ten independent judges rated level of familiarity, imageability and concreteness of the cues on a 7-point scale (1 “low” - 7 “high”). The set of 90 word-phrases used in the infrequent cues condition was also used in the frequent cues condition. Moreover, the additional 210 word-phrases used in the frequent cues condition did not differ for imageability, familiarity and concreteness from the other 90 word-phrases. A set of 210 arithmetic operations in the form of easy sum and subtractions was prepared, and used in the infrequent cues + math condition. In each group, an equal number of positive (e.g. relaxing on a beach), neutral (e.g. washing hands) and negative (e.g. armed robbery) cues were used. The presentation order of the cues was pseudo-randomised for each participant

Autobiographical Memory Questionnaire. Participants recorded details of their memories on a modified version of a questionnaire used by Schlagman and Kvavilashvili (2008). We asked participants to rate how often the memory had been thought of/rehearsed before (1 = never; 5 = many times), how pleasant or unpleasant the memory event was (1 = very unpleasant; 3 = neutral; 5 = very unpleasant), the intensity of the feeling experienced during the retrieval (1 = none; 5 = a lot), whether the

remembered event was general or specific, and the life-period of the event (1 = childhood; 2 = adolescence; 3 = young adulthood). At the end of the experiment we also asked participants to rate on a 5-point scale their overall level of concentration during the vigilance task (1 = not at all concentrated; 5 = fully concentrated) and their level of boredom during the task (1 = not at all; 5 = very bored).

Procedure. Participants were tested individually. In the information sheet explaining the vigilance task, they were instructed to say out loud ‘‘yes’’ to each target stimulus (vertical lines), and that they would also see words or arithmetic operations in some of the trials. They were told that they were not supposed to do anything with these items. It was explained that the condition they were taking part in was looking at how people could keep their concentration on the patterns and that in another condition participants would have to concentrate on the words or arithmetic operations.

Participants were further instructed that, due to the task being quite monotonous, they could find themselves thinking about other things, which was quite normal. Participants were asked to click the mouse to interrupt the presentation of the stimuli if any task-unrelated mental contents (thoughts, plans, considerations, past events, images, etc.) popped into their mind during the task (see Vannucci et al. 2014). This would stop the vigilance task and allow them to write a short description of the mental content and to indicate whether it was triggered by internal thoughts, by an element in the environment or a word on the screen (if the mental content was triggered by a word on the screen, participants were asked to specify the word). They were told that this initial brief description of the mental content should be sufficient to remind them of that specific mental content at the end of the vigilance task when they would be presented with the brief descriptions of their mental contents

and asked to complete a brief questionnaire. After the instructions, participants were given a short 20-trials practice of the vigilance task. As in the experimental session, they were allowed to stop the presentation if they had any task-unrelated thoughts. At the end of the vigilance task, participants were shown their descriptions of mental contents one by one and asked first to classify them as an involuntary memory or a non-memory thought. For each item classified as involuntary memory they had to also complete the brief questionnaire assessing various aspects of memories on rating scales.

Results

All participants completed the vigilance task successfully, with an average of 8.79 (*SD* = .60) targets detected (out of 9), and no significant difference between the three groups (Frequent cues: M = 8.79, SD = .83; Infrequent cues: M = 8.75, SD = .53; Infrequent cues + Math: 8.83, SD = .38) ($F < 1$).

No significant difference was found in the level of concentration in the three groups (p = .44). The mean level was 3.86 (SD = .86) for the total sample. Level of boredom was significantly higher in the infrequent cues + math group (M = 3.33, SD = .96) compared to the other two groups (infrequent cues, M = 2.00, SD = .93; frequent cues, M = 2.30, SD = .93) ($p < .001$)[1].

Twelve out of 72 participants did not report any involuntary memories throughout the session, three in the frequent cues condition, two in the infrequent cues condition, and seven in the infrequent cues + math condition. Participants gen-

[1] Due to a technical error, the data of 3 participants (2 of the infrequent cues group and 1 of the frequent cues group) were not recorded.

erated a total of 259 IAMs with a mean of 3.60 (SD = 3.82, range 0-19) per participant, and a total of 398 non-memory mental contents, with a mean of 5.53 (SD = 6.57, range 0-31). Out of 259 IAMs, 86.49% were triggered by the word-phrases presented on the computer screen, 11.58% were triggered by internal thoughts and only 1.93% by other environmental cues.

The frequencies of IAMs and non-memories as well as their qualitative ratings in all experimental conditions can be found in Table 1. To assess the effects of the three experimental conditions on IAMs, the average number of IAMs per person was calculated and entered into a one way ANOVA. Results showed an effect of group, F (2, 69) = 9.39, MSE = 11.82 , $p < .0001$, with the infrequent cues group reporting more than twice the number of IAMs reported by the frequent cues (post hoc Bonferroni, $p < .005$) and infrequent cues + math ($p < .0005$) groups, which in turn did not differ significantly from each other ($p = 1.0$) (see Figure 1).

A similar pattern was obtained also with mental contents that were not memories (globally called thoughts), F (2, 69) = 5.25, MSE = 38.56, $p < .01$. The infrequent cues group reported more than twice the number of thoughts reported by the frequent cues group (post-hoc Bonferroni $p < .05$) and the infrequent cues + math group ($p < .05$) (see Figure 1).

A similar pattern was obtained also when we limited the analyses to IAMs that participants reported as being triggered by the cues presented on the computer screen. For cue-triggered IAMs, the effect of condition was significant, F (2, 69) = 7.34, MSE = 10.82, $p < .001$. More IAMs were reported with infrequent cues (M= 5.17, SD = 4.81) than with frequent cues (M = 2.46, SD = 2.50, post-hoc Bonferroni, $p < .05$) or infrequent cues + math (M = 1.71, SD = 1.76, $p < .005$). These two last conditions were not significantly different. These results consistently show that the

infrequent cues condition was the most effective in eliciting both IAMs and thoughts.

Next, we assessed whether the experimental manipulation affected the phenomenological qualities of IAMs. The mean ratings for all recorded memory characteristics were calculated for each participant before entering into several one-way ANOVAs. Analyses were first performed on the total number of IAMs and then on the subset of memories triggered by the cues. The Two-Step Adaptive Procedure of Benjamini-Hochberg (Benjamini, Krieger, & Yekutieli 2006) was used to correct for multiple comparisons. This procedure provides an effective control of the false discovery rate while limiting the loss of statistical power associated to the Bonferroni correction. No significant differences were found between the groups in any memory characteristic (see table 1).

However, using the software GPower (Faul, Erdfelder, Lang & Buchner, 2007), we estimated that the available sample size would allow us to detect only large effect sizes. Since any correction of the comparisonwise significance level to limit the inflation of Type I errors leads to a further decrease of statistical power, for exploratory purposes we repeated the analyses on the characteristics of IAMs (total number of IAMs) without such correction. A significant difference between the groups was found only in the intensity of the feeling experienced during the retrieval, F (2, 59) = 3.94, MSE = .39, $p < .05$. Post-hoc Bonferroni revealed that higher levels of intensity of feeling at retrieval were reported with frequent cues (M = 3.94, SD = .68) than with infrequent cues (M = 3.44, SD = .59).

For those IAMs and thoughts that were reported by participants as being triggered by cues presented on the computer, it was also possible to calculate retrieval

times. When participants had an IAM or a thought, they clicked the mouse, and the computer recorded a reaction time (RT). Retrieval times were calculated by adding the RT for the present (clicked on) trial, to the RTs for all the trials back, up to the trial that presented the word that was reported by the participant as the trigger of the mental content. To assess the effect of the experimental conditions on retrieval times of IAMs, the median reaction time per person was calculated and entered into a one-way ANOVA. No significant differences were found in the three groups (frequent cues: M = 12.31 sec, SD = 20.81 sec; infrequent cues: M = 5.65 sec, SD = 3.08 sec; infrequent cues + math: M = 4.95 sec, SD = 4.04 sec) (p = .14). The same pattern was found with thoughts (p =.71). Given that RTs in this experiment were skewed, we also repeated, after checking for outliers, the analysis of retrieval times of IAMs after log-transformation of RTs. This did not change the pattern of results, which again showed no reliable effect of the experimental group (p = .20).

Discussion

In everyday life autobiographical memories can come to mind spontaneously, without any deliberate attempt to recall. These involuntary memories are more likely to occur when one is engaged in automatic activities that require little attention and concentration (e.g., Berntsen & Hall 2004; Kvavilashvili & Mandler 2004) and in the presence of easy identifiable cues/triggers, mainly external as opposed to internal (e.g., Berntsen 1996; Berntsen & Hall 2004). These real-life observations led Schlagman and Kvavilashvili (2008) to develop a novel laboratory procedure to examine IAMs under well-controlled conditions. In the present study, we used a modified and improved version of this procedure (Mazzoni et al. 2014; Vannucci et al.

2014) and we confirmed its suitability for examining the phenomenon of IAMs. Not only were we able to obtain reliable levels of IAMs related to well-specified environmental cues, we also demonstrated that the rate of incidence of IAMs can be manipulated by modifying the rate of cue presentation.

The present study was largely motivated by a persistent enigma in the research on IAMs: given that these memories are triggered by environmental cues and given the constant flow of such cues in real life, why we are not flooded by involuntary memories? The use of the laboratory procedure developed by Schlagman and Kvavilashvili (2008) allowed us to simultaneously test three hypotheses concerning this problem. The *volume hypothesis* suggests that relative scarcity of IAMs is due to the fact that only a small pool of quite specific cues is capable of eliciting such memories. The *cognitive load hypothesis* suggests that the analysis of the constant stream of environmental cues taxes the cognitive system in a way that precludes memory retrieval. The *memory interference hypothesis* suggests that rapid succession of environmental cues precludes the full development of IAMs because different memories stimulated by various cues interfere with each other, stopping memory retrieval.

The results of our study provide unequivocal support for the cognitive load hypothesis. We found that IAMs are by far more common under a relatively low frequency of presentation of environmental cues, when the cognitive system is less engaged in the analysis of external stimulation. This finding is inconsistent with the volume hypothesis as using more cues should increase rather than decrease the chances of obtaining a specific match between a cue and a related memory. Also, including arithmetic operations alongside verbal cues in our task led to fewer IAMs. Arithmetic operations should not lead to episodic memory retrieval and thus the drop

in the number of IAMs caused by their inclusion in the task cannot be accounted for by the memory interference hypothesis. The result remains, however, fully consistent with the cognitive load hypothesis, which clearly predicts that engaging the cognitive system in any type of demanding activity, whether verbal or non-verbal in nature, should reduce the number of IAMs, exactly as observed.

By emphasising the role of cognitive load in spontaneous autobiographical retrieval, our results are in agreement with several previous observations. For example, Kompus (2011) found that failures to incidentally retrieve memories were selectively associated with reduced activation of the default mode network (lateral and medial parietal regions as well as ventromedial frontal cortex), a pattern consistently found when the cognitive demands increase (e.g. Raichle et al. 2001), which is related to disruption of task-irrelevant thoughts (McKiernan et al. 2006).

In their studies on visual attention, Forster and Lavie (2008a, 2008b) have shown that a stimulus onset may capture attention even when it is irrelevant to the task and to any attentional settings associated with task performance. The cost of this capture by external distractors is a robust interference on the task performance. Our results suggest that, when the task is easy, monotonous and undemanding, external stimuli presented at high rates do not interfere with the behavioral performance in the vigilance task but with the involuntary occurrence of memories and thoughts.

It is also interesting to note that the results of our manipulation were the same for IAMs and for other non-memory mental contents– mental images or other mental contents that did not refer to a specific autobiographical memory. The effects of cognitive load observed here on non-memory contents are consistent with the results of previous studies on daydreaming and task-unrelated thoughts (Singer 1966,

1975), which showed that frequency of task-unrelated thoughts decreases when cognitive demands increased.

Interestingly, our manipulation of cue frequency strongly affected the number of IAMs, with less, if any, effect on their characteristics. On the one hand the null findings reported here might suggest that the characteristics of IAMs, as a particular type of mental contents, are largely unaffected by the way cognitive load impacts upon the process of creating them. However, the absence of evidence is not evidence of the absence: hence, a closer look at the data using a more explorative approach (justified by the small sample and the consequently reduced statistical power) showed a moderate effect of the rate of external cues on the intensity of the feeling experienced during the retrieval: IAMs reported by the "frequent cues" group were characterized by a stronger emotional experience during retrieval compared to IAMs reported by the "infrequent cues" group. Although this result needs to be replicated, it seems to suggest that in presence of high competition between memories at retrieval and high cognitive load, the few reported IAMs are the ones accompanied by a stronger emotional experience. Future studies should investigate further this aspect and they should also assess the effect on other characteristics of the memory, such as the degree of self-involvement in the event portrayed in the memory, or how the content is linked to self-relevant goals, etc., which have not been assessed in the present study and, indeed, represent crucial elements in autobiographical memory (see for example the model by Conway, 2005).

The exact mechanism by which cognitive load influences the occurrence of task-irrelevant thoughts more broadly, and IAMs more specifically, also remains to be established. One possibility includes the involvement of attentional processes operating within the working memory system. Working memory may be occupied by

the ongoing, cognitively-demanding processing, precluding the spontaneous formation of involuntary memories (see Baddeley, 1993). However, a long tradition of research documenting a relatively minor role of attentional resources in retrieval from long-term memory seems to argue against the attentional basis of the described effects. For example, Craik, Govoni, Naveh-Benjamin, and Anderson (1996) showed that dividing attention at study has profound effects on memory performance but dividing attention at the time of retrieval leaves memory performance unaffected. Also, studies that focused on the role of working memory in memory retrieval have generally stressed that this role is confined to strategic and controlled aspects of retrieval, such as specifying cues appropriate for accessing sought after information in memory (e.g., Unsworth, Brewer, & Spillers, 2013). In the present study the focus is on spontaneous retrieval. Hence the need for cue specification and other strategic aspects of retrieval should be circumvented, possibly downplaying the role of working memory. On the other hand, some recent studies suggest that the resistance of memory retrieval to manipulations taxing attentional resources might have been overstated in the literature. For example, Jones, Marsh, and Hughes (2012) showed that auditory distraction present at the time of retrieval from long-term memory does adversely affect the effectiveness of retrieval processes. If word-phrases and algebra presented in our study play the same role as the auditory distraction presented by Jones et al. (2012), then the role of diverted attentional resources in limiting retrieval of autobiographical memories cannot be excluded.

A variant of this attentional hypothesis implicates inhibitory mechanism as responsible for limiting access to the autobiographical memory system. Performing cognitively-demanding activities might require recruiting attentional inhibition towards associative processes that would otherwise lead to the activation of involun-

tary memories and thoughts (see Mandler 1994). Hasher and her colleagues (e.g., Hasher, Zacks, & May 1999) argued for an important role of inhibitory processes in supporting performance in the focal task. Interestingly, the inhibitory framework allows for formulating predictions that could be tested in further studies. First, inhibitory processes are known to be deficient in older adults (e.g., Healey, Hasher, & Cambell 2013) and this suggests that older adults may be less effective in limiting spontaneous retrieval of autobiographical memories under conditions of continuous external stimulation. Second, the recruitment of inhibitory processes is known to have, at least sometimes, lasting after-effects, limiting subsequent memory access to information undergoing inhibition (Healey, Cambell, Hasher, & Ossher 2010). If attentional inhibition is responsible for limiting spontaneous autobiographical memories in the present study, then it could be that access to inhibited memories, even a voluntary one would be impaired following the main experimental task. These possibilities await further research.

Moreover, apart from these possibilities, there is also one more possible explanation of the pattern of IAMs observed in the present study. A high cue frequency and the related additional cognitive demands may not so much affect the process of forming mental contents, but rather influence participants' awareness of their internal state and current contents of their own mind. Recently it has been proposed that in mind wandering, meta-awareness (i.e. one's explicit knowledge of current thoughts' contents) corresponds to an intermittent process whereby individuals only periodically notice the current contents of their mind. Direct comparisons between self-catching measures of the mind-wandering state and probe-catching sampling have shown that individuals routinely mind wander without noticing it (zoning out) (see for a review and discussion, Schooler et al. 2011). In a recent study, Vannucci

et al. (2014) found that people do not always notice that they have had a memory/thought during a vigilance task and they might then omit reporting them on numerous occasions. However, if stopped during the task they might become aware of having memories/thoughts at the moment or seconds earlier. In a related vein, we propose here that an increase in cognitive load, due to presenting many cues, might have a negative effect on the level of awareness of these task-unrelated mental contents, as external stimuli capture attention, leaving fewer of the resources available that are necessary in becoming aware of what happens during a mind-wandering task. Future studies should further examine this hypothesis, by using a probe catching method instead of the self-catching method employed here and by assessing the level of awareness of the mental state (e.g. aware vs unaware mind-wandering, in Christoff, Gordon, Smallwood, Smith & Schooler 2009).

The present findings, which deserve further investigation, provide an important contribution to our knowledge as to why, in our daily life, we are not constantly flooded by IAMs (Berntsen 2009). What our study demonstrates is that external stimulation responsible for IAMs may at the same time serve as a factor limiting the incidence of involuntary memories. Whenever we stop to analyze, consider, scrutinize incoming stimulation, we effectively engage in cognitive activities that increase the cognitive load, reducing the chances that we will experience a conscious autobiographical memory.

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Figure captions

Figure 1. Number of involuntary autobiographical memories (IAMs) and non-memories (thoughts) as a function of the experimental group (frequent cues, infrequent cues, infrequent cues + math).