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Abstract

Three experiments investigated the relationship between future thinking and false memories. In Experiment 1, participants remembered familiar events (e.g., a holiday) from their past, imagined planning the same events in the future, or took part in a control condition in which they visualized typical events. They then rated a series of schema-related and schema-unrelated nouns for how likely they were to be encountered within those events. In a surprise recognition test, participants in the future condition falsely recognized more schema-related items than participants in the past and control conditions. No reliable effects of rating condition were observed in correct recognition. Experiment 2 found the same pattern when participants imagined unfamiliar events (e.g., taking part in a bank robbery) from past or future perspectives. Participants in Experiment 3 remembered a past or imagined a future holiday and were then instructed to generate items that someone might take on a holiday. Participants in the future condition generated more nonstudied items and fewer studied items relative to participants in the past condition. The findings of Experiments 1 and 2 indicate that simulating future events enhances the activation of related items that gives rise to false memories. The findings of Experiment 3 suggest that these activation processes play an adaptive role in guiding the planning of future events.

Key words: false memory; future thinking; simulation; planning

Simulation, False Memories, and the Planning of Future Events

There is an emerging view that one of the key functions of human memory is to help us anticipate and plan for the future (for recent discussions see Klein, 2013, and Szpunar, Spreng, & Schacter, 2014). According to Tulving (1993), the episodic memory system allows individuals to engage in "mental time travel" whereby they can simulate future events as well as remember past events (see also Suddendorf & Corballis, 1997). The concept of mental time travel subsequently formed the basis of the constructive episodic simulation hypothesis (e.g., Schacter, Addis, & Buckner, 2007, 2008; Schacter & Addis, 2007a, 2007b), which proposes that the neural systems and cognitive processes that support the retrieval of episodic memories also support episodic simulation of possible futures. There is evidence that other forms of memory, such as semantic memory, can also support the simulation of future scenarios (Anderson, 2012; Cordonnier, Barnier, & Sutton, 2016). According to the semantic scaffolding hypothesis (Irish & Piguet, 2013) semantic knowledge provides a framework that guides the construction of future events. Recently, Szpunar et al. proposed a broader taxonomy of future thinking that incorporates simulation alongside other types of future-oriented, or prospective, cognition such as planning. This taxonomy further emphasises the underlying role of both episodic and semantic memory across all aspects of prospective cognition. Considered together, the convergent literature illustrates the view that human memory is oriented towards the future.

The notion of a future-oriented function of memory is supported by findings that simulating future events acts as a powerful mnemonic device. This was first demonstrated by Klein, Robertson, and Delton (2010) in a study in which participants were instructed to recall a past camping trip or imagine planning a future camping trip. The participants were then presented with a series of object nouns, either related or unrelated to camping. Participants in the past condition were asked to rate how likely it was that each of the objects was at the camping trip that they remembered, while participants in the future condition were asked to rate how likely it was that they would take each of the objects as they planned the camping trip. Participants in an atemporal control condition were asked to form an image of a campsite and rate the likelihood of each object being at the campsite. In a surprise recall test, participants who rated the nouns in relation to a future camping trip recalled more of the nouns than those who rated them in relation to a past camping trip. Future rating also led to better recall of the nouns than rating their relevance to a typical camping trip (without reference to past or future events) or to a survival scenario (see Nairne, Thompson, & Pandeirada, 2007). In a follow-up study, Klein, Robertson, and Delton (2011) provided evidence that planning is the key factor in producing the survival processing effect (see Nairne et al., 2007).

Continuing this line of research, Klein, Robertson, Delton, and Lax (2012) investigated the role of personal experience in producing the mnemonic effect of planning. They compared four encoding conditions; two that were likely to invoke personal experiences (planning a dinner party and planning a picnic) and two that were less likely to invoke personal experiences (planning to feed animals at a local zoo and planning a trip to Antarctica). Participants in each condition rated the same set of nouns (food items) for the likelihood that they would be considered when planning the activity. Klein et al found that the two rating conditions that invoked personal experiences led to higher levels of recall of the rated items than the two conditions that did not invoke personal experiences. They interpreted their findings in terms of the distinction made by Klein, Loftus, and Kihlstrom (2002) between *lived* *time*, based on episodic memories, and *known time*, based on semantic memory. Although future planning tasks based on lived and known time both enhanced the recall of words rated in relation to those tasks, the effect was greater for planning tasks that invoke lived time.

In a recent study, we (Dewhurst, Anderson, Grace, & van Esch, 2016) investigated the effects of past and future thinking on false memory. In a series of experiments, participants were instructed to recall a past holiday or imagine planning a future holiday. They then took part in the Deese/Roediger-McDermott (DRM) procedure (Deese, 1959; Roediger & McDermott, 1995) in which they were presented with lists of words (e.g., *bed*, *dream*, *wake,* etc.) that were associates of a nonpresented critical lure (e.g., *sleep*). The DRM procedure produces a powerful illusion of memory whereby participants show high levels of false recall and false recognition of the critical lures (see Gallo, 2010, for a review). We found that levels of false memories increased when DRM lists were rated for their relevance to a future holiday, relative to conditions in which the words were rated for their relevance to a past holiday or rated for pleasantness. This effect occurred in both recall and recognition memory, and with both between- and within-subjects manipulations of rating tasks.

The findings of Dewhurst et al. (2016) were interpreted in relation to the view that imagining the future leads to more flexible thinking than remembering the past (see D’Argembeau, Ortoleva, Jumentier, & van der Linden, 2010). We speculated that the greater flexibility of future thinking enabled participants to think creatively about the items they may encounter in a future event. This greater flexibility enhanced the associative processes that give rise to false memories in the DRM paradigm, thereby increasing the likelihood that critical lures were activated at study and, subsequently, falsely remembered at test. This interpretation is consistent with findings recently reported by Campbell, Benoit, and Schacter (2017), who investigated the effects of inhibition on imagining the future. As Campbell et al. observed, tasks such as retrieval-induced forgetting show that successful retrieval often requires the inhibition of related concepts (see Anderson, Bjork, & Bjork, 1994). In contrast to the effects typically observed in retrieval, Campbell et al. found that related concepts were automatically primed, rather than inhibited, when imagining future events.

Although Dewhurst et al. (2016) reported reliable effects of future thinking on false memories in three experiments, our findings raised a number of issues that warrant further investigation. First, it is important to determine whether the effect of future thinking on false memory extends beyond DRM lists, which were designed to produce high levels of false memories. In the studies reported below, participants studied schema-related words of the type used by Klein et al. (2010) rather than DRM lists. Schema-driven false memories have been well documented. In a classic study by Brewer and Treyens (1981), participants falsely remembered objects consistent with an office schema (e.g., filing cabinet) after waiting in a graduate student's office, from which those items had been removed. Schema-driven false memories have also been created using pictures (Miller & Gazzaniga, 1998) and stories (e.g., Dewhurst, Holmes, Swannell, & Barry, 2008; Lampinen, Faries, Neuschatz, & Toglia, 2000). Although the types of knowledge that underlie schema-based false memories differ from those that give rise to the DRM illusion, both schema-based and associative memory illusions are driven by the activation of stored knowledge (see Roediger, Watson, McDermott, & Gallo, 2001). One of the aims of the current study is to determine whether future thinking increases schema-driven false memories, which have been credited with having greater ecological validity than the DRM illusion (Miller & Gazzaniga).

A second issue addressed in the current study is that Dewhurst et al. (2016) found no effects of rating condition (past vs. future vs. control) on correct recall or recognition. These null effects contrast with the findings of Klein et al. (2010) that rating words for their relevance to a future event, compared to a past event, enhanced correct recall of the words. We discuss possible reasons for this discrepancy below. Finally, the finding that future simulation increased false memories raises important questions about the potential adaptive nature of false memories (see Fernandez, 2015, Howe, 2011, Schacter, 2012, and Schacter, Guerin, & St Jacques, 2011, for recent discussions of the view that false memories can be adaptive). Specifically, are there positive consequences associated with the increase in false memories as a result of future simulation?

The current experiments were designed to address these and other questions. The primary aim of Experiment 1 was to investigate whether the effects of future thinking on false memory can also be found with schema-related words of the type used by Klein et al. (2010). Experiment 2 investigated whether the effects of future thinking on false memory reflect the hypothetical nature of future events rather than their temporal direction. Comparison between past and future events is essentially a comparison between real events that happened in a particular way and hypothetical events that may unfold in numerous ways (see Schacter, Addis, Hassabis, Martin, Spreng, & Szpunar, 2012). Experiment 2 was designed to address this confound by instructing participants to simulate hypothetical events from either a past or future perspective. The aim of Experiment 3 was to investigate the positive consequences of future thinking by replacing the memory test with a task in which participants were instructed to generate items associated with the activity presented in the study phase.

As noted above, Dewhurst et al. (2016) reported no significant effects of rating condition on correct recall or recognition. We speculated that the associative nature of the DRM lists overshadowed the effects of rating condition in correct memory. It is possible, however, that the nonsignificant effects were simply due to insufficient power. In the first experiment reported by Dewhurst et al., the null effect of rating condition in correct recall was based on a sample size of 48 per condition. However, power analysis using G Power 3 software (Faul, Erdfelder, Lang, & Buchner, 2007) showed that a minimum sample size of 85 per condition would be required to achieve adequate power (1 – 0.8) to replicate the small to medium effect size (d = .43) observed by Klein et al. (2010). Some support for the validity of the nonsignificant result reported by Dewhurst et al. was provided by Experiment 2, which showed a nonsignificant effect of rating condition in correct recognition using a more powerful within-subjects design. Nevertheless, the failure to replicate the effects observed by Klein et al. in correct memory warrants further investigation.

One way to determine whether nonsignificant results are genuine null effects or simply the result of insensitive data is to conduct a Bayesian analysis. Bayesian analyses produce a Bayes factor, B, which allows one to judge whether the data support the experimental hypothesis or the null hypothesis (see Dienes, 2014, for a review). According to Jeffreys (1939; see also Dienes, 2016), $B > 3$ provides powerful support for the experimental hypothesis, whereas $B < 1/3$ provides powerful support for the null hypothesis (rather than simply a failure to reject it). A Bayesian analysis of the correct recall reported by Dewhurst et al. for past versus future rating, using the means reported by Klein et al. (2010) for the expected effect size, produced a value of

B = 0.29. This provides strong support for the null hypothesis that rating condition has no reliable effect on correct memory, at least when the stimuli consist of DRM lists.

The primary aim of the current experiments, however, was to investigate whether the effects of future thinking on *false* memory extend to schema-related stimuli. Our sample sizes were, therefore, chosen on the basis that they would be sufficient to reveal effects in false recognition. Nevertheless, we also report the correct recognition scores and, where appropriate, Bayesian analyses of nonsignificant results. In the experiments reported below, participants were presented with past or future scenarios and instructed to rate the likelihood of encountering a series of objects within those scenarios. Participants in a control condition were instructed to visualize typical scenarios with no reference to temporal direction. In each experiment, half the studied items were related to the scenario and half were unrelated. In order to investigate the effects of future thinking on false recognition, some of the more typical items were omitted from the rating tasks and presented as lures in the recognition test.

Experiment 1

In order to determine the required sample size to produce an effect of rating condition on false recognition, we conducted a power analysis of the false recall data in the *past (planning)* and *future (planning)* conditions reported by Dewhurst et al. (2016; Experiment 1). This showed that a minimum sample size of 20 per condition would be sufficient to achieve adequate power (1 – 0.8) to replicate the large effect size (d = 1.09) we observed. Comparison with our previous study is problematic, however, for a couple of reasons. First, Dewhurst et al. presented participants with tests of free recall rather than recognition. Second, our previous study used DRM lists, which typically produce higher levels of false memory than schema-related lists (see, for example, Dewhurst, Bould, Knott, & Thorley, 2009). On the other hand, the current experiments featured more lure items than our previous studies (18 related lures in Experiment 1 and 15 in Experiment 2, compared to six DRM critical lures in Dewhurst et al., Experiment 1). It was decided, therefore, that a sample size of 30 participants per condition should have more than adequate power to detect the large effect observed in our previous research.

Method

Participants. Participants were 90 undergraduate students (69 females) in the age range 18-36 (M = 20.49, SD = 3.08). All were native English speakers. Participants were tested at individual workstations in groups of up to 5 and received course credit for their participation. There were 30 participants in each of the three rating conditions. All experiments reported in this manuscript were approved by the Ethics Committee of the Psychology Subject Group, School of Life Sciences, University of Hull.

Stimuli and design. An important decision in the current study was whether to use a within- or between-subjects manipulation of rating condition. Whereas a within-subjects design offers greater power, it comes with the risk of carry-over effects between orienting tasks. This was pertinent for both Experiments 1 and 2, in which participants were presented with three different scenarios. It was decided that manipulating both rating condition and scenario in a fully within-subjects design would be unwieldly and likely to produce carry-over effects. For these reasons, participants were presented with all three scenarios in the same rating condition (past, future, or control) with rating condition manipulated between-subjects.

The three scenarios used in Experiment 1 were a holiday, a picnic, and a camping trip. For each scenario, participants were presented with 24 object nouns, of which 12 were related to the scenario and 12 were unrelated. The nouns were chosen following a normative study in which six participants provided ratings for the likelihood of encountering the items in the given scenarios. The mean ratings (out of 5) were 4.12 for the related items and 1.32 for the unrelated items. For the holiday scenario, related items included *sunblock*, *currency*, and *air tickets*, and unrelated items included *hammer*, *piano*, and *telescope*. Participants were randomly allocated to past, future, or visualization conditions and instructed to remember (or imagine) all three scenarios. The recognition test contained 72 items. For each scenario, there were 12 items that had been presented at study. Of these, 6 were related to the scenario and 6 were unrelated. There were also 12 new items per scenario, of which 6 were closely related to the scenario and 6 were unrelated. There were two versions of each study condition allowing old and new items to be counterbalanced. The order in which the three scenarios were presented was rotated through participants. The full set of stimuli and rating instructions are available from the first author. Stimuli presentation and data collection were controlled using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA).

Procedure. Participants were told that they would be asked to generate familiar scenarios and rate the likelihood of encountering a series of objects within those scenarios. An incidental learning procedure was used whereby no mention was made of the forthcoming memory test. Participants were told that the purpose of the study was to investigate the processes involved in thinking about familiar events. The rating instructions were adapted from those used by Klein et al. (2010). For illustration, the past, future, and visualization instructions for the holiday scenario are shown below.

Past condition. *Think back and remember a time in your past when you went on a beach holiday abroad. Try to remember specific details of this holiday, such as the things you did, the people you were with, the sights and sounds you experienced, and so on. Please spend a few moments remembering this holiday. While you are remembering this holiday I am going to present you with a list of words describing physical objects. I would like you to rate how likely it was that you took each of the objects on the list on the holiday you remember. For some objects, it may be likely that you brought them on your holiday. For others, it may be unlikely. It is up to you to decide.*

Future condition. *Think ahead and imagine a time in your future when you will go on a beach holiday abroad. Try to imagine specific details of this holiday, such as the things you will do, the people you will be with, the sights and sounds you will experience, and so on. Please spend a few moments imagining this holiday. While you are imagining this holiday I am going to present you with a list of words describing physical objects. I would like you to rate how likely it is that you would take each of the objects on the list as you plan your beach holiday abroad. For some objects, it may be very likely that you take them on the holiday. For others, it may be unlikely. It is up to you to decide.*

Visualization condition. *Use your imagination to form a picture of a beach holiday. What items appear in the image that you have created of the holiday? While you are imagining this holiday I am going to present you with a list of words describing physical objects. I would like you to rate how likely it is that each of the objects on the list is at the holiday that you have imagined. For some objects, it may be likely that they appear in your image. For others, it may be unlikely. It is up to you to decide.*

Participants were allowed 30 seconds to remember or imagine an event. The object nouns then appeared one at a time on the screen and participants rated the likelihood of encountering (or having encountered) each object on a 5 point Likert scale from 1 = Very unlikely to 5 = Very likely. Each word remained on the screen for 5 seconds regardless of how quickly participants responded. After completing the rating task for all three scenarios, participants were engaged in a nonverbal filler task for 10 minutes. They were then given a surprise recognition test that included studied and unstudied items from each scenario, presented in a different random order for each participant. The recognition test was self-paced.

Results and Discussion

Alpha was set at .05 for all main effects and interactions, and all pairwise comparisons were Bonferroni-adjusted. Data from the three scenarios were collapsed into a single score. Mean numbers of related and unrelated items correctly and falsely recognised are displayed in Table 1. Correct and false recognition scores were analysed in separate 3 (rating condition: past vs. future vs. visualization) x 2 (item type: related versus unrelated) mixed ANOVAs with repeated measures on the second factor. The analysis of false recognition showed a significant main effect of rating condition, F (2,87) = 4.32, MSE = 2.38, p = .016, η_p^2 = .09. Pairwise comparisons showed that false recognition was significantly higher in the future condition relative to both the past condition, p = .045, and the visualization condition, p = .033. The past and visualization conditions did not differ significantly from each other, p = 1.00. There was also a significant main effect of item type whereby related lures were more likely to be falsely recognised than unrelated lures, F (1,87) = 59.23, MSE = 1.32, p < .001, η_p^2 = .41.

These main effects were qualified by a significant interaction, F (2,87) = 8.17, MSE = 1.32, p = .001, η_p^2 = .16. Pairwise comparisons showed that, for related lures, future thinking led to reliably higher levels of false recognition than the past, p = .008, and visualization, p = .010, conditions, which did not differ significantly from each other, p = 1.00. There were no significant differences between the rating conditions in the numbers of unrelated lures falsely recognised, all ps = 1.00. Study ratings were analysed in a one-way (rating condition) between-groups ANOVA. The effect of rating condition was not significant, $F < 1$.

Analysis of correct recognition showed a significant main effect of item type, whereby correct recognition scores were higher for related than for unrelated items, F (1,87) = 12.18, MSE = 2.70, p = .001, η_p^2 = .12. Neither the main effect of rating condition nor the interaction were significant, both Fs < 1. In order to conduct a Bayesian analysis, the correct recognition scores from the past and future conditions were converted into proportions and compared to the expected value derived from the correct recall data from Klein et al. (2010), also converted into proportions. The analysis found B = 0.22. This provides strong evidence for the null hypothesis that rating items in relation to a future event does not enhance correct recognition.

The main finding of Experiment 1 is that rating items in relation to a simulated future event led to higher levels of false recognition than rating them in relation to a remembered past event. This pattern is consistent with the findings of Dewhurst et al. (2016) and shows that the effect of future thinking on false memory extends beyond DRM lists. The significant interaction between rating condition and item type showed that the effect was present for related lures but not for unrelated lures. Also consistent with the findings of Dewhurst et al., the manipulation of rating condition had no reliable effect on correct recognition. This is at odds with the findings of Klein et al.

(2010) who found that rating nouns in relation to a future camping trip led to higher levels of correct recall than rating them in relation to a past camping trip.

The findings of Experiment 1 support our previous findings that simulating future events enhances the semantic activation processes that give rise to false memories (Dewhurst et al., 2016). An alternative explanation, however, is that that the effects of future thinking on false memory reflect the fact that past events have already happened in a particular way, whereas future events could be simulated as happening in numerous ways. This corresponds to the distinction made by Klein et al. (2002) between *lived time* and *known time*. The difference between the past and future conditions may, therefore, reflect the difference between real versus simulated events, rather than past versus future events. We believe this is unlikely given that future thinking led to higher levels of false recognition than the visualization condition, in which participants were instructed to imagine a typical scenario. It is also notable that Klein et al (2010) found that future thinking led to higher levels of correct recall than imagining an atemporal scenario. However, it is important to address the potential confound between temporal direction and the real versus simulated nature of the events.

The confound between temporal direction of type of event was previously discussed by Schacter et al. (2012). As they noted, some studies have provided evidence for a dissociation between imagining a future event and imagining an atemporal scenario. For example, de Vito, Gamboz, Brandimonte, Barone, Amboni, and Della Sala (2012) found that patients with Parkinson's disease showed impairments in imagining future events but not in imagining atemporal events. However, as Schacter et al. also observed, other studies have shown considerable overlap between imagined future events and imagined atemporal events. For example, de Vito, Gamboz, and Brandimonte (2012) found that future and atemporal simulations were associated with similar phenomenological details. Comparisons have also been made between imagining future events and imagining past events. In an fMRI study, Addis, Pan, Vu, Laiser, & Schacter, (2009) instructed participants to imagine events featuring three event details (person, location, and object). The critical manipulation was whether participants remembered past events, imagined plausible future events, imagined plausible past events, or performed a visualization task. Addis found that imagined events were associated with the same patterns of brain activity irrespective of whether they were imagined as occurring in the past or in the future. These inconsistent findings indicate that the confound between imagining future events and imagining hypothetical events has not been fully resolved. We cannot, therefore, rule out the possibility that the difference between the past and future conditions of Experiment 1 simply reflects the difference between real versus simulated events.

Another possible explanation for the higher levels of false recognition in the future rating condition is that participants in the past condition may have used a “recall-to reject” strategy (see Clark & Gronlund. 1992, for a review) whereby they were able to reject lure items on the grounds that they did not feature in the event they recalled during the study phase. This strategy would not have been available to participants in the future or visualization conditions.

We addressed both of these issues in Experiment 2 by asking participants in the all three rating conditions to simulate hypothetical events. Briefly, participants were instructed to simulate a series of unfamiliar scenarios (e.g., taking part in a bank robbery) and the critical manipulation was whether they simulated an event occurring in the future, an event occurring in the past, or a typical (atemporal) event. If the findings of Experiment 1 reflect the difference between real and simulated events, then we would expect to find no difference between past and future simulated events. If, however, the findings of Experiment 1 are due to the future-oriented nature of the simulated events, then we should find the same enhancement of false memories in the future condition of Experiment 2.

The use of unfamiliar scenarios in Experiment 2 also allowed us to investigate the role of semantic memory in the generation of future events. As noted by Szpunar et al. (2014), both episodic and semantic information can be utilised in the generation of future events (see Anderson, 2012, and Cordonnier et al., 2016, for examples). In Experiment 2, participants were unlikely to have episodic memories for the events they were instructed to generate. If false recognition is enhanced in the future condition, this would indicate that the pattern observed in Experiment 1 and our previous research (Dewhurst et al., 2016) can be driven by semantic knowledge.

Experiment 2

Method

Participants. A new group of 90 undergraduates (70 females) in the age range 18-44 (M=20.41, SD=3.97) took part in Experiment 2. All were native English speakers. They were tested at individual workstations in groups of up to 5 and received course credit or payment of £5 for their participation.

Stimuli and design. The three scenarios used in Experiment 2 were a bank robbery, going into space, and making a movie. For each scenario, participants were presented with 20 items, of which 10 were related to the scenario and 10 were unrelated. Six participants provided normative ratings for the likelihood of encountering the items in the given scenarios. The mean ratings (out of 5) were 4.23 for the related items and 1.40 for the unrelated items). For the bank robbery scenario, related items included *guard*, *account*, and *weapon*, and unrelated items included *doctor*, *towel*, and *guitar*. Old and new items were counterbalanced, and the order in which the scenarios were presented was rotated through participants. The recognition test contained 60 items. For each scenario, there were 10 studied items (5 related and 5 unrelated) and 10 lures (5 related and 5 unrelated). Stimuli and rating instructions are available from the first author. Stimuli presentation and data collection were controlled using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA).

Procedure. Participants were randomly allocated to past, future and visualization conditions and instructed to imagine the three scenarios in sequence. As in Experiment 1, an incidental learning procedure was employed. Past, future, and visualization rating instructions for the bank robbery scenario are shown below.

Past condition. *In this task, we would like you to imagine that you have just led the robbery of a well-guarded bank. Over the past few months, you managed to find people to help you, made a plan, and gathered the supplies you needed. We are going to show you a list of words, and we would like you to rate how relevant each of these items was for you in this situation. Some of the words may be relevant and others may not – it's up to you to decide.*

Future condition. *In this task, we would like you to imagine that you are planning the robbery of a well-guarded bank. Over the next few months, you'll need to find people to help you, make a plan, and gather any supplies you might need. We are going to show you a list of words, and we would like you to rate how relevant each of these items would be for you in this situation. Some of the words may be relevant and others may not – it's up to you to decide.*

Visualization condition. *Use your imagination to form a picture of a bank robbery. What items appear in the image that you have created of the bank robbery?*

While you are imagining this bank robbery I am going to present you with a list of words. I would like you to rate how relevant each of these items would be at the bank robbery that you have imagined. For some objects, it may be likely that they appear in your image. For others, it may be unlikely. It is up to you to decide.

After completing all three rating tasks, participants were engaged in a nonverbal filler task for 10 minutes and then given the surprise recognition test. The recognition test was self-paced and the items were presented in a different random order for each participant.

Results and Discussion

As in Experiment 1, the data from the three scenarios were collapsed into a single score. Table 2 shows the mean numbers of related and unrelated items correctly and falsely recognised as a function of rating condition and item type. Hits and false alarms were analysed in separate 3 (rating condition: past vs. future vs. visualization) x 2 (item type: related vs. unrelated) ANOVA with repeated measures on the second factor. The analysis of false recognition showed a significant main effect of rating condition, F (2,87) = 7.81, MSE = 2.63, p = .001, η_p^2 = .15. Pairwise comparisons showed that false recognition rates were higher in the future condition relative to the past and visualization conditions, p = .021 and p = .001, respectively. The past and visualization conditions did not differ significantly from each other, p = .86.

There was also a significant main effect of item type, whereby related lures were more likely to be falsely recognised than unrelated lures, F (1,87) = 30.19 MSE = 1.46, p < .001, η_p^2 = .26. The interaction between rating condition and item type was also significant, F (2,87) = 4.35, MSE = 1.46, p = .016, η_p^2 = .09. Pairwise comparisons across rating conditions showed that false recognition rates for related lures were higher in the future condition than in the past and visualization conditions,

$p = .015$ and $p = .001$, respectively. No significant differences were observed in the unrelated lures. Pairwise comparisons across item type showed that participants in the future condition falsely recognised more related than unrelated lures, $p < .001$. The same pattern was observed in the past condition, $p = .027$, but was not reliably present in the visualization condition, $p = .091$.

In the analysis of correct recognition, neither the main effect of rating condition nor the main effect of item type were significant, both *F*s < 1. The interaction between rating condition and item type also failed to reach significance, $F(2,87) = 1.72$, $MSE = 1.66$, $p = .19$, $\eta_p^2 = .04$. A Bayesian analysis comparing proportions of words correctly recognised in the past and future conditions, again using the correct recall from Klein et al. (2010) for the predicted effect size, found $B = 0.23$. This provides further evidence for the null hypothesis that rating items in relation to a future event does not enhance correct recognition. Study ratings were analysed in a one-way (rating condition) between-groups ANOVA. The effect of rating condition was not significant, $F < 1$.

The findings of Experiment 2 are consistent with those of Experiment 1. Rating nouns in relation to a future event led to higher levels of false recognition than rating them in relation to a past event or visualizing a typical scenario. Experiment 2 also confirmed that this effect does not simply reflect the hypothetical nature of future events. Participants in both the past and future conditions were instructed to simulate hypothetical events, but rating the nouns in relation to a simulated future event led to higher levels of false recognition than rating them in relation to a simulated past event. These findings indicate that the findings of Experiment 1 (and those of Dewhurst et al., 2016) do not simply reflect the difference between a real event that happened in a particular way and a hypothetical event that could unfold in numerous ways.

The findings of Experiment 2 also indicate that the effect of future thinking on false memory does not depend on the activation of episodic memories, but can also occur when participants simulate events by drawing on semantic knowledge (see Anderson, 2012, and Cordonnier et al., 2016, for discussion of the role of semantic memory in the generation of future events). The hypothetical nature of the events in Experiment 2 also rules out the possibility that participants in the past condition used a "recall-to-reject" strategy whereby they rejected lures because they did not feature in the event they remembered in the study phase. The findings are more consistent with the view that simulating a future event enhances the activation of related concepts that enables one to think beyond the information presented.

One possible interpretation of the findings of Experiments 1 and 2 (and those of Dewhurst et al., 2016) is that simulating a future event activates a "planning mode" that directs attention to items one might need in the future. When planning an activity, such as a holiday, one typically generates a mental checklist of items that might be needed. The activation of related knowledge in such situations would be adaptive if it guided attention towards items that might otherwise be forgotten. We investigated this possibility in Experiment 3 by replacing the memory test with a task in which participants were instructed to generate items that one would typically require in a given scenario. Participants took part in the past, future, or visualization conditions of the holiday scenario used in Experiment 1 and were instructed to rate the objects nouns for how likely they were to be encountered. Immediately after the rating task, participants were asked to generate as many items as they could think of that someone might take on a holiday.

Experiment 3

Method

Participants. A new group of 90 undergraduates (58 females) in the age range 18-44 (M=21.79, SD=4.47) took part in Experiment 3. All were native English speakers. They were tested at individual workstations in groups of up to 5 and received a payment of £5 for their participation.

Stimuli and design. The rating instructions and object nouns from the holiday scenario used in Experiment 1 were employed again. Rating condition (past, future, or visualization) was manipulated between participants. Stimuli presentation and data collection were controlled using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). The dependent variables were the numbers of studied words and new words generated in the listing task.

Procedure. Participants were instructed to remember a past holiday, imagine planning a future holiday, or imagine a typical holiday, and then to rate the nouns in relation to the target scenario. Immediately after the rating task, participants received the following instructions:

Please list as many items as you can think of that someone might take on holiday. These can be items from the list you just rated or new items not on the list. Please list as many as you can.

Participants were allowed 10 minutes to complete the listing task.

Results and Discussion

All items listed by at least one participant were compiled into a single document and rated by two independent raters according to the following instructions:

Please rate the likelihood that the following items would be taken on a holiday. It could be any kind of holiday. Please do not rate the likelihood that YOU *would take them on a holiday, but that someone could in principle take them on a holiday. Please rate them on a 5-point scale from 1 = very unlikely, to 5 = very likely.*

Inter-rater reliability was good (Cohen's Kappa = .72). For each listed item, the mean of the two ratings was calculated, ensuring that synonyms (e.g., *travel guide* and *guidebook*) received the same ratings. As expected, given that participants had been instructed to generate items that someone might take on a holiday, ratings made by the two independent raters were high (see Table 3). These ratings were used to calculate the mean ratings for each participant, which were then analysed in a 3 (rating condition: past vs. future vs. visualization) x 2 (Status: old vs. new) ANOVA with repeated measures on the second factor. A significant main effect of status showed that likelihood ratings were higher for studied items than for unstudied items, $F\ (1,87) = 227.69$, $MSE = .07$, $p < .001$, $\eta_p^2 = .72$. Neither the main effect of rating condition nor the interaction were significant, both $F < 1$. The finding that likelihood ratings were lower for unstudied than for studied items is likely a reflection of the fact that the study lists contained the majority of the items previously rated as being associated with a holiday (see stimuli and design section of Experiment 1).

The numbers of items generated by participants in the listing task were then analysed. Table 4 shows the mean numbers of studied and unstudied items generated as a function of rating condition. Ten items rated by both raters as "very unlikely" were omitted from these analyses. The first analysis was a one-way (rating condition: past vs. future vs. visualization) between-groups ANOVA on the total number of items generated in the listing task. A significant main effect of rating condition was observed, $F\ (2,87) = 9.82$, $MSE = 45.56$, $p < .001$, $\eta_p^2 = .18$. Pairwise comparisons showed that participants in the visualization condition listed fewer items than those in the past and future rating conditions, $p = .020$ and $p < .001$, respectively. The past and future conditions did not differ significantly from each other, $p = .34$.

This was followed by separate analyses of studied and unstudied items. A significant main effect of rating condition was observed in studied items, $F(2,87) = 10.05$, $MSE = 4.22$, $p < .001$, $\eta_p^2 = .19$. Pairwise comparisons showed that participants in the past condition generated more studied items than participants in the future, $p = .012$, and visualization, $p < .001$, conditions, which did not differ significantly from each other, $p = .46$. There was also a significant main effect of rating condition in the number of unstudied items generated, $F(2,87) = 8.66$, $MSE = 41.84$, $p < .001$, $\eta_p^2 = .17$. Pairwise comparisons showed that participants in the future rating condition generated more unstudied items than those in the past, $p = .032$, and visualization, $p < .001$, conditions, which did not differ significantly from each other, $p = .41$. Study ratings (i.e., the ratings made by participants when studying the items) were analysed in a one-way between-groups ANOVA. The effect of rating condition was not significant, $F < 1$.

Comparison of the past and future conditions indicates that participants in the future rating condition generated fewer studied items and more unstudied items than participants in the past rating condition. In order to confirm this, we conducted a 2 (temporal direction: past vs. future) x 2 (status of generated item: studied vs. unstudied) mixed ANOVA with repeated measures on the second factor. This showed a nonsignificant main effect of temporal direction, $F(1,58) = 2.08$, $MSE = 28.29$, $p = .16$, $\eta_p^2 = .04$, but a significant main effect of status, whereby participants generated more unstudied than studied items, $F(1,58) = 74.91$, $MSE = 24.99$, $p < .001$, $\eta_p^2 = .56$. These effects were qualified by a significant interaction, $F(2,87) = 10.56$, $MSE = 24.99$, $p = .002$, $\eta_p^2 = .15$. Pairwise comparisons confirmed that participants in the future rating condition listed more unstudied items, $p = .019$, and fewer studied items, $p = .006$, than participants in the past rating condition.

Experiments 1 and 2 showed that future thinking enhances the semantic activation processes that give rise to schema-based false memories. The findings of Experiment 3 suggest a potential adaptive role for this effect by showing that future thinking facilitates the generation of items that might be needed in a hypothetical scenario. It is also notable that the novel items listed in the future condition were no less likely to be taken on holiday than those listed in the past and visualization conditions, as judged by the independent raters. While participants in the future condition generated more unstudied items in the listing task, there was no loss in the plausibility of the items generated. The finding that future thinking enhanced the generation of novel items, but not studied items, suggests the activation of a planning mode that goes beyond the information presented and directs attention to items that one might otherwise forget. The current findings thus suggest close links between the simulation and planning modes of prospection proposed by Szpunar et al. (2014) by showing that simulation of a future event facilitates the subsequent planning of the event.

One unanticipated finding from Experiment 3 was that participants in the future condition generated fewer studied items than participants in the past condition. This contrasts with the findings of Experiments 1 and 2 and our previous research (Dewhurst et al., 2016) in which levels of correct recall and recognition of studied items were not affected by rating condition. We suspect this discrepancy is due to the use of a listing task in Experiment 3, which did not explicitly instruct participants to recall the items they rated at study. In this sense, the listing task could be seen as an implicit test of memory (see Roediger & McDermott, 1993, for a review). In contrast, participants in our previous studies were explicitly instructed to retrieve items from the study phase. This raises the intriguing possibility that the effects of future thinking on correct and false memory will depend on how memory is tested. An interesting direction for future research would be to investigate the effects of future thinking on a wider range of memory measures, including both explicit and implicit measures.

General Discussion

The current study investigated the relationship between future thinking and false memory. In Experiment 1, rating common objects for their relevance to an imagined future event increased the false recognition of related objects, relative to conditions in which the objects were rated for relevance to a past event or an atemporal visualization of an event. Experiment 2 extended this effect to events that participants were unlikely to have experienced personally, thereby showing that the effect of future thinking is not simply the result of thinking about a hypothetical event as opposed to a real event. The current findings are consistent with those of Dewhurst et al. (2016) and extend them by showing that the effects of future thinking on false memory are not confined to the use of associative (DRM) lists designed to produce high levels of false memory. Future thinking can also increase false memories via the activation of semantic knowledge in the form of schemas.

In terms of the taxonomy of prospection proposed by Szpunar et al. (2014), the current findings show that false memories are increased by the simulation of future events, irrespective of whether the simulation draws on episodic memory or semantic knowledge. The findings of Experiment 2, in particular, suggest that this effect is driven by the future orientation of the simulation task rather than the type of knowledge on which the simulation is based. Even when participants are instructed to simulate events for which they are unlikely to have episodic memories, simulating a future event still leads to higher levels of false recognition than simulating a past event. According to D'Argembeau et al. (2010), imagining a future event leads to more flexible thinking than remembering a past event. The findings from Experiment 2 suggest that this greater flexibility is not simply due to differences in the types of knowledge from which past and future events are drawn. It is the future-oriented nature of the simulated event that is crucial.

The increase in false memories when imagining the future is also consistent with the recent finding by Campbell et al. (2017) that related concepts are automatically activated when simulating a future event. Whereas successful remembering often requires the inhibition of related concepts in tasks such as retrieval-induced forgetting (Anderson et al., 1994), Campbell et al. found no evidence of inhibition of related concepts when imagining future events. On the contrary, they found that related concepts were primed when participants were instructed to imagine a future event. Extending this to the current study, it is possible that related concepts were inhibited when participants retrieved details of a past event, but primed when participants imagined a future event. When these related concepts matched the lures in the recognition test, false recognition was more likely to occur when those concepts were primed rather than inhibited at study. This interpretation is consistent with findings that false memories are reduced by tasks that require the inhibition of studied items, such as retrieval-induced forgetting (starns & Hicks, 2004).

Experiment 3 revealed a potential adaptive role for the associative processes that give rise to false memories by demonstrating their role in generating items that one might require when planning an event. However, a caveat to this is that participants in the future condition generated fewer studied items than those in the past condition. A stronger case could be made for an adaptive function if future thinking increased the generation of both studied and unstudied items. It is possible that some participants in the past condition interpreted the listing task as a memory test and prioritised the retrieval of studied items (analogous to problem of "retrieval intentionality" that can contaminate tests of implicit memory; see Schacter, Bowers, & Booker, 1989). If so, the number of studied items listed in the past condition could have been inflated, giving the impression that the future condition was less effective in terms of generating studied items. This could be prevented in future studies by asking participants to indicate whether they intentionally retrieved studied items during the listing task and replacing those who respond in the affirmative. In the meantime, however, we can conclude that future thinking facilitates the generation of items that one has not recently thought about.

The current findings provide further support for the emerging view that false memories can be adaptive in the sense of having positive consequences for behaviour. Previous research has shown that false memories can be associated with successful problem solving. For example, Arkes and Harkness (1980) found that students who successfully diagnosed a medical condition from a list of symptoms were more likely to falsely recognise nonstudied symptoms associated with the condition than students who failed to make the diagnosis. More recently, Howe, Garner, Dewhurst, and Ball (2010) found that participants were more likely to solve remote associate problems when the solution was a falsely recalled critical lure from a DRM list (see also Howe, Garner, Charlesworth, & Knott, 2011, Howe, Garner, & Patel, 2013, and Howe, Threadgold, Norbury, Garner, & Ball, 2013). Planning a future activity can also be seen as a problem solving activity. The current findings, together with those discussed above, show that false memories of goal-related information can facilitate planning and problem solving activities.

It could be argued that the difference between the past and future conditions in Experiment 2 is at odds with the findings of Addis et al. (2009) that imagining past and future events led to the same patterns of brain activity. However, the main aim of Addis et al. was to address the confound between past versus future events and real versus imagined events. Their findings demonstrated that the same brain areas are recruited when imagining hypothetical past and future events. The findings from the current study are not incompatible with this view. They simply show that the associative processes activated when imagining hypothetical events are enhanced when the events are imagined as occurring in the future rather than the past. The findings of Experiment 3 suggest one possible reason for this difference. We have discussed the possibility of a planning mode than directs attention to items one might need when planning an activity. Whereas activating a planning mode is likely to serve a functional role when imagining a future event, it is less likely to be useful when imagining a past event.

The effects of Experiment 2 might also seem at odds with the finding by Klein et al. (2002) that the mnemonic effect of planning is greater when planning tasks invoke *lived time*, based on episodic memories, rather than *known time*, based on semantic memories. The rating tasks in Experiment 2 are unlikely to have invoked lived time – in fact, they were chosen on the basis that participants were unlikely to have relevant personal experience – yet participants in the future rating condition still showed higher levels of false recognition than participants in the past and visualization conditions. However, Klein et al. did not claim that the effects of planning on recall is confined only to tasks than invoke lived time, merely that such tasks produce a greater memory enhancement than events that invoke known time. We have not yet compared the effects of lived versus known time on false memory. Comparison of the data from Experiments 1 and 2 would be misleading as they involved different tasks and different study lists. Nevertheless, a more direct comparison of the effects of lived versus known time might reveal more about the respective roles of episodic and semantic memories in producing false memories.

In contrast to the effects observed in false recognition, the manipulation of rating condition did not significantly affect correct recognition in either Experiment 1 or Experiment 2. These null effects are consistent with the findings of our previous study (Dewhurst et al., 2016) but at odds with the findings of Klein et al. (2010). The Bayesian analyses of both the current data and our previous data support the null hypothesis that future thinking does not affect correct recall or recognition, so how can these inconsistencies be explained? The most salient difference between our experiments and those of Klein et al. is that we used study lists that were designed to produce high numbers of false memories. In contrast, the lists used by Klein et al. were not constructed for this purpose. Although Klein et al. did not report intrusion rates, the follow-up study by Klein et al. (2011) reported only five extra-list intrusion errors from 162 participants, with no participant producing more than one, and Klein et al. (2012) reported only three intrusions from 120 participants. One possible explanation for the discrepant findings is that the omission of related items from the study lists (DRM critical lures in our previous research and schema-related lures in the current experiments) caused the effects reported by Klein and colleagues in correct memory to shift to false memory. It is notable that the overall pattern we observed in false recognition matches the pattern observed by Klein et al. in correct recall. Specifically, both studies showed significant increases in the future condition but virtually identical performance in the past and visualization conditions (which Klein et al. referred to as an atemporal condition).

This shift from true to false memory could be explained in terms of the distinction between relational and item-specific encoding (Hunt & Einstein, 1981). As discussed above, imagining the future leads to more flexible thinking than remembering the past (D'Argembeau et al., 2010). It is possible, therefore, that thinking about future events enhances relational encoding. Relational encoding has been shown to enhance correct recall. For example, Guynn, McDaniel, Strosser, Ramirez, Castleberry, and Arnett (2014) found that relational encoding enhanced the generation component of recall. This can explain the effects of future thinking on correct recall reported by Klein et al. (2010). However, both McCabe, Presmanes, Robertson, and Smith (2004) and Huff and Bodner (2011) found that relational encoding did not enhance correct recall in the DRM paradigm. It did, however, increase false recall rates. This raises the possibility that, when study lists are not conducive to producing high levels false memory, as in the lists used by Klein et al., the effects of relational encoding occur in correct memory. However, when critical items are omitted from study lists (as in DRM lists or the schema-related lists used in the current experiments), the effects of relational encoding shift from correct to false recall. This is highly speculative but suggests one possible direction for future research.

To summarize, the current findings show that imagining future events increases the false recognition of items associated with those events. Consistent with our previous research (Dewhurst et al., 2016), rating items for their relevance to a future event led to higher levels of false recognition than rating their relevance to a past event or a visualized scenario. The findings of Experiment 1 showed that our previous findings are not confined to DRM lists designed to produce high levels of false memory. The findings of Experiment 2 indicate that the effect of future thinking is not simply due to a comparison between a real event that happened in a particular way and a hypothetical event that could unfold in numerous ways. The current findings are more consistent with the view that the simulation of a future event directs attention to items one might need when planning a future activity. The potentially adaptive nature of this effect was demonstrated in Experiment 3, in which participants who rated items for relevance to a future holiday generated more new items and fewer old items when listing objects one might take on a holiday. These findings are consistent with the notion of a planning mode that is facilitated by the activation processes that give rise to false memories.

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