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Visual attentional load affects the frequency of involuntary autobiographical memories and their level of meta-awarenesss

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Abstract

Involuntary autobiographical memories (IAMs) are memories of past events that come to mind without deliberate retrieval attempts. Common in everyday life, IAMs have recently become a topic of experimental investigations with laboratory procedures. In the present study, we build on the recent methodological advancement in the study of IAMs and we investigate the effects of manipulating the attentional load on the incidence of IAMs, as well as on the level of meta-awareness of these memories. In two experiments, attentional load was manipulated by varying the demands of the focal vigilance task and reports of IAMs were collected. In Experiment 1, participants were instructed to stop the vigilance task whenever mental contents unrelated to the task came to their minds (self-caught method). In Experiment 2, participants were intermittently interrupted and probed regarding the contents of their experience (probe-caught method) and the level of meta-awareness for these contents. In both experiments we found a reduction in the frequency of IAMs under increased attentional load. Moreover, in Experiment 2, IAMs were characterized by varied levels of meta-awareness, which was reduced by increased attentional load. These results suggest that attentional resources are necessary both for retrieving IAMs and for meta-awareness of these memories.

Key words: involuntary autobiographical memories, autobiographical memory, meta-awareness, attentional load

Introduction

For a long time, research on autobiographical memory has been mainly 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, in many situations in our daily lives we find ourselves being engaged in memories of personal events that come to mind with no conscious or deliberate attempt directed at their retrieval (Berntsen, 1996, 2010; Mace, 2007). During the last two decades, there has been a surge of interest in both psychology and neuroscience toward the investigation of involuntary autobiographical memories (IAMs) (see, for a review, Berntsen, 2010).

Up until recently, the most common approach for studying IAMs has been the naturalistic diary method, in which individuals are asked to keep a diary of the IAMs they experience in everyday life (e.g., Berntsen, 1996; Berntsen & Hall, 2004; Mace, 2004). The studies using the diary method established two major features of IAMs as experienced outside laboratory. First, the majority of IAMs are elicited by identifiable external cues, generally related to prominent aspects of the remembered experiences (cue-memory match, e.g., Berntsen, 1996; Berntsen & Hall, 2004). Second, IAMs are more likely to occur during undemanding activities that require little attention or concentration.

Over the last years, the study of IAMs has been extended to laboratory settings. Building on the first regularity of IAMs – their cue-dependent nature – a number of experimental procedures have been developed that aim specifically at eliciting IAMs (e.g., Ball, 2007; Schlagman & Kvavilashvili, 2008; Vannucci, Batool, Pelagatti, & Mazzoni, 2014). These procedures, by gaining control over triggers for IAMs, allowed for a detailed examination of the question concerning the properties of the cues that are effective in eliciting IAMs. For example, in the study by Schlagman & Kvavilashvili (2008), participants were asked to perform a vigilance task while being simultaneously exposed to task-irrelevant cue-phrases. Participants were instructed to stop the procedure whenever they experience an IAM, to record basic details about the memory (i.e., memory description, triggers, concentration rating) and then resume the vigilance task. In the study, the majority of IAMs reported during the task were triggered by the word-cues on the screen, with cues of negative emotional valence being more effective in eliciting IAMs compared to positive and neutral cues. Using a modified version of this experimental paradigm, Mazzoni, Vannucci, and Batool (2014) directly compared the effectiveness of verbal and pictorial cues in eliciting IAMs and showed that more IAMs were elicited when verbal cues were presented during a vigilance task. In a related vein, Berntsen, Staugaard, and Sørensen (2013) showed that only cues that uniquely pointed to a single memory, at the exclusion of other memory records, were capable to produce cue-memory matches strong enough to elicit IAMs (see also Rubin, 1995).

While the issue of cue-dependence of IAMs received much empirical scrutiny, the second regularity concerning IAMs derived from the diary studies – their preponderance in states of diffused rather than concentrated attention – remains understudied.

The results of diary studies suggest that the frequency of IAMs depends on the attentional demands of the ongoing task, but the intrinsic limitations of such studies, the inability to manipulate variables being the most obvious pitfall, prevent the possibility of identifying the exact mechanism(s) by which attentional load influences the occurrence of IAMs. To our knowledge, the role of attention in the elicitation of IAMs has been experimentally investigated only in a single study (Ball, 2007). Ball had participants produce free associations to word cues (concrete nouns). At the end of the trial, participants were asked to report if a personal experience had come to their minds while they were giving the free-association responses. Importantly, while providing free associations, half of the participants (control condition) observed an unchanging box in the middle of the computer screen, whereas the other half (dual-task condition) were asked to perform a secondary task of pressing a button in response to a color-changing box. The comparison between the two conditions revealed a negative effect of the higher attentional load: more associations preceded the IAM in the dual-task condition than in the control condition, suggesting that when attention load is low, memory cuing can lead to wider and faster spreading of activation throughout the memory networks, and thus to facilitated retrieval of IAMs.

The results obtained by Ball (2007) converge with the results of diary studies in suggesting the role of attentional load in triggering IAMs. However, the specific mechanism by which this modulation occurs remains unclear. Specifically, we argue that the reduction in the rate of IAMs under high level of attentional load might arise for two reasons. Attention-demanding activities might hamper the involuntary retrieval of autobiographical memories because attention allocated to a demanding focal task is removed from retrieval-related processes such as accessing and developing a memory (Baddeley, 1993) and/or inhibiting the memories competing for retrieval access (see Anderson & Spellman, 1995; Mandler, 1994). Apart from this retrieval effect, a post-retrieval effect of increased attentional load also seems possible. Specifically, attention-demanding activities might impact upon higher monitoring processes such as meta-awareness – people's ability to become aware of the contents of their own minds.

In the context of research on autobiographical memory, a recent study by Vannucci et al. (2014) found that people do not always notice that they have had an IAM 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. Recent studies on trauma-related intrusions reported that people often failed to recognize the occurrence of intrusive thoughts, suggesting that people may lack meta-awareness of their trauma-related thoughts (Takarangi, Lindsay, & Strange, 2015; Takarangi, Nayda, Strange, & Nixon, 2017; Takarangi, Strange, & Lindsay, 2014). In a related vein, studies of the phenomenon of mind wandering have shown that individuals routinely fail (at least temporarily) to notice that their minds have started wandering, as people are only intermittently aware of their current focus of attention (Smallwood, McSpadden, & Schooler, 2008).

Overall, all these findings lead to a hypothesis whereby attentional load may impact upon the incidence of IAMs not by, or rather not solely by, affecting memory retrieval but also by impacting upon post-retrieval processes associated with meta-awareness of cognitive states. The aim of the present study is thus to examine the role of attentional load in the involuntary retrieval of autobiographical memories, and specifically to assess separately the effects on both *retrieval* and *post-retrieval* (meta-awareness) processes involved in reporting IAMs. In two experiments, we manipulated attentional load associated with the focal task in a between-subjects design, with high attentional load being experienced by one group (High-AL), and low attentional load by the other (Low-AL). To assess IAMs, we employed a modified version of the vigilance task with irrelevant cue-words developed by Schlagman and Kvavilashvili (2008), already used in previous studies of IAMs (Barzykowski & Niedźwieńska, 2016; Mazzoni et al., 2014; Vannucci et al., 2014; Vannucci, Pelagatti, Hanczakowski, Mazzoni, & Rossi Paccani, 2015). In Experiment 1, IAMs were assessed using the self-caught method, by which participants were instructed to stop the vigilance task whenever mental contents unrelated to the task came to their minds. The reported contents were further analyzed to extract instances of IAMs. In Experiment 2, we applied the same experimental manipulation as in Experiment 1, but we assessed IAMs with the probe-caught method, by which participants were intermittently and pseudo-randomly interrupted and probed regarding the contents of their experience. By using the probe-caught method, the role of monitoring in reporting IAMs should be minimized, allowing for a clearer examination of the retrieval dynamics. Moreover, the probes used in Experiment 2 were also accompanied by a meta-awareness rating, asking how aware participants were of where their attention was focused immediately prior to the probe. In this way, we were able to assess the level of meta-awareness associated with retrieved IAMs in different attentional load conditions. In both experiments phenomenological properties of IAMs, as specificity, vividness, pleasantness, and intensity of the feeling experienced during the retrieval, were also assessed and analyzed for exploratory purposes.

3. Experiment 1

3.1. Methods

3.1.1. Design

The experiments in this study conformed to a between-subjects design comparing the effect of attentional load (low *vs.* high) on the number of IAMs and their phenomenological properties. For those IAMs that were reported by participants as being triggered by cues presented on the screen retrieval times were also collected and analysed.

As no previous research had addressed a similar issue, we had no a priori information to determine an expected effect size. Hence, for both experiments we decided to collect a number of participants that could allow us to detect significant differences with a large effect size. Given that we planned to mainly perform independent samples *t*-tests, we computed through G*Power 3.1.7 (Faul, Erdfelder, Lang, & Buchner, 2007) that, in order to detect significant differences with a large effect size ($d \geq 0.80$) with a significance level (two-tailed) of .05, a statistical power of .80, and the same number of participants in each group, a minimum total sample size of 52 participants could be considered adequate. Since some participants could decide to drop out from the experiment at any time and/or problems with the data collection devices could lead to missing or invalid data, some more participants were recruited.

3.1.2. Participants

Sixty-four undergraduate students from the University of Florence (42 females, mean age = 21 years, SD = 2.6 years; age range: 18-35 years) were randomly assigned to one of the two conditions, High-AL (n = 32) and Low-AL (n = 32). They were all native Italian speakers, with normal or corrected-to-normal vision. Groups did not significantly differ in age and sex ratio.

3.1.3. Materials

Vigilance task. During the experimental session, participants completed a modified version of the vigilance task developed by Schlagman and Kvavilashvili (2008) and used in previous studies to investigate IAMs (Mazzoni et al., 2014; Vannucci et al., 2014, 2015; Vannucci, Pelagatti, Chiorri, & Mazzoni, 2016). The task consisted of 510 trials of target detection, presented in a pseudo-random order (see below), each remaining on the screen for 1.5 sec. In the Low-AL condition, on each trial, an image was shown on the computer screen depicting either a pattern of black horizontal and black vertical lines (non-target stimuli) or a pattern of black horizontal and red vertical lines (target stimuli). In the High-AL condition, non-target stimuli consisted of a pattern of red horizontal and black vertical lines, whereas the target consisted of a pattern of black horizontal and red vertical lines (as in the Low-AL condition) (Figure 1).

In both groups, the target stimuli appeared on 10 trials and they were presented pseudo-randomly, that is, every 40-60 trials, in order to ensure that they occurred at long and irregular intervals (Schlagman & Kvavilashvili, 2008; Vannucci et al., 2014, 2015). Word-phrases that were to serve as cues for IAMs (e.g., “washing hands”, “favourite food”, “falling down stairs”) were placed in the middle of the image, presented in 18-CPI Arial font, and displayed without obscuring any of the lines. These were included on 102 trials (1/5 of the total number of trials). The word-phrases were selected from the Italian adaptation of a standardized pool of 800 word-phrases developed by Schlagman and Kvavilashvili (2008) and already used in previous studies on IAMs (for more details on the adaptation, see Vannucci et al., 2015). Equal numbers of neutral (*n* = 34), positive (*n* = 34), and negative (*n* = 34) cues were presented during the task.

<u>Memory characteristics questionnaire</u>. Participants recorded details of their memories on a modified version of a questionnaire used in previous studies on IAMs (Vannucci et al., 2015). We asked participants to rate the vividness of the memory (from 1 = 'very vague, almost no image at all', to 5 = 'very vivid, almost like normal vision'), its pleasantness (1 = 'very unpleasant'; 3 = 'neutral'; 5 = 'very pleasant'), and the intensity of the feeling experienced at retrieval (1 = 'none'; 5 = 'a lot'). We also asked participants to specify whether the remembered event was general or specific. Participants received instructions on how to identify a general and a specific memory (for more details, see Vannucci et al., 2016). At the end of the experiment, participants also rated their overall

level of concentration (1 ='not at all concentrated'; 5 = 'fully concentrated') and the level of boredom experienced during the task (1 = 'not at all'; 5 = 'very bored').

3.1.4. Procedure

Participants were tested individually. After completing the informed consent form, participants were told that they would take part in a study examining concentration using a vigilance task and they were instructed to detect target stimuli (images with red vertical lines and black horizontal lines) among a large number of non-target stimuli by saying "yes" out loud each time they detected a target stimulus. They were told that they would also see short word-phrases in some of the trials, but 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 (line detection group) and that in another condition (word detection group) participants would have to concentrate on the words (this was a cover story, the word-detection group did not exist). Participants were further instructed that, due to the task being quite monotonous, they could find themselves thinking about other things, which was quite normal. They were told that if any task-unrelated mental content (mental contents could refer to thoughts, intentions, plans for the future, past experiences, etc.) crossed their mind during the task, they should click the mouse to interrupt the presentation and write a short sentence describing their mental content. They were informed that this initial brief description of the mental content should be sufficient to remind them of that specific mental content at a later point in time. They were also asked to indicate whether the mental content was triggered by something (internal thoughts, an element in the environment, or a word-phrase on the screen) or whether there was no trigger. If the mental content was triggered by a word-phrase shown on the screen, they were asked to specify which one. The actual task was preceded by a short 15 trials practice phase (training). At the end of the vigilance task, after all stimuli had been presented and all contents recorded, participants were informed about the nature of involuntary memories and they were presented with the descriptions of their mental contents one by one and asked to indicate the involuntary memories. For each of the involuntary memories they were asked to complete a brief questionnaire assessing phenomenological properties of memories (see Materials). The session lasted approximately 45 to 60 minutes.

3.2. Results

We first assessed whether the manipulation of attentional load was effective in varying the demands of the vigilance task by examining the rate of errors in detection of the target perceptual patterns. Indeed, the High-AL and Low-AL groups differed in this respect, (χ^2 (1, n = 64) = 5.38, p = .020, r = .29), with the participants in the High-AL being more likely to make at least one error (94%) compared to the Low-AL group (72%). We decided to dichotomize the number of errors since 53 (82.8%) participants did not make any error, 6 (9.4%) made 1, 4 (6.3%) made 2, and 1 (1.6%) made 3.

No significant differences between the two groups were found in the self-reported level of boredom (High-AL: M = 3.00, SD = 0.84; Low-AL: M = 3.03, SD = 1.09; t(62) = -0.13, p = .898, d = 0.03) and concentration (High-AL: M = 3.59, SD = 0.56; Low-AL: M = 3.41, SD = 0.80; t(62) = 1.09, p = .281, d = 0.26) experienced during the task.

During the vigilance task participants were asked to report all task-unrelated mental contents that came into their mind. At the end of the task, participants performed the classification of mental contents as memories or not. Before conducting the data analyses, all mental contents classified as involuntary memories were read through by the experimenter to check that they were autobiographical in nature (semantic “mind-pops” were excluded).

Participants generated a total of 219 IAMs with a mean of 3.42 (*SD* = 2.38, range = 0-9) per participant. The majority of reported IAMs (96.35%) had an identifiable trigger. Of these, 82.94 % were reported to be triggered by the cues on the screen, 16.11% by internal thoughts, and 0.95% by other environmental cues. The comparison of the total number of IAMs between the two groups revealed that the Low-AL group reported more than twice the number of IAMs reported by the High-AL group (Low-AL: M = 4.81, SD = 2.07; High-AL: M = 2.03, SD = 1.79; $t(62) = 5.75$, $p < .001$, d = 1.44). A similar pattern was obtained when the analyses were limited to the subset of IAMs reported as being triggered by the specific cues on the screen: Low-AL reported a higher number of IAMs triggered by the cues compared to High-AL (Low-AL: M = 3.81, SD = 1.93; High-AL: M = 1.66, SD = 1.72; $t(62) = 4.73$, $p < .001$, d = 1.18).

We also compared in the two groups the mean proportion of memories that were reported to have a trigger. Triggers could be a cue, a thought or an environmental stimulus. Because environmental cues were reported as triggers of a memory in only two cases they were not further analysed. *t*-tests for independent samples revealed no significant differences between High-AL and Low-AL in the mean proportion of IAMs triggered by the cues (High-AL: M = 0.75, SD = 0.34; Low-AL: M = 0.78, SD = 0.25; $t(55) = 0.34$, $p = .733$, d = 0.10) or by thoughts (High-AL: M = 0.22, SD = 0.34; Low-AL: M = 0.17, SD = 0.23; $t(55) = -0.67$, $p = .504$, d = 0.18).

Next, we assessed whether the experimental manipulation affected the phenomenological qualities of IAMs. In this case the phenomenological qualities were rated for *each* reported IAM, and could vary not only between participants, but also within participants. Hence, we had to consider as a unit of analysis a single memory. Given that participants could report more than one IAM, we used a multilevel (or hierarchical) dataset, in which IAMs were nested into participants. The use of this strategy of analysis not only allowed us to take into account the non-independence of the units of analysis, but also to accommodate for unequal numbers of data points within participants (Jahng, Wood, & Trull, 2008). We thus specified random-intercept multilevel models to test for associations of the group factor (Low-AL *vs.* High-AL) with the ratings of phenomenological qualities of the IAMs, which were considered as the dependent variables. No significant differences between the two groups were found in any phenomenological qualities of IAMs (see Table 1), nor in their specificity (Odds ratio with "Low" as reference: 0.88, confidence interval [CI]: 0.43-1.74, $p = .746$)

For those IAMs that participants reported as being triggered by word-phrases shown on the screen, retrieval times (RTs, as in Schlagman & Kvavilashvili, 2008) were calculated. RTs 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. Similarly to the analyses on the phenomenological qualities of the IAMs, we specified random-intercept multilevel models. Given that RTs in this experiment were substantially skewed (4.53) and kurtotic (29.77), we conducted the analysis of retrieval times of IAMs after log-transformation of RTs. The analysis revealed an effect of the Group ($F(1, 59.30) = 5.59$, $p = .021$), where RTs were slower in the High-AL group (estimated $M = 3.84$, 95% CI: 3.73-3.94) compared to the Low-AL group (estimated $M = 3.68$, 95% CI: 3.61-3.76)

4. Experiment 2

The reduction in the rate of IAMs found in Experiment 1 might arise for two reasons: attention-demanding activities may have interfered with the retrieval processes and/or they might have reduced the ability to monitor one's mind in order to notice and report IAMs. To distinguish between these two effects, in Experiment 2 we assessed

IAMs by using a probe-caught method, together with an assessment of the level of meta-awareness.

4.1. Methods

4.1.2. Participants

Sixty undergraduate students from the University of Florence (47 females, mean age = 21.35 years, *SD* = 1.87 years; age range:) were randomly assigned to one of the two conditions, High-AL (*n* = 30) and Low-AL (*n* = 30). All participants were native Italian speakers, with normal or corrected-to-normal vision.

4.1.3. Materials

Vigilance task. The vigilance task and the experimental manipulation of focused attention was the same as in Experiment 1 but the number of trials was extended from 510 to 800. The target stimuli (black horizontal lines and red vertical lines) appeared on 16 trials and the word-phrases on 160 trials (54 were neutral, 53 positive and 53 negative). At 15 fixed points during the presentation, the vigilance task was stopped and two questions (a probe trial) appeared on the screen. The first question was "What were you thinking about just immediately prior to the probe?" with response options "I was focused on the task", "I was thinking about" (and write down a short sentence describing their mental content and the trigger, if any) and "My mind was blank". The second question was "How aware were you of where your attention was focused?" Participants indicated their level of awareness by using a 7-point scale (1 = fully aware; 7 = fully unaware). The first probe was at trial 35 and there were a minimum of 35 and a maximum of 72 trials between each probe trial.

Memory characteristics questionnaire. Participants were asked to fill out the same memory questionnaire used in Experiment 1.

4.1.4. Procedure

Participants were tested individually in the same way as in Experiment 1. They received the same training phase and the same tasks upon the completion of the main vigilance sections of the experiments. The instructions were modified to inform participants that they would be interrupted during the performance and presented with thought probes consisting of two questions.

4.2. Results

Due to a technical error, the data of two participants (one in the High-AL group) were not recorded. The High-AL group was more likely (93%) to commit at least one error in the vigilance task than the Low-AL group (72%) (χ^2 (1, *n* = 58) = 4.35, *p* = .040, *r* = .27), confirming that our manipulation served to vary the demands of the focal task. We again decided to dichotomize the number of errors since 48 (82.8%) participants did not make any error, 7 (12.1%) made 1, 1 (1.7%) made 2, 1 (1.7%) made 4, and 1 (1.7%) made 6.

No significant differences between the two groups were found in the self-reported level of boredom (High-AL: *M* = 3.03, *SD* = 0.91; Low-AL: *M* = 3.07, *SD* = 0.92; *t*(56) = 0.14, *p* = .886, *d* = 0.04) and concentration experienced during the task (High-AL: *M* = 3.38, *SD* = 0.68; Low-AL: *M* = 3.59, *SD* = 0.87; *t*(56) = 1.01, *p* = .315, *d* = 0.27).

Participants generated a total of 143 IAMs with a mean of 2.47 (*SD* = 2.04, range = 0-9) per participant. The majority of IAMs (95.10%) had an identifiable trigger. Of these, 77.21% were reported to be triggered by the cues on the screen, 16.91% by internal thoughts, and 2.94% by other environmental cues.

The comparison of the total number of IAMs between the two groups showed that Low-AL group reported significantly more IAMs than did the High-AL group (Low-AL: *M* = 3.31, *SD* = 2.25; High-AL: *M* = 1.62, *SD* = 1.37; *t*(56) = 3.45, *p* = .001, *d* = 0.91). A similar pattern was obtained when the analyses were limited to the subset of IAMs reported as being triggered by the specific cues on the screen: Low-AL reported a higher number of IAMs triggered by the cues compared to High-AL (Low-AL: M = 2.72, SD = 2.03; High-AL: M = 0.93, SD = 1.05; $t(55)$ = 4.17, p < .001, d = 1.10). These results replicate the main results of Experiment 1, but this time with a probe-catching rather than self-catching method.

We also compared in the two groups the mean proportion of memories that were reported to have a trigger. Triggers could be a cue, a thought, or an environmental stimulus. Environmental cues as triggers of a memory were reported in only two cases and were not further analysed. *t*-tests for independent samples revealed that the High-AL reported a lower proportion of IAMs triggered by the cues compared to Low-AL (High-AL: M = 0.55, SD = 0.43; Low-AL: M = 0.84, SD = 0.25; $t(51)$ = 3.12, p = .003, d = 0.85), but no significant difference was found in the mean proportion of IAMs triggered by thoughts (High-AL: M = 0.16, SD = 0.29; Low-AL: M = 0.09, SD = 0.16; $t(47)$ = -1.23, p = .225, d = 0.36).

Next, we assessed whether the experimental manipulation affected the level of awareness associated with the retrieval of IAMs. As in Experiment 1, we allowed a multilevel structure to the data, since the level of awareness of an IAM could vary both between and within participants. Again, the unit of analysis was the single IAM. Low-AL participants reported a higher level of awareness (lower rating) compared to High-AL (Low-AL: estimated M = 2.63 (95% CI: 2.08-3.18); High-AL: estimated M = 3.63 (95% CI: 2.97-4.28); $F(1, 49.40)$ = 5.47, p = .023). Thus, increased attentional load not only reduced the number of IAMs caught by the probes, as seen in the earlier analysis, but it also reduced awareness of the remaining IAMs that were eventually caught by the probes. These results point to a double-whammy effect of attentional load on IAMs, with the effects located both at the stage of memory retrieval and at the stage of conscious experience of retrieved memories. No significant differences between the two groups were found in any phenomenological qualities of IAMs (see Table 2), nor in their specificity (Odds ratio with "Low" as reference: 0.92, CI: 0.29-2.95, p = .885).

5. General Discussion

The present study looked at the incidence of IAMs elicited in a laboratory procedure as a function of attentional load of the primary task during which IAMs were collected. Overall, increased attentional load was associated with the reduced number of IAMs, as assessed with both self-caught (Experiment 1) and probe-caught method (Experiment 2). These results indicate that attentional load posed by the focal task in which one is engaged is a major factor determining whether spontaneous and unrelated memories of one’s past are likely to occur. The fact that this reduction was observed with the probe-caught method – a procedure specifically designed to circumvent the post-retrieval monitoring processes – indicates that one mechanism by which increased attentional load reduces the incidence of IAMs is by limiting the basic retrieval processes operating within the system of autobiographical memory. However, additional results from Experiment 2 indicate also that increased attentional load not only interferes with the retrieval of IAMs, but at the same time it reduces the self-reported meta-awareness of the spontaneous memories that pass the retrieval threshold. Taken together, these results point to a double role of attentional resources in shaping both the retrieval (occurrence of IAMs) and post-retrieval processes (meta-awareness of IAMs) related to spontaneously arising autobiographical memories.

By emphasizing the role of attentional load in the occurrence of spontaneous autobiographical memories, our findings are in agreement with the results of the diary studies, which showed that IAMs are more likely to be reported when one is engaged in undemanding activities that require little attention and concentration (Berntsen & Hall, 2004; Kvavilashvili & Mandler, 2004). They also join the empirical contribution of Ball (2007), who found that IAMs came to mind later during a word-association task if attentional load was increased under dual-task conditions. Importantly, in the present study, we could clearly demonstrate a causal role of focused attention in controlling IAMs by using a direct experimental manipulation targeting attentional load while equating experimental conditions in terms of other variables such as the amount of visual stimulation and response demands. However, the crucial insight that our use of the laboratory procedure enabled was a clear delineation of the double-mechanism account by which attentional load operates both at retrieval and post-retrieval levels of cognitive processing within the system of autobiographical memory.

The negative effects of attentional load on the rates of IAMs observed here could help to clarify the results of a recent study on IAMs in which the effect of cue frequency on the rate of IAMs was observed (Vannucci et al., 2015). In this study, which also used the vigilance task employed here, cue frequency was experimentally manipulated, so that participants were presented with frequent verbal cues or infrequent verbal cues with the remaining trials in the vigilance task either left empty or filled with arithmetic operations. It was found that, compared to infrequent cues, both conditions with frequent cues and infrequent cues plus arithmetic operations decreased the number of IAMs reported (for a similar effect on involuntary musical imagery, see Floridou, Williamson, & Stewart, 2016). The present study suggests that this difference in the incidence of IAMs arose because increased external stimulation – either in the form of frequent verbal cues or arithmetic operations – constituted additional cognitive load that interfered both with retrieval of IAMs and with participants' subjective insight into the contents of their own minds which is necessary for reporting an IAM.

Apart from informing research on IAMs, the present results are of consequence also for investigations of other forms of spontaneous cognition, as, for example, mind wandering. Indeed, so far, the lines of research focused on IAMs and mind wandering have developed to a large extent independently, with little discussion concerning the theoretical links between the two phenomena (but see McVay & Kane, 2013; Plimpton, Patel, & Kvavilashvili, 2015; Vannucci, Pelagatti & Marchetti, 2017). Both IAMs and MW are mental contents that are incidental to the focal task and spontaneously generated (but see Seli, Risko, Smilek, & Schacter, 2016, for a discussion of intentional MW), potentially creating a common conceptual framework encompassing both phenomena. Indeed, a significant proportion of episodes examined in mind wandering studies have been described as concerning personal past and thus could be possibly classified as IAMs (Smallwood, Nind, & O'Connor, 2009; Stawarczyk, Cassol, & D'Argembeau, 2013). However, the theoretical considerations of IAMs and mind wandering differ in one important aspect. IAMs are clearly cue-dependent (Berntsen, 1996; Berntsen & Hall, 2004), with a number of studies being devoted specifically to elucidating the nature of the cues that are most likely to elicit IAMs. Indeed, the cue-dependent nature of IAMs forms the basis of the procedures used to investigate this phenomenon, including the procedure used in the present study. By contrast, in the mind wandering literature, mind wandering episodes have been mainly described as self-generated (e.g., Smallwood, 2013) and stimulus-independent (Antrobus, 1968), terms that emphasize their independence from perception and ongoing actions. Only very recently, a few studies employed a modified version of the vigilance task with irrelevant cues originally developed for studying IAMs, to investigate the association between external cues and the frequency and temporal orientation of mind wandering (Plimpton et al., 2015; Vannucci et al., 2017). The results of these studies demonstrated that task-irrelevant verbal stimulation (i.e. word-phrases) increases the frequency of mind wandering and steers its temporal orientation toward the past.

In fact, previous studies on mind wandering have consistently shown that the frequency of mind wandering depends heavily on the cognitive demands of the ongoing task. The rate of mind wandering is reduced whenever the focal task is made more difficult, requiring a stronger involvement of the attentional processes operating within the working memory system (Levinson, Smallwood, & Davidson, 2012; Teasdale et al., 1995) or focused attention (e.g., manipulation of perceptual load, Forster & Lavie, 2009) – that is, when the attentional load is increased. Our results on the effects of attentional load on retrieval and post-retrieval processes of IAMs, collected within a paradigm designed specifically to assess IAMs clearly parallel the observations reported in the mind wandering studies and add to the argument for common cognitive principles governing mind wandering and IAMs.

Apart from exploring the links between mind wandering and IAMs, three other future directions present themselves. First, in Experiment 1 we found that for IAMs reported as being triggered by word-phrases, retrieval times (RTs) were slower in the High-AL group compared to the Low-AL group. These findings suggest that attentional load might also interfere with the time needed to generate and/or become aware of an IAM. So far, research on IAMs has been focused on the rates of IAMs but these results suggest that the temporal dynamics of IAMs should also be explored. Second, in the present study we investigated the effects of attentional load on IAMs and their meta-awareness in a sample of young adults. Future studies might investigate these effects in other populations of special interest for research on IAMs, such as elderly people. A few studies using diary methods (Schlagman, Kliegel, Schulz, & Kvavilashvili, 2009;

Schlagman, Kvavilashvili, & Schulz, 2007) found age-related reduction in IAMs when elderly participants reported being more concentrated on the ongoing activities compared to younger adults. The decrease in the frequency of IAMs could thus potentially be explained, at in least in part, by the age-related reduction in attentional abilities, a possibility that awaits further work. Finally, in our study we focused on ordinary, daily-life IAMs. However, research on spontaneously evoked memories is of importance not only for understanding cognition in standard, every-day situations but also for advancing investigations into abnormal forms of cognition, such as intrusive memories occurring in post-traumatic stress disorder. For this reason, future studies might extend the investigation of the role of attentional load in governing spontaneous memories to unpleasant and unwanted intrusive memories/images for negative or adverse material. Recent studies on trauma-related intrusions reported that people are not always aware of them (i.e., people may lack meta-awareness of their trauma-related thoughts) (Takarangi et al., 2014, 2015, 2017), suggesting that self-report may underestimate the frequency of intrusive thoughts and memories. Future studies are needed to investigate whether and how (i.e., retrieval and post-retrieval processes) attentional load might affect the frequency of occurrence of this other kind of spontaneous cognition.

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Compliance with Ethical Standards

-All the authors declare that they have no conflict of interest.

-All procedures performed in the study are in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

-Informed consent was obtained from all individual participants included in the study.

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Captions

Fig1. Example of the stimulus displays in High-Attentional Load (High-AL; top) and Low-Attentional Load (Low-AL; bottom) group

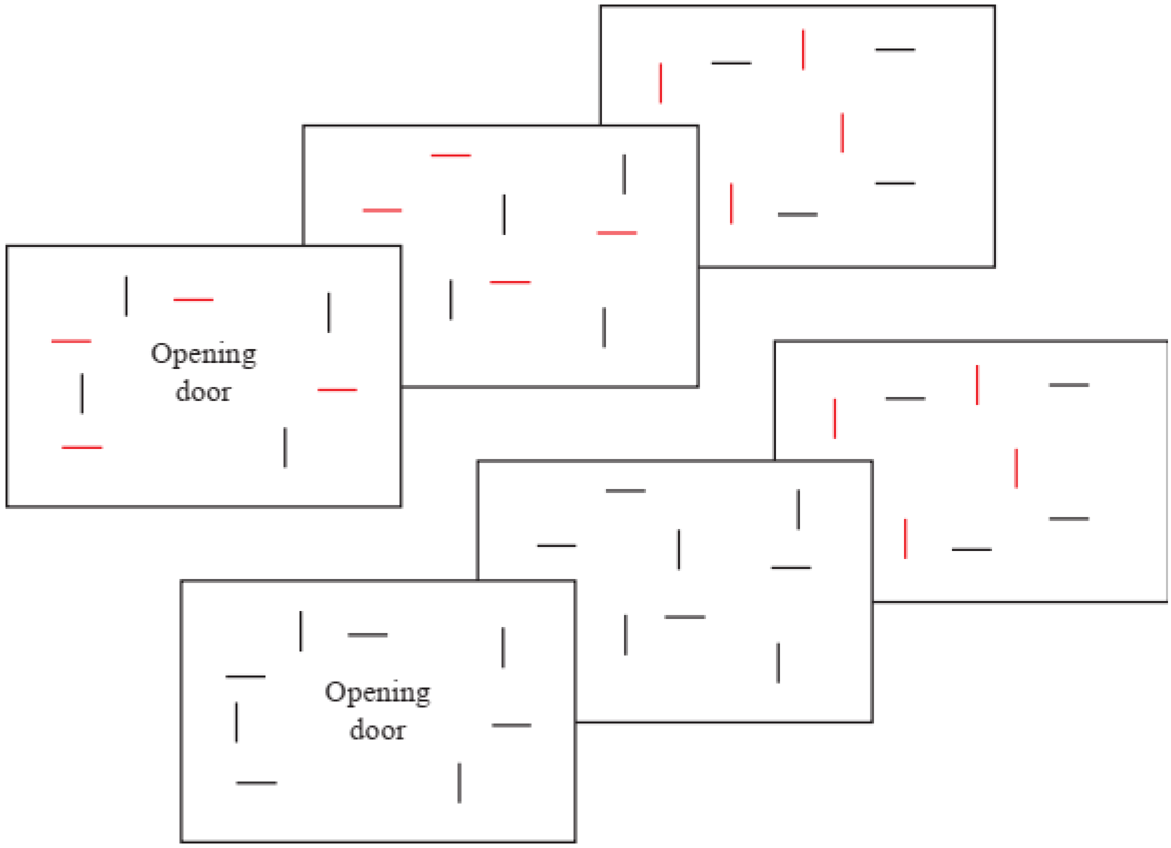

Table 1. *Phenomenological qualities of involuntary autobiographical memories in High-Attentional Load (High-AL) and Low-Attentional Load (Low-AL) groups in Experiments 1 and 2.*

Variable	Estimated group means (95% CI)		F	df	p
	Low-AL	High-AL			
Experiment 1					
n	32	32			
Vividness	4.20 (4.01-4.38)	4.10 (3.84-4.36)	0.34	1, 60.54	.559
Pleasantness	3.35 (3.11-3.59)	3.29 (2.94-3.64)	0.07	1, 64.92	.795
Intensity	3.36 (3.13-3.60)	3.18 (2.85-3.51)	0.80	1, 64.41	.374
Experiment 2					
n	29	29			
Vividness	3.99 (3.69-4.28)	3.92 (3.54-4.31)	0.06	1, 51.13	.793
Pleasantness	2.95 (2.64-3.25)	3.12 (2.70-3.54)	0.46	1, 44.15	.498
Intensity	3.30 (2.98-3.62)	3.05 (2.63-3.47)	0.91	1, 40.28	.345

Note: CI: confidence interval; df = degrees of freedom; *n* = number of participants