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ORIGINAL ARTICLE

Involuntary memories and involuntary future thinking differently tax cognitive resources

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Abstract

During the past 20 years involuntary memories have been established as a noteworthy phenomenon, which occur spontaneously in everyday life and with greater frequency than expected. Other types of ideations also occur involuntarily and very frequently, both in the normal population and in clinical groups. The aim of this paper was to assess for the first time whether involuntary memories and involuntary future thoughts differ in the amount of cognitive resources, considering that both are experienced as being rather automatic. As in previous work on mind wandering, this was done by assessing the effect of different conditions on frequency of spontaneous thoughts about past and future. Involuntary memories and future thoughts were obtained in an experimental setting (vigilance task) that mimics a mind-wandering task. In it, participants saw slides (trials) with horizontal or vertical (target) lines. In half or one-fourth of the trials verbal cues were also presented. In a third condition one-fourth of the trials had verbal cues and one-fourth had simple arithmetic calculations. Participants were asked to report any mental content that crosses their mind when the vigilance task stopped. Results show that the manipulation modulates the number of both involuntary memories and future thoughts, and both engage cognitive resources. Future involuntary thoughts seem to require more cognitive effort than involuntary memories and, specifically, future scenarios require more cognitive resources than both involuntary memories and future plans. The results support previous findings showing that reporting spontaneous mental contents makes use of cognitive resources and are discussed linking the involuntary memory literature with mind wandering and metacognitive processes.

Introduction

This paper represents an initial attempt to understand whether the spontaneous retrieval of memories require more or less cognitive resources than the spontaneous production of future thoughts. This has been assessed by measuring the frequency of thought occurrence in various conditions, similarly to the way previous research on mind wandering has assessed the role of executive functions in spontaneous thinking (e.g., Smallwood, Brown, Baird & Schooler, 2011). Research starting from the work of Antrobus (1968) on stimulus-independent thoughts has consistently shown that people commonly experience the spontaneous production/retrieval of various types of mental contents during undemanding activities. Spontaneous mental production and ideation has been variably labelled as stimulus-independent thought (e.g., Antrobus, 1968; Antrobus, Singer, Goldstein & Fortgang, 1970; Teasdale, Lloyd, Proctor, & Badgeley, 1993), or task-unrelated images and thoughts (Giambra, 1995), and more recently as task-unrelated thought (e.g., Smallwood, Baracaia, Lowe, & Obonsawin, 2003), mind pops (Kvavilashvili & Mandler, 2004), or zone outs (e.g., Schooler, Reichle, & Halpern, 2005). This whole body of research has then mainly been subsumed under the larger umbrella of mind wandering (Smallwood & Schooler, 2006).

In an independent and parallel way, substantial research has focussed on involuntary memories (e.g., Ball, 2007; Batool & Mazzoni, 2011; Berntsen, 1996; Berntsen, 1998; Berntsen, & Hall 2004; Berntsen, 2009; Mace, 2004; Mazzoni, Vannucci & Batool, 2014; Rasmussen & Berntsen, 2011; Schlagman & Kvavilashvili, 2008; Vannucci, Batool, Pelagatti, & Mazzoni, 2014), which are spontaneous mental contents about past personal experiences activated by external and internal triggers. In everyday life, involuntary memories typically occur during undemanding activities (Berntsen, 2009; Mace, 2007; however, see Barzykowski & Nidwienska, 2018) and are more common than expected

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(Berntsen, 2009). In initial diary studies, for example, involuntary memories were reported by participants as occurring during periods in which they were not focussed on any specific task, for example when idly walking or letting their mind wander (e.g., Berntsen 1996; 1998). In these studies necessarily participants were informed in detail about the nature of involuntary memories and asked to notice and report any involuntary memory that had occurred during the day. The report could be done at the moment of the realization or at any time during the day or the whole period of observation.

In these diary studies, it has been shown that involuntary memories are subjectively reported as occurring on an average four times per day (Berntsen, 2009). Subsequent studies using more controlled paradigms in the laboratory (Schlagman & Kvavilashvili, 2008; Batool & Mazzoni, 2011; Vannucci, Batool, Pelagatti & Mazzoni, 2014; Mazzoni, Vannucci & Batool, 2014; Vannucci, Hanczakowski, Pelagatti, Mazzoni, Paccani, 2015; for a different procedure, see Berntsen et al. 2013) have shown that during a vigilance task lasting approximately 1 h participants report even more involuntary memories than in diary studies, on average eight per session. In the experimental vigilance task (which is undemanding and rather boring) participants are presented with many trials (between 150 and 800, depending on the study). In each trial a screen is shown with horizontal or vertical (target) lines. Participants are asked to press a key only for target trials (vertical lines), which occur very rarely. In the original study (Schlagman & Kvavilashvili, 2008), for each trial in the middle of the screen short word-phrases were also presented (e.g., a glass of wine), that participants were instructed to disregard (the cover story stated that a second group was to pay attention to these word-phrases). In subsequent studies word-phrases have not been presented in each trial, but in predetermined spaced ways (see Vannucci et al. 2015), a manipulation that led to an increase in the number of involuntary memories reported.

In the original study participants were instructed to report only when they realized to have an involuntary memory (Schlagman & Kvavilashvili, 2008), instructions that could have had an effect on attention and monitoring processes during retrieval, thus affecting the likelihood to report an involuntary memory. To leave retrieval as spontaneous as possible, in subsequent studies participants were told to report any mental content that was crossing their mind (Batool & Mazzoni, 2011; Mazzoni et al., 2014; Vannucci et al., 2014). This procedure is akin to more typical mind-wandering procedures of thought or experience sampling (e.g., Christoff, Gordon, Smallwood, Smith & Schooler, 2009) in which people's experience was assessed in an ecologically valid way (see Shiffman, 2000 for a review). In all conditions, word phrases were the most frequently reported triggers of involuntary memories. These verbal cues activated spontaneous memories also when participants were interrupted by the experimenter, thus bypassing in the participants the need to monitor constantly online their mental production (Batool & Mazzoni, 2011; Vannucci et al., 2015). In this thought-sampling procedure the frequency of involuntary memories was even higher, reaching an average of 13 per session (Batool & Mazzoni, 2011; Vannucci et al., 2014).

When people were left free to report any mental content (e.g., Batool & Mazzoni, 2011; Vannucci et al., 2014), other mental contents besides memories were mentioned, with a frequency between two and three times that of involuntary memories. These 'other thoughts' can be linked to mental contents that pop up during mind wandering (e.g., Smallwood & Schooler, 2006; see also Vannucci this issue). Mind wandering occurs frequently in everyday life (e.g., Kane et al. 2007). People experience memory and non-memory contents which are unrelated to the task and can occur also during daydreaming (e.g., Singer, 1966). Most relevant to the present paper, it has been observed that part of these spontaneous thoughts processes may also be directed towards the future (e.g., D'Argembeau, Renaud & Van der Linden, 2011). Berntsen and Jacobsen (2008) have shown that spontaneous representations of future events may be as common as spontaneous memories.

Do IAMs require cognitive resources?

The question addressed in this paper is whether involuntary memories require more or less executive control than other types of spontaneous thinking. More specifically the paper focuses on possible difference in the amount of cognitive resources used to spontaneously retrieve memories about the past (involuntary memories) or spontaneously produce thoughts about the future.

It has been proposed (see Berntsen, 2009, see also Rasmussen & Berntsen, 2011) that involuntary retrieval might be the basic retrieval mode from memory. It seemingly relies more on direct, associative retrieval, and depends on the possible match between the content of the cue and that of the memory representation (to be noticed that in this paper as well as in most papers on involuntary memories the term 'cue' is used as a general term even when the items used as cues in fact do not cue any mental content). Involuntary retrieval is thought to presumably represent an evolutionarily earlier type of retrieval that requires little executive control to monitor the memory processes involved (Rasmussen & Berntsen, 2011). Indeed, involuntary memories feel spontaneous, involuntary and rather automatic. However, in a recent study Vannucci et al. (2015) have shown that the production of IAMs requires cognitive resources. The Vannucci et al. (2015) study is here described in detail because it illustrates both the logic and the methodology used in the current experiment.

The main question addressed in the Vannucci et al. (2015) study was to understand why IAMs are fewer than what would be expected on the basis of the associative matching hypothesis. To this aim, Vannucci et al., compared three hypotheses that would lead to different outcomes, the Volume hypothesis, the Interference hypothesis and the Cognitive load hypothesis. Retrieval of IAMs seems to be based on the ability of contextual cues to trigger memory representations, and it has been proposed that only highly specific cues trigger a IAM. The Cue Overload hypothesis (Watkins & Watkins, 1975) states 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 (Berntsen et al., 2013, see also Rubin, 1996). If this is correct, and retrieval of IAMs is automatic, then the main bottleneck for IAMs is lack of sufficiently distinctive cues in the environment. Therefore, the likelihood of finding a sufficiently distinctive cue increases when the total number of cues is increased. This is the volume hypothesis, stating that more cues, compared to less cues, would increase the number of IAMs reported.

According to the second hypothesis, the Interference hypothesis, fewer IAMs are obtained when many cues are presented because of processing times being too short. Too many attempts to retrieve starting from different cues without much spacing between one and the next would create interference. This can occur during activation or retrieval. During activation, one consequence of increasing the rate of cue presentation is that the process of forming a new memory may not always be completed 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, higher presentation rates can interfere with the process of forming the mental representation of the IAM that potentially would have been triggered by the previous cue. It is also possible, however, that interference can occur at retrieval. If many memory representations are activated, each by a cue, and there is little spacing between each, then the interference effect can occur because of the bottleneck at retrieval. Both possibilities come under the Interference hypothesis.

An alternative hypothesis, the Cognitive Load hypothesis, states that retrieval of IAMs requires effort and thus taxes cognitive resources even if it feels effortless. Cognitive resources is the rather generic term intentionally used in the Vannucci et al. (2015) and in the current study to refer to resources required to complete controlled cognitive tasks (e.g., Hasher & Zacks, 1979). This is in line with the idea of a working memory central executive (Baddeley, 1986) that controls and coordinates cognitive processes during the performance of complex cognitive tasks, by assigning and distributing adequate resources within a relatively limited resource pool.

The claim of the paper by Vanucci et al. (2015), as well as of the current study, is that involuntary memories are necessarily consciously reportable experiences and as such make use of resources. In conditions with concomitant tasks that also make use of resources, the frequency of involuntary memories should be reduced. The argument made for IAMs is similar to what has been claimed for other spontaneous mental ideations in mind wandering (e.g., Smallwood & Schooler, 2006; Smallwood, 2010), in studies showing that taxing resources reduces the frequency of reported mental contents (Smallwood & Schooler, 2006; Christoff et al., 2009; Kane et al., 2007; Teasdale et al., 1995). These studies show that the mental activity in mind wandering interferes with cognitively demanding tasks, indicating the engagement of the executive system, a finding that has been more recently confirmed by Christoff et al. (2009) in a neuroimaging study showing that executive function areas of the brain are indeed recruited during mind wandering. Contents activated during mind wandering are conscious experiences than can be reported, and as such demand resources, even if just when reaching awareness (one idea proposed is that they need access to a 'workspace that supports conscious experience', Dehaene, Kerszberg, Changeux, 1998; Smallwood, 2010). In addition to showing failures in concomitant complex tasks when mind wandering increases (see also Smallwood et al., 2004; Smallwood, Riby, Heim, & Davies, 2006), more pertinent to the current study are results showing that frequency in mind wandering contents is reduced when working memory is engaged (e.g., Mason et al., 2007; Smallwood et al., 2003; Smallwood, Obonsawin, & Heim, 2003; see also Smallwood, Brown, Baird, & Schooler, 2012; Smallwood et al., 2009). Most of these studies use frequency as a proxy to assess the cost on mind wandering when resources are taxed. Similarly, the frequency of mental contents (in the Vannucci et al. study only involuntary memories, in the current study also future-related thoughts) is used as a way to infer the demands posed on resources by the activation and retrieval of spontaneous mental contents related to the past and the future.

In involuntary memory retrieval the assumption (Berntsen et al., 2013) is that each cue can potentially associatively activate a retrieval process for a mental content. As the content reaches awareness, a coordinating central executive function assigns and distributes adequate resources for the elaboration the content undergoes, including being monitored and reported. Thus, the retrieval process can be completed only if enough resources are available. With more cues and additional tasks (e.g., math tasks that are known to use executive resources), more resources are used leading to a decrease in the number of reported spontaneous mental contents because of unsuccessful retrieval attempts due to the inability to bring the process to completion.

To contrast these three hypotheses, Vannucci et al. compared three conditions. All participants were presented with 450 trials during a vigilance task, as in Schlagman & Kvavilashvili (2008). In the Frequent cues condition, 300 cues were presented, while only 90 cues were presented in the Infrequent cues condition. The volume hypothesis predicts to obtain more IAMs in the frequent compared to the infrequent cues condition. Finding more memories in the Infrequent cues condition could be interpreted as due to either Interference (fewer cues imply less interference) or to Cognitive Load (fewer cues mean lower expenditure of cognitive resources and thus enough resources for each cue). To contrast these two hypothesis, Vannucci et al. (2015) introduced a third condition, in which cues were infrequent (90, as in the infrequent cue condition), but in 210 trials a math problem (simple arithmetic operation) was introduced which needed to be solved, thus increasing the expenditure of resources, as simple arithmetic operations involve working memory.

In the Vannucci et al. (2015) study a total 300 trials had either a cue or the math task. The logic for using this Infrequent + Math condition is that if retrieving IAMs leads to interference at ideation or retrieval then adding the math problems should not have any effect on IAMs. Math problems would not lead to any activation of memory representations, and thus there would be no interference. The results should then be similar to those obtained in the Infrequent condition with 90 cues. If instead retrieving IAMs is at least in part a controlled process that requires cognitive resources, then adding arithmetic operations would use up resources necessary for the activation and retrieval of IAMs. The number of IAMs should then drop and be similar to the frequent cues condition, in which each cue would use up cognitive resources. The results of the study clearly showed that the reason why we are not flooded by involuntary memories is the need of cognitive resources when involuntarily retrieving a memory.

The present study: are the resources required for IAMs less or more than those required to produce mental contents about the future?

In the current paper, the logic and procedure of the Vannucci et al. (2015) study were used to assess differences in cognitive resource expenditure between IAMs and future thoughts. When comparing IAMS to spontaneous future thoughts, it becomes necessary to define more clearly what future thoughts are. It is easy to agree that 'future thoughts' is a rather vague term that encompasses many different types of thought processes (see for example the distinction made by judges in Plimpton, Patel & Kvavilashvili, 2015, p. 22 in 'future planning', 'thinking about an upcoming event' and 'thinking about a hypothetical event'). Thoughts about the future can also be worries, hopes, as well as comments, considerations, future scenarios, plans, etc. It is then necessary to identify which types of spontaneous future contents will be compared to IAMS, as various types of future mental contents might require different amounts of cognitive resources.

In a preliminary test, the ability of participants to spontaneously categorize the entire set of spontaneous mental contents reported during the vigilance task was assessed. In the main experiment the use of cognitive resources was examined by comparing the three conditions used by Vannucci et al. (2015). As this is a preliminary study, the issue of meta awareness (Schooler & Smallwood, 2007) is not addressed. Here it suffices to say that the prediction is that taxing the executive/control system should reduce the number of reports. This study does not address the question of whether the effect is at the level of activation/production per se, or if it is at the level of meta awareness of the contents produced. For a discussion of the role of meta awareness see Schooler, Smallwood, Christoff, Handy, Reichle et al., 2011; Chin & Schooler (2010).

As involuntary memories (IAMs hereinafter) are a subgroup of spontaneous mental ideations occurring during undemanding tasks (e.g., during mind wandering), they must share processes with other spontaneous mental contents that occur in similar conditions. For example, all spontaneous mental contents should be the result of the activation of existing mental representations due to internal and external triggers. Additionally, the experience of involuntariness of activation and retrieval similarly characterizes all these spontaneous mental contents. There are reasons then to think that involuntary memories and future thoughts might share some basic processes. For example, theoretical explanations of the retrieval mechanisms involved in involuntary memories invoke the notion of encoding specificity (Tulving, & Thomson 1973), by which the probability of retrieving a memory increases by increasing the overlap between the content of the cue (or context) and the content of the memory representation (see Berntsen, 2009 for a review; see also Moscovitch, 1995). This set of processes might not only occur during the retrieval of involuntary memories, but also be responsible for the activation of other spontaneous mental contents about the future. It is true that involuntary retrieval is conceived as due to a sufficient match between elements of the cue and central features or themes of the memory representation (e.g., Ball, Mace, & Corona 2007; Berntsen & Hall 2004; Berntsen 2009; see also Conway's (2005) model of direct retrieval, and the direct mapping idea in episodic memory). However, similarly, the creation of future thoughts might depend on an initial activation of mental representations determined by the content of the cue. It has been shown, for example, that imagining the future shares brain areas involved in autobiographical memory (e.g., Addis, Wong & Schacter, 2007; Buckner, 2010; Schacter, Addis, & Buckner, 2007). In memory, the representation has some central features or themes which, when activated by a cue, elicit the whole memory; in future thinking the representation activated by the cue in turn activates additional processes responsible for the complete creation of the ideation about the future.

An additional hypothesis proposed for involuntary memories retrieval can be applied to future contents. Cue overload (Watkins & Watkins, 1975) explains why some specific memories are retrieved and not others. The idea of a cue overload states that "the probability of recalling an item declines with the number of items subsumed by its functional retrieval cue" (Watkins & Watkins, 1975, p. 442; see also Berntsen et al, 2013). The same can in principle be true for the activation of some specific future thoughts and not others.

However, involuntary memories and future thoughts are also different. One can consider that mental representations of experienced events which are memories not only refer to the past, they also have special characteristics/qualities. For example, only memories, and no other mental content, are characterized by a strong subjective recollective quality [i.e., only mental contents which can be re-lived by travelling back in time are experienced as 'memories' (Gardiner & Java, 1990)]. Thus, some very specific processes might be involved only when spontaneously retrieving IAMs and be less active or even absent when other types of mental contents pop up in mind.

Conversely, some processes are most likely involved only in future thinking. Let's start by defining which types of spontaneous future thoughts will be compared to involuntary memories in the present study. Among all possible future contents, future scenarios and future plans were selected for the present experiment for two reasons: they were more frequently reported, and in principle shared some mental processes with involuntary memories as both involve, for example, the activation of episodic mental representations. They might also occur thanks to the activation of semantic elements, and the integration of episodic and semantic components. Differently from involuntary memories, however, in future mental contents hypothetical and counterfactual thinking can also be at play (see for example the idea of scenario creation according to the mental models account, Johnson Laird, 1980; 1983).

Which type of process might then require more mental resources? Given the role of reasoning/executive processes in future thinking, it is conceivable to hypothesize that spontaneous future scenarios and plans might require more resources than involuntary memories. The idea of effortful spontaneous future thinking has already been proposed in previous work on mind-wandering showing that future-oriented thoughts are more affected by working memory ability than spontaneous contents referring to the past (e.g., Baird, Smallwood & Schooler, 2011). However, in mind wandering the distinction between different types of mental ideations was not clearly drawn, as most studies seem to call all future thoughts 'plans' for the future. In the distinction adopted here between future scenarios and plans, one hypothesis is that more mental resources might be required for future plans than for future scenarios alone. To clarify, when creating a plan about a future trip, one not only can create a mental future scenario about a beach scene. The plan requires considering the period, the flights, the arrangement etc. A future plan is a much more complex mental construct compared to a future scenario, thus requiring more cognitive resources.

Conversely, it is also possible to conceive a future plan as a 'past memory for the future', a plan that has already been conceived and that simply pops up in mind triggered by a cue as if it was a memory about the past (the creation of the plan is a past event). At the same time it is about a future event. If the spontaneous activation of future plans is a past memory about the future (for previous discussions of the idea of 'memories of the future' in relation to directly retrieved or spontaneous future thoughts see Jeunehomme & D'Argembeau, 2016; Cole, Staugaard & Berntsen, 2016), future plans that pop up spontaneously should require less resources than creating future scenarios during the undemanding activity, and behave as if they were involuntary memories about the future. In line with this, for example, in the mind wandering literature McVay et al. (2013), in contrast with many others (e.g., Smallwood et al., 2003) have found no correlation between working memory ability and spontaneous future-oriented thoughts obtained during mind wandering. Their participants, however, did not distinguish between different types of future-oriented thoughts, so it might be that they tapped mostly on types of future thoughts that make less use of executive functions.

In this study the subjective classification into IAMs and future thoughts represents the basis for subsequent distinctions (for a similar approach in studying autobiographical memory, see Uzer, Lee, & Brown, 2012) which are based on the assessment of the amount of cognitive resources required for memories and future contents to pop up (see also Somos, Mazzoni & Jellema, 2015, for this method applied to voluntary retrieval from autobiographical memory).

Pilot study

In both the Pilot and the main Experiment, a modified version of the Schlagman and Kvavilashvili (2008) procedure was adopted, already successfully used to investigate IAMs (e.g., 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. Rather they are asked to report any content crossing their mind, including thoughts about the past, plans, intentions for the future, etc., as long as these contents are not task-related. Second, the monotonous vigilance task during which mental contents pop up is interrupted by the program itself according to a predefined schedule already used before (Batool & Mazzoni, 2011; Vannucci et al., 2014). Both modifications make the task more akin to a mind wandering task (Schooler et al. 2011).

The aim of the pilot study was to assess whether a sufficient number of involuntary memories and future-related thoughts would be elicited when presenting 100 word-phrase cues over 200 trials, and whether participants were able to classify future thoughts as future scenarios and future plans. The initial classification was then used in Experiment 1 to assess the effect of a potential resource-consuming task.

Participants

30 undergraduate students (26 females) from the University of Hull, with normal or corrected-to-normal vision and fluent in English, took part in the pilot study for course credit. Their age ranged between 20 and 21.

Materials

The same vigilance task was used as in Batool and Mazzoni (2011), and Vannucci et al. (2014, experimental condition "No IAM instructions/Self-interruption"). The number of trials was 200, each remaining on the screen for 1.5 s. Each showed a card depicting either a pattern of black horizontal (non-target stimuli) or black vertical lines (target stimuli). Target stimuli appeared on fie trials of the task at pseudo-random intervals (i.e., approx every 40–60 trials), so to occur at long and irregular intervals. Cue words were presented in size 18 Arial and placed in the middle of the card. One hundred cue word-phrases were selected from the pool of phrases used by Vannucci et al. (2015) which were also rated for familiarity, imageability, and concreteness on a 7-point scale (1 "low"–7 "high"). Cues were pseudo-randomised for each participant, as in Vannucci et al. (2015).

Procedure

After signing the informed consent, participants were presented with the 200-trial vigilance task, in a single session that lasted approx. 45 min. Only the Frequent cues condition (100 cues over 200 trials) was used and participants were tested individually. Horizontal lines were presented 195 of the 200 trials, while the target trials with vertical lines were 5 and scheduled in a pseudo-random way (i.e., every 30–50 trials). To maximize the number of IAMs a probe-catch procedure was adopted (Batool & Mazzoni, 2011), that in a previous study (Vannucci et al., 2014) was found to lead to a rather high number of IAMs. Participants were instructed to say ''yes'' when a target stimulus (vertical lines) appeared on the screen. They were told that short phrases would also appear on some of the slides, but they were supposed to ignore them. The cover story was that participants belonged to the control group, who had to keep their concentration on the patterns while also being presented distracters, while that in another condition participants would have to concentrate on the words instead.

Crucially, in the instructions it was also mentioned that the task was rather monotonous, and because of this their mind could wander. They could find themselves thinking about many things, which was quite normal. Participants were informed that they could let their mind wander. Once in a while the experimenter would interrupt the vigilance task, and at that point they would be asked to report what was going through their mind (participants were free to report more than one mental content that was crossing their mind each time as in the Vannucci et al's (2014) prompted condition). They were not informed about the number of interruptions, that were 13. Any type of content was acceptable (thoughts, plans, considerations, past events, images, etc.). When reporting the mental content, they were asked to write a short description that was then used by the author to check the categorization chosen by the participants. Mental contents referring to past events were categorized as memories or non-memories. Non-memories were comments about the past, worries, or had a purely semantic content. After the instructions, participants were given a short 20-trials practice of the vigilance task before starting.

Pilot: results and discussion

All participants completed the vigilance task successfully, with an average of 4.3 (SD = 0.45) targets detected (out of 5). All participants reported at least one involuntary memory throughout the session. A total of 422 mental events were reported. Of these, a substantial majority (61%) were classified as pertaining to the past, 36% to the future, and 3% to the present. Eighteen percent of the thoughts about the past were memories (approx 11% of the whole report), the remaining were classified as comments, worries and other. Amongst future thoughts, participants were able to distinguish between future scenarios (45%) and future plans (55%). Worries and reports with emotional content about the future were all classified as future scenarios.

This pilot study showed that participants were able to discriminate between past and future thoughts, and to operate more subtle classifications. The study also confirmed that it is possible to obtain a sufficient number of IAMs and future thoughts even with 100 cues.

Experiment

The main experiment addressed two questions. The first was to assess whether future-oriented thoughts require more cognitive resources than involuntary memories. As already stated in the Introduction, there are reasons to believe that they require more resources compared to involuntary memories. Creating a mental future scenario involves complex processes that include (but are not limited to) the activation of past mental representations, the activation of semantic elements, integration of the two, counterfactual thinking, validation/monitoring of goodness. Creating future plans involves even additional processes, as listed below.

The second question addressed in this experiment was to assess differences in cognitive resources between future scenarios and future plans. The working hypothesis was that creating a plan for a mental future event should involve more processes, and hence more cognitive resources, than just creating future scenarios. Scenarios should be more similar to static or kinematic mental images, and thus not need the amount of resource-consuming executive processes necessary for coming up with future plans. The creation of a plan, on the other hand, involves not just all the processes already at play in the creation of a scenario, but also intentions, the planning itself by which the various steps for the implementation of a future scenario are created, assessed and linked. In addition, it requires inferential and counterfactual thinking, feasibility assessment, and other higher order and resource-consuming processes. Alternatively, however, one can conceive future plans as 'past memories for future events', as plans that pop into mind spontaneously might not be created during mind wandering. They might have been created in the past and just pop in mind as ready-made plans for the future, 'memories about future plans'. In this case, future plans that pop up spontaneously should require less resources that creating future scenarios during the undemanding activity, and behave as if they were involuntary *memories about the future*.

Because in the Pilot study we noticed that participants tended to insert into 'future scenarios' all future thoughts that were not future plans (e.g., comments, worries, etc), in Experiment 1 they were instructed and trained to report as future scenarios only future-related thoughts that involved a mental representation about the future, e.g., seeing oneself on the beach the following summer, a party with friends for somebody's graduation, etc. Comments, worries and similar contents had to be classified as 'other'. In this way we ensured that only what legitimately can be considered scenarios were included in this category.

As explained in the introduction, a way to estimate the amount of resources used by each type of spontaneous mental content (past, present, future) is to assess the reduction in frequency of mental contents reported in the Frequent and Infrequent + Math conditions compared with the Infrequent condition. The three conditions had already been successfully used by Vannucci et al. (2015) when they showed that eliciting involuntary memories requires cognitive resources. The logic is that in the Infrequent condition the expenditure of cognitive resources should be significantly less than in the Infrequent + Math and the Frequent conditions, both of which have additional elements to process (50 cues, in the Frequent condition, and 50 very simple arithmetic problems in the Infrequent + Math condition). Additional cues and additional arithmetic problems present an additional cost, which can be measured by examining the drop in the number of mental contents reported in these two conditions compared to the Infrequent condition. The higher the drop, the higher the mental cost. Finding a larger drop for Future compared to Past thoughts would imply that future thoughts require more cognitive resources. Similarly, a larger drop for Future plans compared to Future scenarios would indicate that more resources are required for the former compared to the latter.

Method

Participants

Sixty undergraduate students (52 females, age range 20–23) from the University of Hull took part in the experiment for course credit. All had normal or corrected-to-normal vision and were fluent in English.

Design

This is a mixed design with two levels of mental reports (involuntary memories vs. involuntary future thoughts) and three between-subjects conditions (Frequent cues, Infrequent cues and Infrequent cues + Math), with 20 participants in each.

Material

The same vigilance task was used as in the Pilot study. In Experiment 1 also a set of 50 math problems (simple arithmetic sums and subtractions) was added for the Infrequent + Math condition. In each condition, 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 questionnaire was the same as in the Pilot study.

Questionnaire Mental content characteristics were collected via a questionnaire. Participants were asked (a) to categorize each mental event as belonging to the task (subsequently not analysed), or to the present, the past or the future; (b) to identify memories, and (c) to classify the non-memory events as either scenarios about the future, plans about the future, comments about the present, comments about the past, comments about the future, other (specifying what). For each mental event, and separately for past, present and future events, they were asked to briefly describe the mental content, rate on a 5-point scale the specificity of the event, how common/unusual, memorable (how easily the content can be remembered), vague vs. detailed, important, and often thought about was. They were also asked to state (yes/no) if accompanied by a mental image.

Procedure

The procedure for the Frequent cues condition was exactly the same as in the Pilot study with the addition at the end of the questionnaire. One hundred cue word-phrases were presented in a pseudo-random order over 200 trials. In the Infrequent condition, 50 word-phrase cues were presented over the same 200 trials. These words were selected amongst the 100 used in the Frequent condition and did not differ for imageability, familiarity and concreteness from the other 50 word-phrases. In the Infrequent + Math condition, in addition to the 50 word cues, 50 arithmetic operations were added to the 50 trials in which the cue words were not presented. The presentation order of the cues was pseudo-randomised for each participant. Instructions were the same in all conditions, and exactly the same as in the Pilot study (when the program is interrupted report any mental content that has been crossing your mind), but for the following addition (*in italics*). When explaining the vigilance task, participants were told 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, as in the Pilot study, using the same cover story. At the end of the experiment participants were asked to rate on a 5-point scale their level of concentration and boredom during the vigilance task.

Results

All participants completed the vigilance task, with an average of 3.9 (SD = 0.40) targets detected (out of 5), and no significant difference between the three groups (Frequent cues: $M = 3.5$, SD = 0.83; Infrequent cues: $M = 4.2$, SD = 0.53; Infrequent cues + Math: 3.8, SD = 0.38) ($F < 1$).

No significant difference was found in the level of concentration or boredom in the three groups (all $p > 0.20$). The mean levels were 3.05 (SD = 0.76) and 3.9 (SD = 0.90), respectively, for the total sample.

Every participant reported at least one involuntary memory. A total of 860 mental contents were generated (without including task-related comments, which were excluded from analyses), of which 448 classified as referring to the past (267 IAMs), 367 to the future, and 45 to the present. The data show that 41% of the thoughts referring to the past were comments, considerations, worries etc, while 59% were memories. The mean reported involuntary memories was 4.45 (SD = 3.22, range 2–18) per participant, and for non-memory mental contents the mean per person was 6.87 (SD = 5.88, range 3–28). Out of 267 involuntary memories, 87% were triggered by the word-phrases presented on the computer screen, 10% were triggered by internal thoughts and only 3% by other environmental cues. Similarly, of the 367 future thoughts 88% were triggered by the word-phrases, 11% by internal triggers and 1% by other environmental cues.

Of the 367 mental contents referring to the future, 182 were plans, 154 scenarios, and 31 neither (comments, worries etc). Distribution of mental contents in the three conditions is reported in Table 1. More mental contents were

Table 1 Descriptive data (total number) for all dependent measures (number of thoughts referring to the past (including the number of IAMs), the present and the future (including scenarios and plans); number of IAMs, future plans, future scenarios, and other contents) in the three experimental groups

	Frequent		Infrequent		Infrequent + Math	
	Frequency	Mean (SD)	Frequency	Mean (SD)	Frequency	Mean (SD)
Past thoughts[a]	125	6.25 (1.56)	203	10.15 (1.78)	120	6.00 (1.43)
IAMs[a]	86	4.30 (1.34)	101	5.05 (1.39)	80	4.00 (1.26)
Present thoughts	15	0.25 (0.44)	17	0.28 (0.45)	13	0.23 (0.43)
Future thoughts	88	4.40 (1.56)	169	8.45 (2.21)	79	3.95 (1.39)
Future plans	58	2.85 (1.04)	75	3.75 (1.02)	49	2.45 (1.19)
Future scenarios	35	1.51 (0.69)	86	4.70 (0.65)	33	1.50 (0.76)
Other	9	0.15 (0.36)	12	0.20 (0.40)	10	0.17 (0.38)

[a]As already mentioned in the text, past thoughts refer to both non-memory thoughts about the past (comments, worries, etc.) and memories (IAMs). IAMs refer to all memories reported

reported overall in the Infrequent condition compared to the Frequent and Frequent + Math conditions. For involuntary memories, compared to the Infrequent condition the decrease in the Frequent condition was 15%, while in the Infrequent + Math condition it was 20%. For overall future thoughts, compared to the Infrequent condition the decrease in the Frequent condition was 48%, and 53% in the Infrequent + Math condition. It seems then that the drop across conditions was larger for future thoughts than for involuntary memories. The table also reports the data for future plans and future scenarios, for which the same trend was observed. For future plans the drop between the Infrequent and the Frequent condition was 23%, whereas it was 35% between Infrequent and Infrequent + Math. For future scenarios the drop was 59% and 62%, respectively. Overall a greater drop for future scenarios than future plans.

To assess the effects of the three experimental conditions, the average number per person of involuntary memories and overall future thoughts was calculated and entered into a 2 (mental content) × 3 (conditions) mixed ANOVA. More future thoughts than involuntary memories were reported overall, $F(1,57) = 16.68$, MSe = 2.37, $p < 0.001$. As in Vannucci et al. (2015), the Infrequent cues condition was more productive compared to the other two conditions, $F\ (2, 57) = 37.59$, MSe = 2.41, $p < 0.0001$. The other two conditions did not differ significantly ($p > 0.5$). Importantly, the interaction was also significant, $F(2,57) = 15.77$, MSe = 2.41, $p < 0.001$. Post hoc paired t tests showed that there were more future thoughts than involuntary memories, but only in the Infrequent condition, $t(19) = 14.43$. The drop between the Infrequent cues condition and the other two conditions was significantly larger for future thoughts than for involuntary memories indicating that the cost of additional cues or math tasks was greater for future than past spontaneous ideations. Two additional ANOVAs assessed differences in Present and Other thoughts, which were all non-significant, Fs < 1.

The number of future scenarios and future plans in the three conditions were compared in a further 2 × 3 ANOVA for mixed design. There were significantly more future plans than future scenarios, $F(1, 57) = 44.77$, MSe = 0.45, $p < 001$, and more overall reports about the future in the Infrequent compared to the Frequent and Infrequent + Math conditions, $F(2,57) = 42.73$, MSe = 2.28, $p < 001$. The interaction was significant, $F(2,57) = 6.91$, MSe = 0.54, $p < 0.01$, indicating that the drop between the Infrequent and the other two conditions was larger for future scenarios than for future plans.

The responses to the questionnaire were also examined. The mean ratings for all recorded characteristics were calculated for each participant before entering them into several 2 × 3 ANOVAs for mixed design. Overall, compared to involuntary memories, involuntary future thoughts were more important (3.36, SD = 0.55 vs. 2.61, SD = 0.34; $F\ (1,57) = 8{,}86$, MSe = 1,95, $p < 0.01$), and more often thought about (3.35, SD = 0.33 vs. 2.50, SD = 0.65; $F(1,57) = 19.48$, MSe = 1.11, $p < 0.001$). Involuntary memories were judged higher than future thoughts on how easily the content can be remembered (3.22, SD = 0.79 vs. 2.35, SD = 0.58; $F(1,57) = 22.88$, MSe = 1.90, $p < 0.001$). No difference was found in event specificity (3.68, SD = 0.81 vs. 3.31, SD = 0. 72), details (3.47, SD = 0.68 vs. 3.22, SD = 0.71), how unusual (3.26, SD = 0.77 vs. 2.87, SD = 0.79) and how frequently past and future mental events were accompanied by a mental image (0.84, SD = 0.36 vs. 0.74, SD = 0.40). The main effects for condition and the interactions were not significant.

General discussion

To understand whether past and future spontaneous thoughts make use of different amounts of resources, the number of spontaneous mental contents elicited during a monotonous and rather boring vigilance task was assessed in three conditions, one in which verbal cues were rather frequent (100 over 200 trials, Frequent condition), one in which verbal cues were rather infrequent and spaced (50 over 200 trials, Infrequent condition), and one in which 50 cues were presented as in the Infrequent condition, but in 50 additional trials memory cues were replaced by very simple arithmetic computations (sums and subtractions, Infrequent + Math). A previous study (Vannucci et al. 2015) had reported a higher number of involuntary memories in the Infrequent condition, when the number of verbal cues that can potentially elicit a memory is lower and presented in a spaced order. While this higher number of involuntary memories can be due to various mechanisms, the comparison with the Infrequent + Math condition revealed that this larger number of involuntary memories was due to the absence of additional items (potential cues) that are elaborated and thus tax cognitive resources. In line with those results, the data of the experiment reported here show that spontaneous mental pop-ups about the past (specifically, involuntary memories) and particularly about the future are affected when there are additional tasks that require cognitive resources. Compared to the Infrequent condition, in both the Frequent (more potential cues) and Infrequent + Math (more potential cues replaced by math tasks) conditions the number of spontaneous past and future thoughts was significantly lower, indicating that having either additional cues or arithmetic tasks represents a cost for the production and/or reporting of both types of mental content. The effect was particularly strong for future-oriented thoughts. The effect of having additional cues or math problems is akin to having a dual task that taxes available cognitive resources in mind-wandering tasks (e.g., Christoff et al., 2009; Smallwood & Schooler, 2006;

Teasdale et al., 1995), when executive mechanisms are at play in creating 'detailed, structured trains of thought' (Baird et al., 2011, p. 1605), mechanisms that allow buffering and co-ordination of information (Smallwood et al., 2012). The current results not only confirm what was already found by Vannucci et al. (2015), but they also underline the mismatch between the purely subjective experience of effortlessness and the actual necessity of employing executive resources for the production/reporting of spontaneous mental pop-ups that occur during undemanding activities. Although not enough is known yet about specific processes involved in involuntary retrieval and in the production of future thoughts, both sets of results (the current ones and Vannucci et al's. 2015) confirm that it is not as effortless and automatic as it feels (see also Baird et al., 2011). The mismatch between perceived effortlessness and actual effort required by executive monitoring and control can be better understood by considering the differences in processes between spontaneous/involuntary and intentional/voluntary ideation. In a typical voluntary task (both memory retrieval and other types of ideation) the access to mental representations is initiated intentionally and thus it involves a goal-directed process that capitalizes on implementation intentions (see Gollwitzer & Sheeran, 2006). The process requires some form of executive monitoring and control. Conversely, in spontaneous ideation such as during mind wandering and when retrieving involuntary memories, it is more likely that executive control is less or not involved during access to the mental content. According to Smallwood and Schooler (2006, p. 946), the activation of goal-relevant information may occur automatically through a process that does not require conscious intention (Chen & Bargh, 1997; Gollwitzer, 1999; Wyer, Neilsen, Perfect, Mazzoni, 2011). In addition, they also link the absence of intent with the absence of explicit awareness of the current content of one's own mental experience (Schooler, 2002). Thus, the subjective experience of involuntariness might be due to the initial lack of intention and concomitant lack of awareness of the activation of ideation processes. However, even spontaneous mental contents need some form of elaboration, monitoring and control when they reach awareness, and for this reason they still make use of cognitive resources.

The main focus of this paper was on potential differences in cognitive resources expenditure between involuntary memories and spontaneous thoughts about the future. The results show, first, that more future-related thoughts were produced compared to involuntary memories, a result that is in line with several previous studies showing a prevalence of spontaneous future-oriented thinking during mind wandering (D'Argembeau et al., 2011; Smallwood et al., 2009). More interesting, the present results also show that overall future thoughts require more cognitive resources compared to involuntary memories, as indicated by the larger drop in the production of spontaneous future mental contents compared to that of involuntary memories when more cues, or math problems, are presented. This result was predicted considering the presumably greater number of processes required for the production of future thinking, if compared to the retrieval of past memories. According to current theoretical proposals, involuntary retrieval of memories is associative and context dependent, being triggered almost automatically when a sufficient match occurs between central elements in prevalently external cues, and central elements in the memory representation (Berntsen, 2009; Berntsen et al., 2013). Involuntary retrieval is thus considered to be rather direct (Berntsen et al., 2013; Conway & Pleydell-Pearce, 2000), and as such it should not involve reasoning (inferential, counterfactual etc) processes that are instead necessarily involved when creating thoughts referring to the future. The current results indeed support the idea that retrieval processes tax cognitive resources to a lesser extent than future thinking. This result is also in agreement with previous data indicating a clear involvement of control components in spontaneous future-oriented thinking during mind wandering, evidenced by the larger reduction in frequency for this type of mental contents, compared to past-related thinking, in conditions involving a working memory load (e.g., Smallwood et al., 2012; Smallwood et al., 2009; Smallwood et al., 2012). This result is in line also with the finding by Baird et al. (2011) showing that individual working memory capacity measured by a span task (OSPAN) is related to future spontaneous thinking. Neuroimaging evidence has been provided (Christoff et al. 2009) on the activation of working memory brain areas when participants intentionally engage in future planning (e.g., dorsolateral pre-frontal cortex).

It was also hypothesized here that people are able to distinguish between future scenarios, defined as static or kinematic mental simulations of a situation (see the mental model theory by Johnson–Laird as an example of how future scenarios can be conceived), and future plans, which are more complex and interconnected series of future scenarios linked by a common final goal. This is confirmed by the data. Additionally, it was hypothesised that future plans should require more cognitive resources, compared to future scenarios, the reason again being the number and nature of processes involved. When making a plan, creating a future scenario is not enough. A plan is the result of a much more complex set of processes, that, from a purely cognitive perspective (and thus not considering emotional involvement, self involvement, etc.) require also the definition of a goal, intentions, planning, evaluations, counterfactual thinking, weighing various possible outcomes against each other, etc. (see for example, theoretical approaches on intention implementation, Gollwitzer, 1999; Gollwitzer & Sheeran, 2006; Carvalho, Mazzoni & Kirsch, 2014, and many others). Data from mind wandering studies also seem to suggest this hypothesis (but see also below). In mind wandering, executive mechanisms have been shown to be involved in future thoughts, typically called plans (see also Baird et al., 2011). Conditions that load working memory reduced the frequency of future thoughts, which led to the conclusions that a strong control component is involved (Smallwood et al., 2012; Smallwood et al., 2009; Smallwood et al., 2012). Future plans, both spontaneous and experimenter-induced, have also been shown to engage brain areas involved in working memory (e.g., Christoff et al., 2009; Gerlach, Spreng, Gilmore, & Schacter, 2011) indicating that future planning is a strongly controlled activity.

However, the current results do not confirm the prediction. Rather, the data suggest that spontaneous future plans require less effort and less cognitive resources than spontaneous future scenarios, a rather counterintuitive result. The result becomes less surprising, however, if one considers that we are talking about spontaneous mental events that occur in response to cues. Cues might presumably activate, as in the retrieval of involuntary memories, existing future plans which are already represented in memory and that are simply triggered by the cue. Thus, future plans that pop up in mind involuntarily when the mind wanders might not be created during mind wandering, they might more simply be 'memories' for future plans, in other words, past memories for the future (see also Cole et al., 2016, for a similar definition). This hypothesis could easily explain the smaller degree of effort required when the cues trigger a future plan, a degree of effort that is just slightly greater (if measured in terms of size of the drop in mental content production) for future plans than for involuntary memories. The discrepancy between the current results with the wealth of data in the mind-wandering literature showing the involvement of executive controlled processes in future-oriented plans can be explained in two ways. First, in those studies there is no clear distinction between different types of future thoughts, and the results might just reflect the preponderance of future scenarios over future plans. It might also be possible that having trained our participants to report as 'other' several types of future thoughts, we are analyzing here a narrower group of better defined mental events. It might be useful also in mind wandering studies to distinguish between different types of future thoughts before making the claim proposed so far that it is future planning that requires a greater amount of mental resources. The interpretation of the results offered above links, in principle, future plans with prospective memory (e.g., Brandimonte, Einstein & McDaniel, 1995; Kvavilashvili & Ellis, 1996; McDaniel & Einstein, 2000). In prospective memory, the memory for the future intention/action has a retrospective component (that is, what is typically called a memory) in addition to a prospective component. The relationship between spontaneously reported future plans and prospective memory has not been explored so far. Future studies might reveal the existence of involuntary prospective memories. It might be the case that until now the reason why only purely retrospective involuntary memories have been reported in diary studies is due to the nature of the instructions given to the participants, which have focussed almost exclusively on memories for the past (possibly reflecting a 'past' bias in the researchers).

Although the data of the current experiment are insufficient to provide a fully satisfying explanation of the processes involved in the production of spontaneous thoughts when the mind is left to wander idly during tasks, some hypotheses can be proposed. Keeping in mind that these are mostly speculative considerations at this point, the results of the current study confirm that spontaneous memory retrieval requires cognitive resources. However, such required resources are less than for other spontaneous thoughts, suggesting that spontaneous retrieval might still be conceived as being rather direct, based on associative links between cues and memory representations, and occurring in a rather automatic fashion when a sufficient match is reached between the cue and the memory. At retrieval, cognitive resources are presumably involved later on, during online monitoring of the goodness of the match and the goodness of the memory (processes that occur in voluntary memory retrieval, but that should be present also during involuntary memory retrieval). Output is still voluntary and aware even in involuntary memory, as people need to decide whether to report or withhold the content activated by the cue (for models of monitoring and control during retrieval, see for example, the models proposed in metacognitive research; Koriat & Goldsmith, 1996; Mazzoni & Kirsch, 2002). It might also be possible that use of cognitive resources rather than being due to monitoring and control processes, might reflect a competition between internally and externally generated activities attempting to gain access to a limited capacity central network, as suggested by some (see Dehaene & Changeux, 2005). Future studies should examine the role of executive and metacognitive processes in the retrieval of involuntary memories, as well as the role of competition given the potentially large number of ideations that are activated by the cues.

Future studies might also productively compare the involvement of metacognitive processes in the production of involuntary future thoughts, and in general in spontaneous mental pop-ups (see D'Argembeau, 2017; Ernst & D'Argembeau, 2017; Scoboria, Mazzoni, Ernst, & D'Argembeau, 2018). One can hypothesize, for example, that if our data hold, involuntary pop-ups of future plans might involve the same retrieval and monitoring/control processes as involuntary memories. The current data might be interpreted as suggesting as well that spontaneous future scenarios require a greater involvement of metacognitive (monitoring/control) processes. It might be also conceivable, however, that future scenarios can be more free-form, not having to conform to any realistic coherent scene, and as such might require less monitoring/control processes. If so, the greater amount of cognitive resources would be engaged in carrying out other processes, most likely involved in the act of creation (of the mental content, see Marcia Johnson's idea of cognitive processes involved in ideation/imagination, Johnson, Hastroudi & Lindsay, 1993).

In the mind-wandering literature an alternative explanation has been proposed by some (e.g., McVay & Kane, 2010) for results that seem to show that spontaneous ideation requires executive resources. The idea is that rather than for the production of spontaneous content, resources are used to tune attention to the task (from which the mind wanders) and to re-orient attention to the task after the mind has wandered off. In the case of the present results certainly there are more 'tasks' in the Frequent and Infrequent + Math conditions compared to the Infrequent condition and thus potentially greater need to reorient attention. This potential alternative explanation, however, cannot be tested with the current data. Future research will examine the predictions of this interpretation.

Conclusions

Spontaneous thinking is not automatic and effortless. The present results show that cognitive effort is involved not just in the case of spontaneous, involuntary memories about the past, but also in spontaneous ideation referring to the future. They also show that people distinguish between different types of spontaneous future thoughts, some being thoughts produced at the moment, while others are like memories of previously formed plans about future events. The involvement of cognitive resources is different for these two types of future thoughts, suggesting that partly different mechanisms might be at play. Future studies should address more directly the question about cognitive mechanisms involved in spontaneous thinking, possibly linking the literature on involuntary thinking with the literature on mind wandering.

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