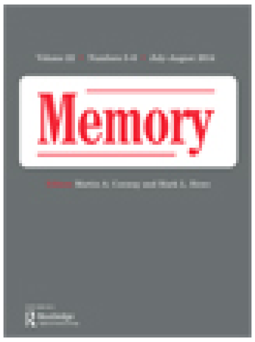

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Priming, not inhibition, of related concepts during future imagining

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ABSTRACT

Remembering the past and imagining the future both involve the retrieval of details stored in episodic memory and rely on the same core network of brain regions. Given these parallels, one might expect similar component processes to be involved in remembering and imagining. While a strong case can be made for the role of inhibition in memory retrieval, few studies have examined whether inhibition is also necessary for future imagining and results to-date have been mixed. In the current study, we test whether related concepts are inhibited during future imagining using a modified priming approach. Participants first generated a list of familiar places and for each place, the people they most strongly associate with it. A week later, participants imagined future events involving recombinations of people and places, immediately followed by a speeded response task in which participants made familiarity decisions about people's names. Across two experiments, our results suggest that related concepts are *not* inhibited during future imagining, but rather are automatically primed. These results fit with recent work showing that autobiographically significant concepts (e.g., friends' names) are more episodic than semantic in nature, automatically activating related details in memory and potentially fuelling the flexible simulation of future events.

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Recent research has documented many parallels between remembering past experiences and imagining future experiences (for recent reviews, see Klein, 2013; Schacter et al., 2012; Szpunar, 2010). Both rely heavily on details stored in episodic memory to create an internal representation of an event (Schacter & Addis, 2007), are characterised by similar phenomenological characteristics (e.g., D'Argembeau & Van der Linden, 2004; McDermott, Wooldridge, Rice, Berg, & Szpunar, 2016) and show similar declines with ageing (e.g., Addis, Wong, & Schacter, 2008; for a review, see Schacter, Gaesser, & Addis, 2013), medial temporal lobe (MTL) damage (Hassabis, Kumaran, Vann, & Maguire, 2007; Race, Keane, & Verfaellie, 2011; but see Squire et al., 2010), and various psychopathological conditions (Brown et al., 2014; D'Argembeau, Raffard,& Van der Linden, 2008; Lind & Bowler, 2010). Consistent with these observations, recent work using an episodic specificity induction designed to increase retrieval of details from episodic memory has shown similar effects on imagination and memory (Madore, Gaesser, & Schacter, 2014; for a review, see Schacter & Madore, 2016). Moreover, remembering the past and imagining the future appear to rely on the same core network of brain regions, including the MTL, ventromedial prefrontal cortex, posterior cingulate, and posterior inferior parietal lobes (e.g., Benoit & Schacter, 2015; Buckner & Carroll, 2007; Schacter, Addis, & Buckner, 2007; Spreng, Mar, & Kim, 2008). Although various differences between episodic remembering and imagining have also been documented (see Schacter et al., 2012; Szpunar, 2010), in light of the numerous parallels it seems clear that some of the same component processes are involved in remembering and imagining.

One such component process may be inhibition. There is now ample evidence to suggest that successful memory retrieval involves inhibition of competing concepts in memory, rendering those concepts less active or accessible (e.g., Anderson, Bjork, & Bjork, 1994; Aslan & Bäuml, 2011; Healey, Campbell, Hasher, & Ossher, 2010; for a review, see Storm & Levy, 2012). For instance, in retrieval induced forgetting (RIF) paradigms, participants learn a list of category-exemplar pairs (e.g., FRUIT-apple), followed by a retrieval-practice phase during which some of the studied items are retrieved in response to partial cues (e.g., FRUIT-a____). In a final recall phase, participants are asked to recall all studied items. The critical comparison is between unpracticed-related items (i.e., unpracticed items from categories that were practiced; e.g., FRUIT-banana) and unpracticed-unrelated items (i.e., unpracticed items from categories that were not practiced; e.g., FURNITURE-lamp). Participants tend to show greater forgetting of unpracticed-related items than unpracticed-unrelated items, which has been attributed to the suppression of unpracticed (yet competing) items during the retrieval-practice phase (Anderson et al., 1994). Although other

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interpretations of the RIF effect have been suggested (e.g., MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003; Raaijmakers & Jakab, 2013), there is mounting evidence from converging methods which suggests that competition at retrieval is resolved by way of inhibition (e.g., Benoit & Anderson, 2012; Healey, Ngo, & Hasher, 2014; Healey et al., 2010; Hulbert, Henson, & Anderson, 2016; Rupprecht & Bäuml, 2016; Storm & Angello, 2010). Given that imagination involves the retrieval of information stored in memory, not all of it relevant to current goals, it is plausible that imagination would produce an inhibitory effect similar to that seen during memory retrieval.

Four recent studies addressed this question, with mixed results. First, Storm and Jobe (2012) had participants study lists of events in specific locations (e.g., Mario feeding hotdogs to pigeons in the park). Then participants either retrieved an autobiographical memory in response to the same location cue (e.g., park) or generated a newly imagined event at that location. They found that retrieving pre-existing autobiographical events caused forgetting of studied events in the same locations (relative to studied events at unused locations), whereas imagining novel events at those locations did not cause forgetting, suggesting that imagination does not require inhibition. In a second study, Ditta and Storm (2016) had participants retrieve their own autobiographical memories in response to location cues (e.g., college housing) and give each memory a label (e.g., "Friendly Roommates"). They then had participants imagine future events at these locations, followed by a cued recall test for the autobiographical events associated to each cue (i.e., given cue "college housing", should recall "Friendly roommates"). In contrast to the previous study, participants showed greater forgetting for imagined cues relative to unused cues, and this effect was replicated across four experiments (including two that used the same third-person materials as Storm & Jobe, 2012). The authors attributed this difference in results to methodological differences between the two studies. In another two studies, Migueles and García-Bajos tested for RIF of past and future autobiographical experiences that participants generated in response to cues (e.g., "The best present I've ever been given/I could ever get … "). They found evidence for RIF for both past and future events in one study (Migueles & García-Bajos, 2015), but only for negative, not positive, past and future events in the other (García-Bajos & Migueles, 2016).

All of these studies used a RIF-style paradigm and involved recall of associations/labels learned earlier in the experiment (i.e., park – Mario feeding hotdogs; college housing – "Friendly Roommates" label). An important question is whether future imagining causes inhibition of *pre-existing* associated concepts in memory, established prior to the experimental session. By inhibition, we mean reduced availability or activation of the representation itself, not reduced accessibility via a particular retrieval cue (Anderson & Spellman, 1995). In order to test the accessibility of competing concepts, we used a modified priming approach (similar to that of Healey et al., 2014), testing response times (RTs) to associated concepts immediately after future imagining. If related concepts compete and are inhibited during future imagining, then participants should be slower to respond to these concepts on a subsequent task. By not re-presenting the same retrieval cues during imagination and test, this paradigm measures implicit access to the competing representations and is less susceptible to common criticisms of some variants of the RIF method (e.g., that RIF is due to interference from the strengthening of practiced associations or a change in context during the retrieval phase; Jonker, Seli, & MacLeod, 2013; Raaijmakers & Jakab, 2013). It also uses pre-existing, personally significant associations from participants' own autobiographical memory and thus, more closely approximates the type of future thinking many investigators have typically studied in the literature discussed earlier that compares episodic remembering and future imagining (e.g., Addis, Musicaro, Pan, & Schacter, 2010; Addis, Pan, Vu, Laiser, & Schacter, 2009; Benoit, Szpunar, & Schacter, 2014).

Experiment 1

Participants came into the lab for two sessions, about a week apart (see Figure 1). In the pretesting session, participants were asked to name 60 places that they were personally familiar with and, for each place, up to 10 people they most strongly associate with that place. In the imagination session, participants first imagined future interactions involving recombinations of the people and places they listed in session one. This procedure was followed by a speeded response task in which participants decided if people's names were familiar to them or not. Critically, there were four name types on this task: *primed* names that were seen on the preceding imagination task, *original associates* that were related to places seen on the imagination task but not seen themselves, *baseline* names not seen or associated with stimuli on the imagination task, and *unfamiliar* names. If imagining a novel future event at a given place requires the inhibition of people normally associated with that place, then we would expect slower RTs to original associates than baseline names. However, if future imagining does not require inhibition, and activation automatically spreads to related concepts in memory in a manner similar to semantic priming (Neely, 1991), then we would expect to see faster RTs to original associates than baseline names. Given the open-ended nature of future imagining, and the mixed inhibition results to date for future imagining, both outcomes are plausible.

Finally, we also tested memory for the imagined events as an indicator of whether participants had performed the imagination task as instructed. This task was followed by a final cued recall test similar to category-cued recall used in classic RIF paradigms (e.g., Anderson et al., 1994).

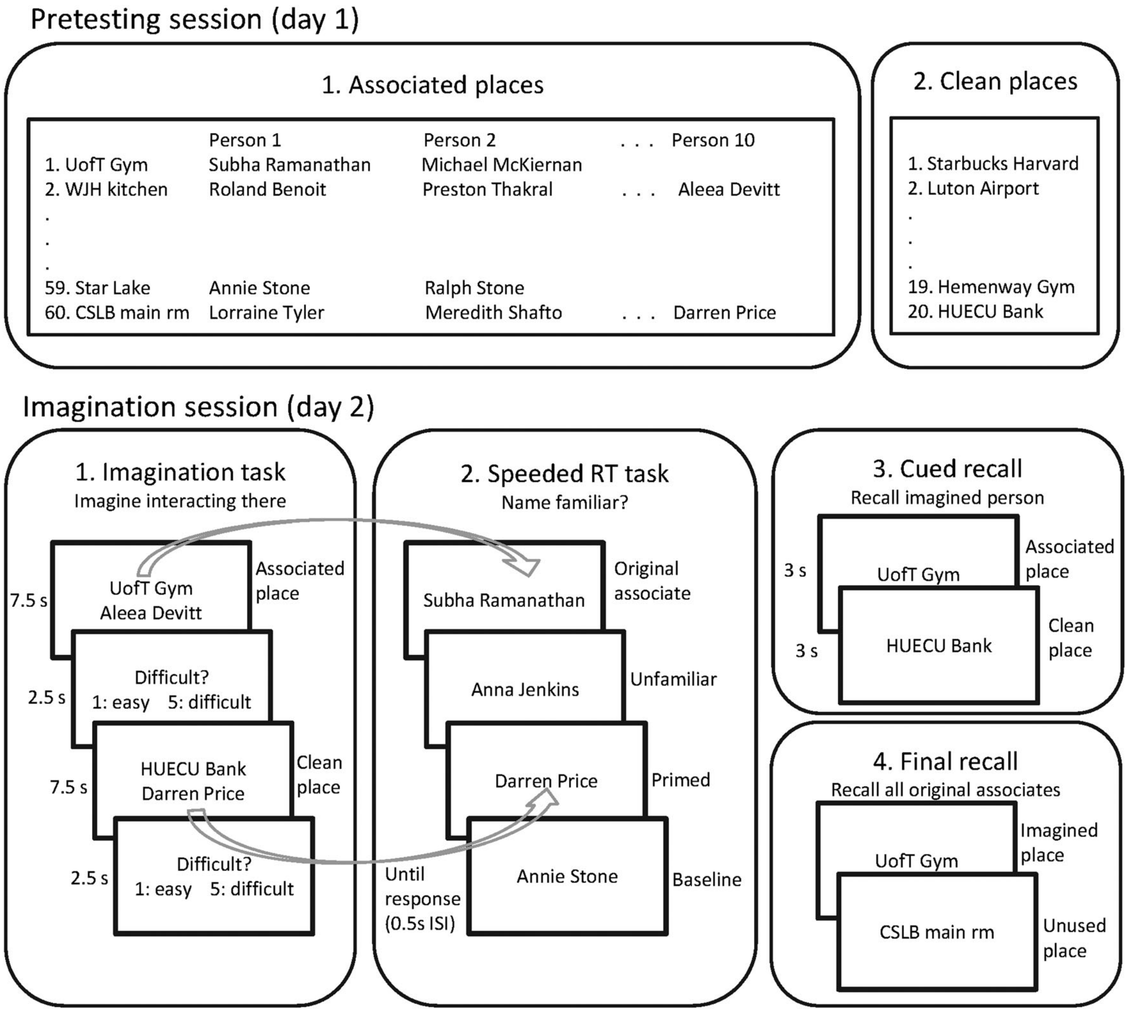

Figure 1. Overview of the experimental procedure. Participants generated a list of familiar places and names in the pretesting session (day 1), which were used to create a personalised version of the experiment for the imagination session (day 2).

Participants were given a list of places (half from the imagination task and half not seen during the second session) and asked to recall all the names they associate with each place. If future imagining causes inhibition, then we would expect greater forgetting of names for the imagined places relative to unused places.

Methods

Participants

Twenty-four young adults (mean age = 20.71 years, SD = 2.29 years; 19 female) were recruited from the Harvard Psychology Study Pool and received partial course credit or pay for their participation. All participants had normal or corrected-to-normal vision and no history of neurological impairment. Prior to the experiment, we decided on a sample size of 24 as this would give us approximately 80% power ($\alpha = .05$, two-tailed, dependent means) to detect a medium-sized effect ($d \approx 0.60$). One participant was replaced for not following task instructions on the name familiarity task.

Tasks and procedure

Pretesting session

The study consisted of a pretesting session followed by an imagination session approximately a week later ($M = 6.88$ days, SD = 0.74). In the pretesting session (see Figure 1), participants were asked to name 60 places they were personally familiar with, and, for each place, generate up to 10 people (first and last names) they most strongly associate with that place. Participants rated each associated name (on a scale from 1 to 10) to indicate how strongly they associate that person with the corresponding place. Participants were told that names could be repeated across multiple locations, but they should try to think of places associated with different aspects of their lives in order to come up with a diverse range of people. This instruction was intended to minimise overlap of people across places as much as possible in order to yield enough distinct people and places to generate pairings for the imagination session. Participants were also asked to generate 20 "clean places", that is, places they have been to on their own and do not associate with anyone (i.e., cannot name any of the people there; e.g., a bank or coffee shop they have been to on their own). These places would subsequently be paired with to-be-primed people (see Figure 1) and were also designed to minimise overlap across stimuli during the imagination phase (in that clean places should not have brought any additional people to mind).

Imagination session

In the second session, participants performed a series of four tasks. The first task was an imagination task in which participants were presented with 30 place/person pairings for 7500 ms each (e.g., gym/friend) and imagined interacting with that person in a location-specific manner (e.g., showing friend how to use rowing machine) as vividly as possible. After each pairing, they had 2500 ms to rate how difficult it was to imagine interacting with that person in that place (1: easy; 5: difficult). This rating was followed by an interstimulus interval (ISI) of 500 ms. Participants were told that the imagined event should only include themselves and the specified person, nobody else. Before starting the task, participants performed three practice trials and then described their imagined events to the experimenter to ensure that the imagined events were location specific and restricted to the specified person. Critically, half of the person-place pairings consisted of places that participants normally associated with other people (i.e., the original associates), while the other half used clean places. The people used on the imagination task were not expected in those locations and were not associated with any of the places used on the imagination task.

The imagination task was immediately followed by a speeded RT task in which participants decided if people's names were personally familiar to them or not. The task consisted of 90 names (first and last), half familiar and half unfamiliar. Unfamiliar names were created by randomly selecting surnames from the top 100 surnames in the 2000 US census (http://www.census.gov/topics/population/genealogy/data/2000_surnames.html) and pairing these with a random selection of first names (half male, half female) from the top 500 names registered for social security numbers in the US in 2000 (http://www.ssa.gov/cgi-bin/popularnames.cgi). A Google search was performed for each unfamiliar name to ensure that no famous names were inadvertently included. Of the familiar names, 15 were seen on the preceding imagination task (primed), 15 were associated with places seen on the imagination task (original associates), and 15 were familiar names not used or associated with stimuli on the imagination task (baseline; see Figure 1). Names were presented one at a time in the centre of the screen until participants made a speeded button response ("1" if familiar, "2" if unfamiliar), followed by a 500 ms ISI. The dependent measure of interest on this task was the time taken to correctly identify familiar names. Anticipatory RTs (<200 ms) and extreme outliers (>3 SD from the condition mean) were removed and RT data were inverse transformed (Ratcliff, 1993) before calculating cell means per condition per subject (means were then reverse-transformed to standard ms units).

Following the speeded RT task, participants were given a cued recall test for the place/person pairings they saw during the imagination task. This task primarily served as a manipulation check to ensure that participants followed instructions during the imagination task, assuming that imaginings would constitute an efficient encoding strategy (e.g., Benoit et al., 2014). On this task, 30 place names from the imagination task were shown in a random order for 3000 ms each (500 ms ISI) and participants recalled the name of the person they imagined interacting with at each place. The experimenter recorded their responses. Finally, participants were given a final cued recall test similar to category-cued recall in RIF paradigms. On this task, participants were shown 15 associated places from the imagination task (i.e., not the clean places) and 15 unused places in a random order and were asked to recall all the people they associate with each place. This task was self-paced and participants typed their own responses.

Results

Imagination and subsequent memory

Difficulty ratings did not differ between associated ($M = 2.84$, $SD = 0.76$) and clean places ($M = 2.76$, $SD = 0.70$), $t(23) = 0.59$, $p = .56$, on the imagination task. Similarly, subsequent memory for imagined events (i.e., cued recall) also did not differ between associated ($M = 10.08$, $SD = 3.27$) and clean places ($M = 11.21$, $SD = 2.73$), $t(23) = 1.87$, $p = .075$, although there was a trend towards greater recall for clean places.

Speeded RT task

Proportion correct on the familiarity task was very high and differed across conditions, $F(3, 69) = 5.81$, $p = .001$, $\eta_p^2 = .20$. This result was attributable to higher accuracy for primed ($M = 0.98$, $SD = 0.05$) and unfamiliar ($M = 0.98$, $SD = 0.03$) names than baseline names ($M = 0.93$, $SD = 0.08$), $t(23) = 3.21$, $p = .004$, and $t(23) = 2.82$, $p = .01$ (for primed and unfamiliar, respectively) and original associates ($M = 0.94$, $SD = 0.06$), $t(23) = 2.70$, $p = .01$, and $t(23) = 3.25$, $p = .004$ (for primed and unfamiliar, respectively).

Figure 2 shows mean RTs per condition (calculated for correct responses only: "no" responses to unfamiliar names, and "yes" responses to familiar names). Mean RTs were submitted to a repeated measures ANOVA with name type (unfamiliar, baseline, original associate, primed) as a within-subjects factor. The main effect of name type was significant, $F(3, 69) = 6.34$, $p = .001$, $\eta_p^2 = .22$. The critical comparison of interest was between baseline names and original associates – names of

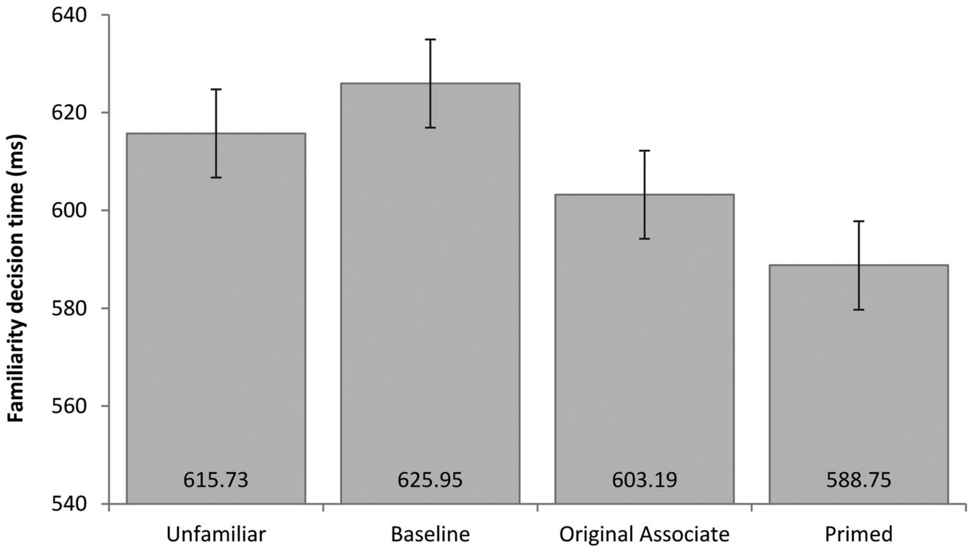

Figure 2. Mean RTs on the name familiarity task from experiment 1. Error bars represent 95% confidence intervals calculated using Masson and Loftus's (2003) method for within-subjects designs.

people who were not seen on the imagination phase themselves, but are strong associates of the places that were imagined. Paired *t*-tests show that RTs were faster to original associates ($M = 603.19$, SD = 73.39) than baseline names ($M = 625.95$, SD = 75.16), $t(23) = 2.57$, $p = .017$,[1] *Cohen's* $d = .52$, suggesting that associated people were not inhibited, but automatically primed, during future imagining. Unsurprisingly, this effect was appreciably smaller than the repetition priming effect for names which themselves appeared on the imagination task ($M = 588.45$, SD = 63.01), $t(23) = 6.85$, $p < .001$, $d = 1.41$, relative to baseline. RTs to primed names and original associates were not significantly different, $t(23) = 1.87$, $p = .074$.

While these results suggest that related concepts are primed during future imagining, further exploration of the data revealed one confounding factor which may have contributed to this priming effect. Despite random assignment to conditions, names in the original associate condition were mentioned more often during pretesting ($M = 1.86$, SD = 1.02) than names in the baseline condition ($M = 1.23$, SD = 0.41), $t(23) = 2.97$, $p = .01$, suggesting that they were more familiar. This difference in frequency may have contributed to the difference in RT between conditions, as RTs were negatively correlated with frequency in both the baseline (mean Pearson's $r = -.18$, SD = 0.20, t (15)[2] = 3.64, $p = .002$) and original associate (mean $r = -.14$, SD = 0.24, $t(16) = 2.38$, $p = .03$) conditions. If we limit our analysis to only those trials with equal frequency (by removing the name with the highest frequency for the original associate condition and the lowest frequency for the baseline condition, recursively, until mean frequency was equated across conditions), the difference between original associates ($M = 608.95$, SD = 73.57) and baseline names ($M = 625.49$, SD = 78.01) is no longer significant, t (21)[3] = 1.72, $p = .10$. While this difference in frequency between conditions is unlikely to explain the lack of *slowing* to original associates that would have been indicative of an inhibitory effect (because we still see a trend towards a priming effect), it does call into question the observed priming effect. Thus, in Experiment 2, we attempted redress this issue by more closely matching these conditions on frequency in order to test whether associated people are primed during future imagining (see below).

Table 1. Mean number of names originally listed per location and recalled during final recall.

Experiment	Imagined/counted		Unused	
	Originally listed	Recalled	Originally listed	Recalled
Experiment 1	3.43 (2.03)	2.55 (1.61)	3.34 (1.94)	2.55 (1.55)
Experiment 2				
Imagination	3.30 (1.58)	2.32 (1.03)	3.52 (1.59)	2.53 (1.19)
Vowel-counting	3.78 (1.43)	2.54 (1.08)	3.74 (1.49)	2.63 (1.22)

Note*:* Standard deviations are provided in parentheses.

Final recall

The speeded RT task only tested suppression of the strongest associate of each imagined place. However, participants listed several associates for each location ($M = 3.85$, SD = 1.96) and it is possible that a test that takes these weaker associates into account may be more sensitive to any suppression effects. Thus, we included a final cued recall test, similar to category-cued recall in RIF paradigms, testing memory for all the people associated with each imagined place, plus 15 unused places for comparison. Mean forgetting for imagined and unused places was calculated as the mean number of names forgotten per location (i.e., that were listed during pretesting but not final recall; Table 1 shows the mean number recalled and originally listed for each place per condition). On average, participants forgot a similar number of people for imagined ($M = 0.88$, SD = 0.78) and unused places ($M = 0.79$, SD = 0.72), $t(23) = 1.19$, $p = .25$, further suggesting that future imagining does not necessarily require inhibition. Imagined places did have slightly more new people mentioned who were not listed during pretesting ($M = 0.94$, SD = 0.68 and $M = 0.74$, SD = 0.38, for imagined and unused places respectively), $t(23) = 2.37$, $p = .03$, and this result was partly attributable to intrusions of the newly imagined person ($M = 0.71$, SD = 1.16, one-sample t-test: $t(23) = 2.99$, $p = .007$; 6 participants made 1 intrusion, 3 made 2, and 1 made 5). Thus, imagining future events involving new people at unexpected places can lead to occasional false memories for those person-place pairings, but does not appear to entail suppression of previous associates.

Experiment 2

Experiment 1 suggests that related concepts are primed, not inhibited, during future imagining, but we cannot rule out the possibility that this effect was attributable to differences in frequency between the baseline and original associate conditions. Thus, in Experiment 2 we aimed to replicate the priming effect associated with future imagining after more closely matching these conditions in terms of frequency. We also tested an additional group of participants using a non-semantic vowel-counting task to determine whether comparable levels of priming are observed in both cases. Counting the number of vowels in the place and person names should not require the inhibition of competitors and thus should show unfettered priming of associated concepts in memory (e.g., Meyer & Schvaneveldt, 1971; Neely, 1977, 1991). If future imagining does involve inhibition of related concepts (just not to baseline or below-baseline levels), then we would expect less priming of associated concepts after future imagining relative to vowel-counting. However, if associated concepts are automatically activated and not suppressed during future imagining, then priming should be comparable between the two groups.

Methods

Participants

Forty-eight young adults (mean age = 21.92 years, SD = 2.12 years; 28 female) were recruited from the Harvard Psychology Study Pool and received partial course credit or pay for their participation. Participants were randomly assigned to either the imagination or vowel-counting condition. Groups did not differ in terms of age, years of education, or days between sessions, t's <1. All participants had normal or corrected-to-normal vision and no history of neurological impairment.

Tasks and procedure

The tasks and procedure were the same as those used in Experiment 1, except that the vowel-counting group counted the number of vowels in the person and place names instead of imagining a future event. Event-timings were kept constant, such that participants had 7500 ms to count the number of vowels in each stimulus, followed by a response screen for 2500 ms. Instead of rating the difficulty of the preceding trial, participants indicated which stimulus had the most vowels (1 = place had more vowels, 2 = person had more vowels, 3 = same number of vowels). All other aspects of the design were the same, and we equated the frequency of names in the baseline and original associate conditions.

Results

Imagination/vowel-counting and subsequent memory

Unlike Experiment 1, difficulty ratings on the imagination task were higher for places with associates ($M = 2.98$, SD = 0.66) relative to clean places ($M = 2.58$, SD = 0.57), $t(23) = 3.32$, $p = .003$, $d = 1.38$. Vowel-counting performance, on the other hand, did not differ between conditions (mean number correct = 13.75, SD = 1.15, and $M = 13.17$, SD = 1.61, for associated and clean places, respectively), $t(23) = 1.69$, $p = .11$. Number of names correctly recalled on the subsequent cued recall task was submitted to a mixed ANOVA with task (imagination, vowel-counting) as a between-subjects factor and place type (associated, clean) as a within-subjects factor. Unsurprisingly, memory for the person-place pairings was higher after imagining events ($M = 20.17$, SD = 5.08) than vowel-counting ($M = 1.75$, SD = 2.45), $F(1, 46) = 255.83$, $p < .001$, $\eta_p^2 = .85$. Place type had no effect on memory, $F(1, 46) = 1.95$, $p = .17$, and did not interact with group, $F < 1$.

Speeded RT task

Proportion correct on the familiarity task was submitted to a mixed ANOVA with task (imagination, vowel-counting) as a between-subjects factor and name type (unfamiliar, baseline, original associate, primed) as a within-subjects factor. The main effect of name type was significant, $F(3, 69) = 5.81$, $p = .001$, $\eta_p^2 = .20$, and as in Experiment 1, this result was attributable to higher accuracy for primed ($M = 0.98$, SD = 0.04) and unfamiliar ($M = 0.98$, SD = 0.04) names than baseline names ($M = 0.94$, SD = 0.08), $t(47) = 2.50$, $p = .02$, and $t(47) = 2.90$, $p = .006$ (for primed and unfamiliar, respectively) and original associates ($M = 0.95$, SD = 0.06), $t(47) = 2.99$, $p = .004$, and $t(47) = 2.98$, $p = .005$ (for primed and unfamiliar, respectively). Neither the main effect of task nor the name × task interaction was significant, both F's < 1.

Mean RTs were submitted to a mixed ANOVA with task (imagination, vowel-counting) as a between-subjects factor and name type (unfamiliar, baseline, original associate, primed) as a within-subjects factor. The main effect of name type was significant, $F(3, 138) = 6.55$, $p < .001$, $\eta_p^2 = .13$, but the main effect of task and the interaction were not, F's <1. Our primary question of interest was whether priming for the original associates differed between the vowel-counting and imagination groups. Limiting the ANOVA to just the baseline and original associate conditions showed a main effect of name type, $F(1, 46) = 12.92$, $p = .001$, $\eta_p^2 = .22$, but critically no interaction with task, $F < 1$, suggesting that both groups showed similar levels of priming. As can be seen in Figure 3, participants in the imagination condition responded faster to original associates ($M = 625.47$, SD = 65.74) than baseline names ($M = 650.83$, SD = 89.08), $t(23) = 2.48$, $p = .02$, $d = 0.51$, as did those in the vowel-counting condition ($M = 642.01$, SD = 78.39 and $M = 664.04$, SD = 101.68, for associates and baseline, respectively), $t(23) = 2.65$, $p = .01$[4], $d = 0.54$.

While the frequency of names in the baseline and original associate conditions were more closely matched in this experiment, the difference between conditions was still significant for both the imagination ($M = 1.44$, SD = 0.37, and $M = 1.61$, SD = 0.45, respectively), $t(23) = 2.87$, $p = .01$, and vowel-counting groups ($M = 1.43$, SD = 0.39, and $M = 1.57$, SD = 0.52, respectively), $t(23) = 2.39$, $p = .03$. If we limit our analysis to only those trials with equal frequency (since the conditions were already quite closely matched, this matching only required removing a single name from each condition for 14 participants in the imagine group and 12 in the vowel group), the difference in RT between the original associate and baseline conditions remains significant for both the imagination group ($M = 627.33$, SD = 66.19, and $M = 648.02$, SD = 86.47, respectively), $t(23) = 2.21$, $p = .02$, and the vowel-counting group ($M = 643.50$, SD = 81.08, and $M = 663.73$, SD = 102.14, respectively), $t(23) = 2.38$, $p = .01$. Thus, imagining interacting with someone new at a familiar place leads to priming for the people normally associated with that place. This priming effect is of comparable size to that seen after a low-level vowel-counting task, suggesting that future imagining does not require the inhibition of competitors.

Final recall

Mean forgetting was submitted to a mixed ANOVA with task (imagination, vowel-counting) as a between-subjects factor and place type (imagined/counted, unused) as a within-subjects factor (Table 1 shows the mean number recalled and originally listed for each place per condition). None of the effects was significant (task: $F(1, 46) = 1.34$, $p = .25$; place type: $F(1, 46) = 1.19$, $p = .28$; interaction: $F(1, 46) = 1.42$, $p = .24$). Even within the imagination group alone, forgetting did not differ between imagined ($M = 0.98$, SD = 0.70) and unused places ($M = 0.98$, SD = 0.59), $t < 1$, again supporting the view that associates were not inhibited. Interestingly, as in Experiment 1, imagination lead to the intrusion of newly imagined people in unexpected places ($M = 0.29$, SD = 0.62, one-sample t-test: $t(23) = 2.29$, $p = .03$; 3 participants made 1 intrusion, and 2 made 2). In contrast, vowel-counting did not ($M = 0.04$, SD = 0.20, $t(23) = 1.00$, $p = .33$; 1 participant made 1 intrusion), suggesting that processes engaged during future imagining increase susceptibility to false memory.

Discussion

This study used a modified priming task to test for inhibition of related concepts during future imagining. Across two experiments, we found no evidence for inhibition of people normally associated with a place after imagining a novel interaction with someone else there. In fact, a modest priming effect was observed for associated people after future imagining, most clearly in Experiment 2, which more closely controlled for the familiarity of names across conditions than did Experiment 1. This priming effect was comparable to that observed after a non-semantic vowel-counting task (which should not have required inhibition of competing concepts), suggesting that activation of related concepts was relatively automatic and not offset by inhibition during future imagining. Finally, both experiments failed to find RIF of original associates on a final cued recall test, further suggesting that imagining the future does not require inhibition of related concepts in memory.

The lack of an inhibitory effect seen here is in line with some previous studies (García-Bajos & Migueles, 2016; Storm & Jobe, 2012, for positive events only), but not others (Ditta & Storm, 2016; Migueles & García-Bajos, 2015; García-Bajos & Migueles, 2016, for negative events only). The current paradigm is quite different from those used previously and thus, there may be several reasons for the partial discrepancy. First and foremost, our paradigm used an indirect or implicit RT measure to test the level of activation of associated concepts, rather than explicit retrieval in response to associated cues (although this type of measure was also used in this case on the final recall test). We would argue that this type of implicit measure offers a stricter test of the hypothesis that competition at retrieval is resolved through suppression of competing representations and that "performance impairments arising from that inhibition should generalize to any cue used to test that item" (Anderson & Spellman, 1995, p. 92; Hasher, Lustig, & Zacks, 2007). All studies to date looking at inhibition during future imagining and, more broadly, autobiographical memory retrieval (e.g., Barnier, Hung, & Conway, 2004; Hauer & Wessel, 2006; Stone, Barnier, Sutton, & Hirst, 2013; Stone, Luminet, & Hirst, 2013) have used some variant of the RIF paradigm. No study, at least to our knowledge, has used an independent probe technique (i.e., presenting a different, but related, retrieval cue at final recall) or measured implicit access to the competitor itself, as we did here. Importantly,

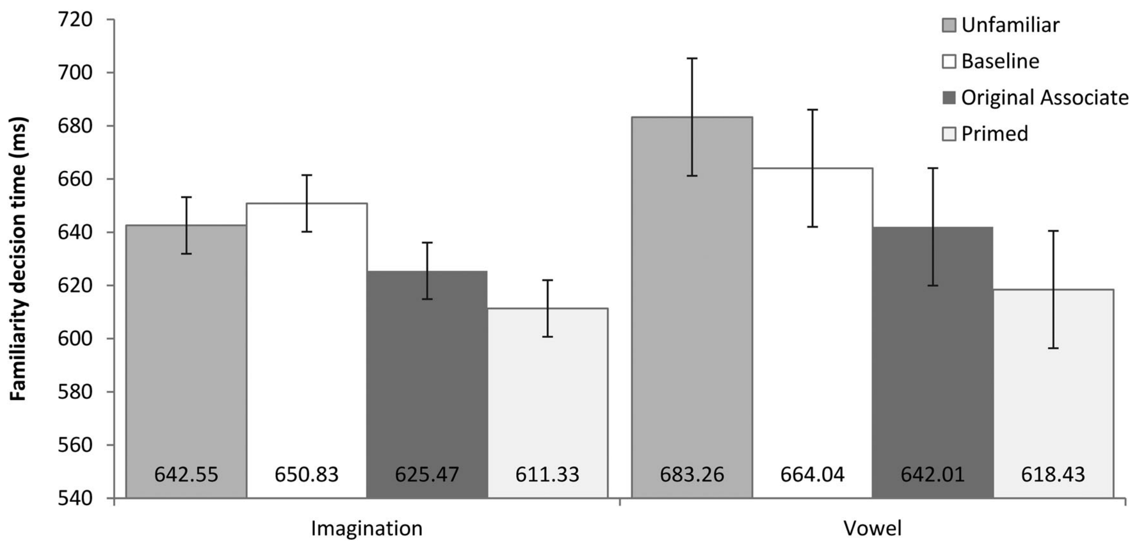

Figure 3. Mean RTs on the name familiarity task from experiment 2. Error bars represent 95% within-subjects confidence intervals.

it remains to be seen whether autobiographical memory retrieval itself leads to reduced accessibility of related (personally relevant) concepts using an implicit paradigm like the one used here. If not, then the evidence would point toward a difference between autobiographical memory and laboratory-based episodic memory, rather than a difference between memory and imagination. This is an important question for future research.

The present study also differed from previous work in a number of other ways. For instance, in this study, participants only had 7.5 seconds to imagine each event and they only imagined each event once, whereas previous RIF-style imagination studies provided more time for imagination and multiple trials per event. This difference may be important, especially if future imagining results in an initial priming effect followed by a subsequent inhibitory effect (Anderson & Levy, 2010). Further, we tested for inhibition of pre-existing person-place associations that participants generated a week before, and were not reminded of during, the imagination session. In the previous RIF-style studies, the to-be-inhibited memories were encoded earlier within the same experimental session (i.e., Mario eating hotdogs; "Friendly Roommates" label generated for a pre-existing memory). Because the imagination context overlapped substantially with the earlier encoding context in those studies, those memories likely generated more competition than the pre-established associations used in the current paradigm, and thus may have required more inhibition. It would be interesting to see if an inhibitory effect emerges if participants first (re)study their original person-place pairings prior to imagination. Finally, most of the participants in our study reported enjoying the imagination task and were generally positive in their descriptions of imagined events during the practice phase. García-Bajos and Migueles (2016) only found evidence of imagination-induced-forgetting for negative future events, not positive ones, and thus, emotional content may be another important factor to consider.

While Experiment 1 hinted at a priming effect for related concepts, Experiment 2 showed that this effect is reliable even after controlling for the familiarity of names across conditions. This priming effect was not as strong as that seen for *directly* primed names, which was echoed in the accuracy data showing higher performance for primed names than original associates and baseline names. While the priming of related concepts may not be surprising in light of the large literature on semantic priming (for a review, see Neely, 1991) this is the first demonstration, to our knowledge, of the priming of autobiographically significant concepts during future imagining. Previous work has shown that autobiographical facts (e.g., apples are my favourite fruit) can be primed by related semantic cues (e.g., FRUITS; Conway, 1987) and that personal semantics, or knowledge about one's past, is preserved in the face of episodic memory loss due to MTL lesions (e.g., Levine et al., 1998; McCarthy, Kopelman, & Warrington, 2005). Thus, the current results could be seen as an extension of semantic priming to autobiographically significant concepts. However, there is reason to believe that concepts with personal significance engage more than just the semantic memory system. Recent work suggests that these concepts may be more similar to episodic memory than general semantic memory (for a review, see Renoult, Davidson, Palombo, Moscovitch, & Levine, 2012), in that autobiographically significant concepts automatically activate related episodes in memory (Westmacott, Black, Freedman, & Moscovitch, 2004; Westmacott & Moscovitch, 2003) and evoke a neural signature more similar to episodic than semantic memory (Renoult et al., 2015, 2016). Thus, the current effects could be partly or entirely driven by episodic memory, with the names of familiar places activating related details of past episodes, including people who were there, in a relatively automatic (and potentially subconscious) manner.

This unconstrained, automatic activation of related details from episodic memory could underlie the creativity and flexibility of future imagining relative to the recollection of specific episodes. Indeed, recent evidence indicates that performance on a divergent creative thinking task that requires generating unusual uses of common objects significantly predicts the number of episodic details imagined in simulated future events, over and above the number of episodic details remembered from past events (Addis, Pan, Musicaro, & Schacter, 2016). Without the goal of retrieving a specific memory, autobiographically significant concepts are free to trigger a cascade of related memories. An intriguing question for future research is whether these self-relevant stimuli automatically bias attention away from the external environment (Humphreys & Sui, 2016) and towards episodic simulation, even at times when it is deemed inappropriate (e.g., when attempting to focus on another task). Although there is considerable evidence that episodic simulation serves adaptive functions, there is also evidence that it is subject to various pitfalls (Schacter, 2012). Studies that attempt to elucidate the functional consequences of automatically activating related details during episodic future simulation should provide additional insights into the costs and benefits of imagining future experiences.

Notes

1. This effect remains significant if a false discovery rate (FDR) correction for multiple comparisons (Benjamini & Hochberg, 1995) is used for the three paired *t*-tests reported here (corrected significance level $q^* = .033$), but not if a Bonferroni correction is used ($q^* = .017$). However, correcting for multiple comparisons is not entirely warranted in this case, given that our primary interest was in the comparison between the original associate and baseline conditions. The other contrasts are simply given for sake of comparison.
2. Note that item-wise correlations could not be calculated for participants who showed no variability in the number of times a name was mentioned during pretesting (i.e., names used on RT task were only mentioned once).
3. Frequency could not be equated for two participants.
4. Both of these tests remain significant if we correct for multiple comparisons using either FDR ($q^* = .05$) or Bonferroni correction ($q^* = .025$).

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