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Characterizing the subjective experience of episodic past, future, and counterfactual thinking in healthy younger and older adults

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Recent evidence demonstrates remarkable overlap in the neural and cognitive mechanisms underlying episodic memory, episodic future thinking, and episodic counterfactual thinking. However, the extent to which the phenomenological characteristics associated with these mental simulations change as a result of ageing remains largely unexplored. The current study employs adapted versions of the Memory Characteristics Questionnaire and the Autobiographical Interview to compare the phenomenological characteristics associated with both positive and negative episodic past, future, and counterfactual simulations in younger and older adults. Additionally, it explores the influence of perceived likelihood in the experience of such simulations. The results indicate that, across all simulations, older adults generate more external details and report higher ratings of vividness, composition, and intensity than young adults. Conversely, younger adults generate more internal details across all conditions and rated positive and negative likely future events as more likely than did older adults. Additionally, both younger and older adults reported higher ratings for sensory, composition, and intensity factors during episodic memories relative to future and counterfactual thoughts. Finally, for both groups, ratings of spatial coherence and composition were higher for likely counterfactuals than for both unlikely counterfactuals and future simulations. Implications for the psychology of mental simulation and ageing are discussed.

Keywords: Episodic memory; Counterfactual thinking; Future thinking; Mental simulation; Autobiographical Interview; Phenomenology; Ageing.

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Increasing amounts of evidence gathered in the past two decades have demonstrated a remarkable overlap in the neural and cognitive mechanisms underlying episodic memory—our capacity to bring to mind specific events of our personal past (Tulving, 1985)—and those supporting episodic future thinking—our capacity to imagine specific events that may happen in our personal future (Atance & O'Neill, 2001; Szpunar, 2010). This observation is supported by numerous neuropsychological studies showing parallel deficits in episodic memory and future thinking in individuals with amnesia (Hassabis, Kumaran, Vann, & Maguire, 2007; Klein, Loftus, & Kihlstrom, 2002; Tulving, 1983), severe depression (Dickson & Bates, 2005; Williams, 1996), schizophrenia (D'Argembeau, Raffard, & Van der Linden, 2008), amnestic mild cognitive impairment (Gamboz et al., 2010), and Alzheimer's disease (Addis, Musicaro, Pan, & Schacter, 2010; Addis, Sacchetti, Ally, Budson, & Schacter, 2009), among others. Similarly, a number of developmental studies have shown analogous patterns of development for both episodic memory and future thinking in young children (Busby & Suddendorf, 2005; Perner, Kloo, & Rohwer, 2010; Suddendorf & Busby, 2005), as well as older adults (Addis, Wong, & Schacter, 2008; Spreng & Levine, 2006), further suggesting commonalities in the mechanisms underlying both cognitive processes. Additional support comes from several neuroimaging studies showing significant overlap in brain regions engaged during episodic memory and future thinking, suggesting that both mental operations recruit common neural mechanisms (Addis, Wong, & Schacter, 2007; Okuda et al., 2003; Szpunar, Watson, & McDermott, 2007; for a recent review see Schacter et al., 2012). Finally, a number of studies exploring the subjective experience of episodic memory and future thinking have revealed parallels in their phenomenological characteristics (D'Argembeau & Van der Linden, 2004, 2006; Szpunar & McDermott, 2008; Winfield & Kamboj, 2010), lending additional credence to the claim that common mechanisms underlie both episodic memory and future thinking.

Many have interpreted these results as providing support to the hypothesis that episodic memory and episodic future thinking are two sides of the same psychological process, often referred to as "mental time travel" (Tulving, 1985): our capacity to mentally travel in time from a past that once was to a future that may come. Strictly speaking, though, this characterization appears to imply that mental time travel is an asymmetric capacity: While we normally envision different possible events when we think about our future, when remembering our past we tend to bring to mind only events that—to the best of our knowledge—actually occurred. However, a more symmetric view of mental time travel is now supported by a number of recent results showing strong commonalities between the cognitive and neural mechanisms engaged during mental time travel and those engaged during episodic counterfactual thinking—that is, our capacity to mentally simulate alternative ways in which past personal events could have occurred but did not (De Brigard, 2014; De Brigard & Giovanello, 2012; Roese, 1997; Schacter, Benoit, De Brigard, & Szpunar, 2015). Support for this observation comes from recent neuroimaging studies showing common engagement of regions of the brain's default network (Andrews-Hanna, Smallwood, & Spreng, 2014; Buckner, Andrews-Hanna, & Schacter, 2008) during episodic memory and future and counterfactual thinking (De Brigard, Addis, Ford, Schacter, & Giovanello, 2013, De Brigard, Spreng, Mitchell, & Schacter, 2015; Van Hoeck et al., 2013; see also Addis, Pan, Vu, Laiser, & Schacter, 2009). Partial support comes also from neuropsychological studies reporting abnormalities in counterfactual thinking tasks in individuals with schizophrenia (Hooker, Roese, & Park, 2000) and amnesia (Mullally & Maguire, 2014), both of which compromise medial temporal lobe functioning. Finally, a recent behavioural study (De Brigard & Giovanello, 2012) exploring phenomenological similarities among episodic past, future, and counterfactual thinking found similar effects of outcome valence during future and counterfactual simulations relative to episodic memory. For instance, memories were rated as more vivid,

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more spatially coherent, and containing more sensory details than both episodic future and counterfactual thoughts, regardless of whether the simulated events had positive or negative outcomes. Additionally, both episodic future and counterfactual thoughts about possible events with imagined positive outcomes were experienced more intensely than simulations of possible events with negative outcomes. Taken together, these results suggest further similarities between the cognitive processes engaged during episodic future and counterfactual thinking.

Despite these results, a more precise characterization of the experience of episodic counterfactual thinking, as compared to episodic recollection and future thinking, remains elusive. The current study aims to clarify this issue in a number of ways. First, it compares the phenomenological characteristics of mental simulations about possible personal future and possible counterfactual past events against the common baseline of episodic autobiographical memories in healthy young and older adults. Previous studies have shown deficits in the simulation of episodic memories in older adults relative to younger adults. Older adults, for instance, show more difficulties retrieving relations among elements in an episode than do young adults (Chalfonte & Johnson, 1996; Lyle, Bloise, & Johnson, 2006). Similarly, Levine and colleagues showed that older adults recover fewer episodic details but more external information when remembering autobiographical episodes than do young adults (B. Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002). Given the evidence suggesting common neural and cognitive mechanisms between episodic memory and future thinking, Addis and collaborators (Addis et al., 2010; Addis et al., 2008) compared episodic future and autobiographical memories in young and old adults (Addis et al., 2010), finding parallel effects for episodic future thinking as well. Similarly, given the aforementioned commonalities between episodic memory and counterfactual thinking, De Brigard and Giovanello (2012) explored similarities and differences in the phenomenological characteristics between episodic future and counterfactual thinking relative to episodic memories in young adults. However, no study has yet compared phenomenological characteristics of episodic memories and future and counterfactual thoughts in young and old adults.

Second, previous studies have shown differential effects of subjective likelihood in episodic future (Szpunar & Schacter, 2013) and counterfactual thinking (De Brigard, Szpunar, & Schacter, 2013) independently, but the extent to which differences in perceived likelihood influence our subjective experience when simulating both episodic future and counterfactual thoughts is unknown. By asking participants to simulate both likely and unlikely episodic future and counterfactual thoughts, the current study contributes to filling this gap in the literature. Finally, the current study also explores, for the first time, possible interactions between perceived likelihood and event outcome valence by asking participants to mentally simulate both positive and negative outcomes for episodic past, future, and counterfactual thoughts.

To investigate these issues, in the current experiment young and old adults were asked to recall positive and negative events, imagine likely and unlikely positive and negative future events, and imagine likely and unlikely positive and negative past counterfactual events. Features of their subjective experiences were measured using adapted forms of the Memory Characteristics Questionnaire (MCQ; Appendix A; Johnson, Foley, Suengas, & Raye, 1988) and the Autobiographical Interview (AI; B. Levine et al., 2002), allowing us to test four general hypotheses. First, and consistent with previous studies (Addis, Pan et al., 2009; Gaesser, Sacchetti, Addis, & Schacter, 2011), we hypothesized more vivid sensory components and more cohesive spatial composition features in all three mental simulations for young than for older adults, as measured by higher ratings of sensory and composition factors respectively in the MCQ, as well as higher number of internal details in the AI. Second, and consistent with previous research (De Brigard & Giovanello, 2012), we expected that, for both young and old adults, memories would have higher ratings of sensory and composition components than both episodic future and counterfactual

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simulations. Third, given the neural similarities between episodic recollection and likely—as opposed to unlikely—counterfactual thinking (De Brigard, Addis et al., 2013), we hypothesized that unlikely simulations will be less vivid and spatially coherent than likely simulations, as reflected by lower ratings of sensory and composition in the MCQ, as well as more external details in the AI. Finally, our fourth hypothesis predicts an interaction between positive valence and likelihood. Given previous studies documenting correlations between subjective likelihood and positive valence during episodic future thinking (e.g., Szpunar & Schacter, 2013), we expected that positive unlikely simulations would be rated as less positive than likely ones in the MCQ (previous results are mixed for negative valences, so we do not have a prior hypothesis about negative simulations).

EXPERIMENTAL STUDY

Method

Participants

Thirty young adults ($M_{\text{age}} = 22.35$ years, $SD = 3.27$, 19 female; years of education, YoE = 15.15, $SD = 2.15$) and 30 older adults ($M_{\text{age}} = 69.32$ years, $SD = 4.85$, 18 female, YoE = 18.12, $SD = 3.02$, $M_{\text{Mini Mental State Exam}} = 28.52$, $SD = 1.62$), with no history of neurological or psychiatric impairment, participated in this study. Participants received monetary compensation for their inclusion in the study, and they all gave consent following the requirements of the Institutional Review Boards at Duke University, University of North Carolina-Chapel Hill, and Cornell University.

Materials and procedure

The current study had two parts. In the first part, participants were asked to complete a "possible autobiographical event questionnaire" (PAEQ; see Supplemental material), containing 30 statements referring to relatively common and uncommon possible events. Half of the events were positive, and half were negative. After each statement participants were asked whether or not that event had occurred to them in the past 5 years. If not, participants were asked whether or not that event could have happened to them in the past 5 years, and whether or not that event could happen to them in the next 5 years. Additionally, they were asked to rate the likelihood of such an event occurring from 1 (unlikely) to 7 (likely). Next, participants engaged in an unrelated maths distraction task for 10 minutes, while the experimenter prepared the stimulus for the second part. From each participant's PAEQ answers, five positive and five negative statements were selected as follows: two events corresponding to participants' actual autobiographical memories (one positive, one negative), two events that participants knew had not occurred in their past but thought were likely to have occurred (one positive, one negative), two events that participants knew had not occurred and thought were unlikely to have occurred in their past (one positive, one negative), two events that participants knew had not occurred in their past but thought could occur in their future (one positive, one negative), and two events that participants knew had not occurred and thought were unlikely to occur in their future (one positive, one negative). Events that received a likelihood rating of 1, 2, or 3 were considered unlikely whereas those that received a likelihood rating of 5, 6, or 7 were considered likely.

In the second part of the study, these 10 events were randomly presented to the participant in 10 trials: *positive memory* (M+), *negative memory* (M–), *positive likely counterfactual* (LC+), *negative likely counterfactual* (LC–), *positive unlikely counterfactual* (UC+), *negative unlikely counterfactual* (UC–), *positive likely future* (LF+), *negative likely future* (LF–), *positive unlikely future* (UF+), and *negative unlikely future* (UF–). Each trial had the same structure. Participants were presented with a sheet of paper that had one of three possible titles: "Memory" (for all M trials), "Possible Past" (for all C trials), or "Possible Future" (for all F trials). Below the title, they read a statement about one of the events that corresponded to the selected trial (e.g., "Hitting 'send' by mistake when writing an important email"), and they

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received verbal instruction from the experimenter. For M trials, participants were instructed to remember the moment in which the displayed event occurred in their past and to describe it in as much detail as possible. For C trials, participants were instructed to imagine the moment in which the displayed event could have occurred in their past and to describe it in as much detail as possible. Finally, for F trials, participants were instructed to imagine the moment in which the displayed event could occur in their future and to describe it in as much detail as possible. Participants described their mental simulations out loud for up to three minutes while being recorded, and they received no further prompting, unless their descriptions ended in less than 30 s, in which case the experimenter encouraged them to continue, saying "Is there anything else you can remember/imagine about this event?" At the end of each trial, participants completed a modified Phenomenological Characteristics Questionnaire (PCQ), in which they recorded subjective ratings for a number of phenomenological characteristics of their mental simulations (e.g., sensory details such as visual and auditory, clarity of perceived space, objects, etc.). This modified version of the PCQ is adapted from Johnson et al. (1988) and was previously used by De Brigard and Giovanello (2012; see Appendix A).

Autobiographical Interview scoring

The recordings of each participant's descriptions were transcribed, and each transcription was scored by three trained scorers according to the AI protocol (B. Levine et al., 2002). Scorers were blind to group and hypothesis. Following previous studies employing the AI to assess memory and simulation (Addis et al., 2008; De Brigard & Giovanello, 2012; Gaesser et al., 2011; Race, Keane, & Verfaellie, 2011), we employed an adapted scoring system. First, for each trial, a main event was identified. Scorers had access to the specific event description that cued each trial for each subject, so the main event was identified as the one that corresponded to the cue. All other events were considered external events. The transcription was then divided into distinct segments or independent chunks of information, such as unique occurrences or thoughts. Details concerning the main event were rated as *internal*. All other details were considered *external*. External details included nonepisodic information such as semantic details, repetitions, or editorial comments, as well as information concerning events different from the main event. Details concerning such external events were tallied as a subcategory within external details and are analysed as *external event* details. For each trial, the number of internal and external details was tallied. Inter-rater reliability of scoring between coders was established on the basis of an interclass correlation analysis for all the tallied scores (for internal detail scores, Cronbach's $\alpha = .81$ in young, .73 in old adults; for external details, Cronbach's $\alpha = .72$ in young, .76 in old adults).

Results

Phenomenological characteristics

To analyse the ratings of phenomenological characteristics, a two-step dimensionality reduction approach was taken. First, following previous studies using PCQ for episodic past (Schaefer & Philippot, 2005; Suengas & Johnson, 1988), future (D'Argembeau & Van der Linden, 2004), and counterfactual thinking (De Brigard & Giovanello, 2012), a factor analysis, employing a nonrotated principal component analysis, of all phenomenological characteristic ratings (Questions 1 to 19) for both young and old adults was conducted. Components were extracted based on eigenvalues greater than 1. This resulted in ratings loading onto four different components. Phenomenological ratings of (1) clarity, (2) colour, (3) visual detail, (4) sound, (5) smell, (6) touch, (7) taste, (8) vividness, (14) sense of feeling of the event, and (19) overall sense of reliving/imagining the event loaded onto a first component (Cronbach's $\alpha = .84$ young, .84 old). Phenomenological ratings of (9) composition, (10) clarity of location, (11) spatial arrangement of objects, (12) spatial arrangement of people, and (13) time of day loaded onto a second component (Cronbach's $\alpha = .85$ young, .84 old). Ratings of

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(15) emotion during the event and (17) emotion during the simulation loaded onto a third component (Cronbach's $\alpha = .80$ young, .76 old). The remaining two ratings—(16) intensity during the event and (18) intensity during simulation—loaded onto a fourth component, but they did not yield an acceptable reliability level for the old adults (Cronbach's $\alpha = .72$ young, $\alpha = .67$ old).

Despite acceptable reliability scores for each of the first three components, we conducted an additional correlational analysis for the phenomenological ratings loading onto each individual component to further corroborate their unidimensionality. Ratings that resulted in strong positive correlations (i.e., Pearson's coefficients of .4 or more, and significant at $p < .001$, two-tailed) for both young and old adults were then averaged into a single phenomenological factor. A first *Vividness* factor, from the first component, averaged scores of clarity, colour, visual detail, vividness, and sense of feeling of the event (smallest $r = .45$, $n = 300$, $p < .001$, young; $r = .58$, $n = 300$, $p < .001$, old). A second factor, *Sound*, was analysed separately, as it only yielded weak or moderate correlations with other ratings for old adults (highest $r = .34$, $n = 300$, $p < .001$). A third factor averaged *Smell and Taste*, as they were strongly correlated for both young ($r = .65$, $n = 300$, $p < .001$) and old adults ($r = .64$, $n = 300$, $p < .001$). A fourth factor, *Touch*, was also analysed separately, as it only yielded weak to moderate correlations with other factors in old adults (highest $r = .36$, $n = 300$, $p < .001$). Likewise, a fifth factor, *Overall*, was analysed separately, for although ratings of overall sense of remembering/imagining were moderately to strongly correlated with every other phenomenological rating from the first component in young adults (smallest $r = .20$, $n = 300$, $p = .001$), they were not correlated at all with any other sensory rating in old adults (highest $r = .07$, *ns*).

All the phenomenological ratings from the second component were strongly internally correlated for both young (smallest $r = .42$, $n = 300$, $p < .001$) and old adults (smallest $r = .44$, $n = 300$, $p < .001$), so they were averaged into a sixth *Composition* factor. The ratings from the third component were also highly correlated for both young ($r = .70$, $n = 300$, $p < .001$) and old adults ($r = .64$, $n = 300$, $p < .001$), so they were averaged into a seventh *Emotion* factor. Finally, not being internally reliable in the fourth component, the ratings of intensity were analysed separately as *Intensity Then* and *Intensity Now* factors (Table 1). Ratings from the resultant phenomenological factors were modelled as nine independent mixed-design $2 \times 2 \times 5$ analyses of variance (ANOVAs), with age group (young, old) as between-subjects factor, and valence (+, −) and condition (M, LC, UC, LF, UF) as within-subjects factors.

- *Vividness:* The analysis revealed a main effect of condition, $F(4, 55) = 6.50$, $p < .001$, $\eta^2 = .32$, with no interactions. Bonferroni corrected pairwise contrasts indicated that, regardless of age, vividness ratings were significantly higher for memories than for both episodic future and counterfactual simulations (largest $p = .016$). There was also a between-subjects main effect of group, $F(1, 58) = 24.65$, $p < .001$, $\eta^2 = .30$, indicating that vividness ratings were overall higher for older than for younger adults.
- *Sound:* The analysis revealed a main effect of valence, $F(1, 58) = 9.20$, $p = .004$, $\eta^2 = .14$, modified by a Valence × Group interaction. To clarify this interaction, two follow-up 2 (group) × 5 (condition) ANOVAs were conducted for positive and negative simulations. This follow-up analysis showed that there were no effects for negative simulations. For positive simulations, however, there was a main between-subjects effect of group, $F(1, 58) = 8.17$, $p = .006$, $\eta^2 = .12$, indicating that, during positive simulations, ratings of sound were higher for older adults than for younger adults.
- *Smell and Taste:* No effects were found.
- *Touch:* No effects were found.
- *Overall*: The analysis revealed a main between-subjects group effect, $F(1, 58) = 46.61$, $p < .001$, $\eta^2 = .45$, indicating that older adults gave higher ratings of overall sense of remembering/imagining than young adults (except for M–). There was also a within-subject main effect of condition, $F(4, 55) = 4.76$, $p = .002$,

Table 1. *Phenomenological characteristics*

	Negative					*Positive*				
		Likely		*Unlikely*			*Likely*		*Unlikely*	
Rating[a]	*Memory*	*CFT*	*Future*	*CFT*	*Future*	*Memory*	*CFT*	*Future*	*CFT*	*Future*
Vividness										
Young	4.28 (0.99)	3.94 (0.78)	3.82 (1.11)	3.80 (1.09)	3.36 (1.06)	4.27 (1.07)	4.20 (1.16)	3.74 (0.99)	3.38 (1.17)	3.53 (1.02)
Old	4.65 (0.89)	4.32 (0.91)	4.51 (0.86)	4.37 (0.93)	4.48 (1.05)	5.00 (0.82)	4.60 (1.00)	4.68 (0.94)	4.38 (1.01)	4.47 (1.11)
Sound										
Young	3.37 (2.06)	3.17 (1.98)	3.43 (1.99)	3.13 (1.93)	2.33 (1.67)	3.67 (1.71)	3.40 (1.77)	3.04 (1.81)	2.83 (1.90)	3.10 (1.97)
Old	3.57 (2.37)	3.07 (2.05)	3.67 (1.94)	3.57 (2.10)	3.03 (2.08)	4.73 (2.07)	3.70 (1.97)	4.27 (1.89)	3.80 (2.19)	4.40 (2.22)
Smell and Taste										
Young	1.82 (1.21)	1.76 (1.06)	2.12 (1.25)	1.75 (0.92)	1.58 (1.12)	2.18 (1.58)	2.68 (1.95)	1.85 (1.23)	1.35 (0.58)	1.77 (1.57)
Old	2.47 (1.99)	1.71 (1.30)	2.09 (1.60)	1.95 (1.64)	2.31 (2.07)	2.10 (1.76)	2.26 (1.72)	2.41 (1.82)	1.64 (1.30)	2.36 (1.63)
Touch										
Young	2.83 (1.98)	2.45 (1.52)	2.40 (1.65)	2.13 (1.41)	2.00 (1.31)	2.53 (1.76)	2.67 (2.09)	1.76 (1.19)	1.87 (1.41)	2.23 (1.61)
Old	2.60 (1.79)	2.47 (1.99)	2.70 (2.15)	2.90 (1.97)	2.67 (2.14)	3.30 (2.31)	2.40 (1.85)	2.80 (2.20)	3.17 (2.42)	3.47 (2.43)
Overall										
Young	5.21 (1.27)	4.83 (1.37)	4.30 (1.42)	4.48 (1.77)	3.50 (1.72)	5.14 (1.22)	4.97 (1.61)	4.62 (1.30)	3.90 (1.79)	4.00 (1.66)
Old	5.13 (1.63)	5.90 (1.54)	5.37 (1.94)	5.43 (1.41)	5.27 (2.17)	5.67 (1.77)	5.63 (1.25)	5.63 (1.25)	5.80 (1.40)	5.23 (1.78)
Composition										
Young	5.35 (1.50)	4.64 (1.18)	4.00 (1.40)	4.33 (1.30)	4.03 (1.28)	5.07 (1.57)	4.86 (1.46)	4.27 (1.39)	4.05 (1.63)	3.91 (1.22)
Old	5.63 (1.28)	4.94 (1.44)	4.73 (1.50)	4.73 (1.50)	4.66 (1.41)	5.93 (1.02)	4.9 (1.45)	5.17 (1.23)	4.63 (1.72)	4.60 (1.58)
Emotion										
Young	3.09 (1.53)	2.93 (1.08)	3.48 (1.31)	2.74 (1.39)	2.70 (1.49)	5.31 (1.42)	5.30 (1.04)	4.85 (1.23)	5.12 (1.28)	5.53 (0.94)
Old	3.65 (1.57)	2.85 (1.09)	3.87 (1.63)	3.00 (1.54)	3.27 (1.65)	5.67 (1.12)	5.77 (1.26)	5.52 (1.31)	5.87 (1.07)	5.28 (1.58)
Intensity Then										
Young	5.14 (1.46)	4.69 (1.64)	4.47 (1.61)	5.00 (1.88)	4.73 (1.68)	4.86 (1.25)	4.33 (1.60)	4.72 (1.62)	5.07 (1.78)	5.47 (1.38)
Old	5.13 (1.59)	4.70 (1.82)	4.97 (1.69)	5.47 (1.80)	5.20 (2.07)	5.02 (1.37)	5.33 (1.75)	5.30 (1.44)	5.63 (1.27)	4.97 (1.69)
Intensity Now										
Young	3.83 (1.68)	3.28 (1.44)	3.03 (1.65)	3.52 (1.36)	3.77 (1.89)	4.06 (1.60)	3.40 (1.83)	3.83 (1.66)	3.93 (1.66)	3. 62 (1.79)
Old	4.20 (1.67)	3.90 (1.79)	3.20 (1.71)	3.70 (1.99)	4.50 (1.82)	4.87 (1.60)	4.43 (1.48)	4.63 (1.67)	4.23 (1.68)	4.50 (1.55)
Likelihood										
Young	—	4.76 (1.6)	5.33 (1.24)	2.76 (1.98)	2.10 (1.49)	—	4.90 (1.72)	5.48 (1.43)	2.33 (1.51)	2.50 (1.70)
Old	—	4.93 (2.20)	4.20 (2.01)	2.77 (2.22)	3.53 (2.24)	—	4.93 (1.96)	4.00 (2.08)	3.13 (2.24)	2.57 (1.85)

(*Continued overleaf*)

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Table 1. *Continued.*

	Negative					*Positive*				
		Likely		*Unlikely*			*Likely*		*Unlikely*	
Perspective[b]	*Memory*	*CFT*	*Future*	*CFT*	*Future*	*Memory*	*CFT*	*Future*	*CFT*	*Future*
Field										
Young	85.19	73.08	55.56	59.26	62.96	77.78	71.43	58.33	56.00	64.29
Old	93.10	82.14	79.31	86.21	79.31	89.66	82.76	76.67	72.41	64.29
Observer										
Young	14.81	23.08	40.74	37.04	33.33	18.52	28.57	37.50	40.00	32.14
Old	6.90	17.86	20.69	13.79	20.69	10.34	17.24	23.33	27.59	32.14
Neither/both										
Young	0	3.85	3.70	3.70	3.70	3.70	0	4.17	4.00	3.57
Old	0	0	0	0	0	0	0	0	0	0

Note: CFT = counterfactual thinking.

[a]Mean ratings for each phenomenological factor for young and old adults. The first five columns on the left correspond to the five conditions with negative valence, whereas the five columns to the right correspond to the five conditions with positive valences. Standard deviations are in parenthesis. [b]Percentage of responses for simulation perspective.

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$\eta^2 = .26$, modified by a Condition × Group interaction, $F(4, 55) = 3.07$, $p = .024$, $\eta^2 = .18$. To clarify this interaction, two 2 (valence) × 5 (condition) follow-up ANOVAs for each group were conducted. There were no effects for old adults. For young adults, however, this analysis revealed a main effect of condition, $F(4, 26) = 8.23$, $p < .001$, $\eta^2 = .56$, with no interactions. Bonferroni corrected pairwise contrasts indicated that, regardless of valence, ratings of overall sense of simulation were higher for M than for LF, UF, and UC (largest $p = .006$). In addition, UF received lower ratings of overall sense of simulation than both LC and LF (largest $p = .014$).

- *Composition*: The analysis revealed a main effect of condition, $F(4, 55) = 14.78$, $p < .001$, $\eta^2 = .52$, with no interaction. Bonferroni corrected pairwise contrasts indicated that composition ratings were significantly higher for memories than for both episodic future and counterfactual simulations (largest $p < .001$). In turn, composition ratings for LC were significantly higher than those for UC ($p = .04$) and UF simulations ($p = .001$). There was also a between-subjects main effect of group, $F(1, 28) = 6.61$, $p = .013$, $\eta^2 = .10$, indicating that overall older adults gave higher composition ratings than younger adults.
- *Emotion*: The analysis revealed a main effect of valence, $F(1, 58) = 187.90$, $p < .001$, $\eta^2 = .76$, modified by a Valence × Condition interaction, $F(4, 55) = 5.13$, $p = .001$, $\eta^2 = .27$. To clarify this interaction, two 2 (group) × 5 (condition) follow-up ANOVAs were conducted for positive and negative simulations. While no effects were found for positive simulations, for negative simulations this analysis revealed a main effect of condition, $F(4, 55) = 3.91$, $p = .007$, $\eta^2 = .22$, with no interactions. Bonferroni corrected pairwise contrasts indicated that both M– and LF– simulations are felt to be less negative than both UC– and LC– simulations (largest $p = .013$).
- *Intensity Then*: The within-subject analysis revealed a main effect of condition, $F(4, 55) = 2.82$, $p = .034$, $\eta^2 = .17$, with no interactions. Bonferroni corrected pairwise contrasts showed that participants rated the intensity of the emotion in UC simulations higher than that in LF ($p = .009$) and LC ($p = .01$).
- *Intensity Now*: The between-subjects analysis revealed a main effect of group, $F(1, 58) = 5.80$, $p = .019$, $\eta^2 = .09$, indicating that overall older adults gave higher ratings of intensity during simulation than did young adults. The within-subjects analysis revealed a main effect of valence, $F(1, 58) = 6.94$, $p = .01$, $\eta^2 = .11$, indicating that positive simulations were felt more intensely than negative simulations. Finally, this analysis also revealed a main effect of condition, $F(4, 55) = 2.96$, $p = .03$, $\eta^2 = .18$, and no interactions. Bonferroni corrected pairwise contrasts showed that, regardless of valence, intensity ratings of M were higher than those of LF ($p = .02$) and LC ($p = .004$).
- *Likelihood:* The analysis revealed a main effect of condition, $F(3, 56) = 74.88$, $p < .001$, $\eta^2 = .80$, modulated by a Condition × Group, $F(3, 56) = 3.78$, $p < .001$, $\eta^2 = .41$, interaction. Subsequent one-way ANOVAs for each condition and post hoc pairwise contrasts showed that old adults rated UC+ as more likely than young adults ($p < .001$, corrected). Additionally, young adults rated both LF– and LF+ as more likely than old adults ($p < .001$), whereas old adults rated UF– as more likely than young adults ($p < .001$).
- *Perspective*: No effects were found.

Autobiographical Interview

Scores for *internal*, *external*, and *external event* details were modelled as three independent mixed-design 2 × 2 × 5 ANOVAs, with age group (young, old) as a between-subjects factor, and valence (+, −) and condition (M, LC, UC, LF, UF) as within-subjects factors. However, since on average older adults produced more segments ($M = 26.75$, $SD = 13.17$) than young adults ($M = 23.91$, $SD = 12.83$), $t(290) = 2.57$, $p = .011$, the number of segments was entered in the models as a covariate. For *internal details*, this analysis revealed a between-subjects effect of group, $F(1, 55) = 15.20$, $p < .001$, $\eta^2 = .22$, indicating that, when the number of segments is

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taken into account, young adults generated on average more internal details than older adults (Figure 1A). There was also a within-subject effect of condition, $F(4, 52) = 5.67$, $p = .043$, $\eta^2 = .17$, modulated by a Condition × Group, $F(4, 52) = 13.70$, $p < .001$, $\eta^2 = .51$, and a Valence × Condition × Group, $F(4, 52) = 4.16$, $p = .007$, $\eta^2 = .24$, interaction. Two follow-up 2 (group) × 5 (condition) ANOVAs showed that the Group × Condition interaction persisted for both negative, $F(4, 52) = 18.64$, $p < .001$, $\eta^2 = .59$, and positive, $F(4, 52) = 4.50$, $p = .003$, $\eta^2 = .26$, valences. Follow-up Bonferroni corrected pairwise contrasts indicated that while older adults produced more internal details for memories than for both future and counterfactual simulations (all $p < .01$), the same pattern was not evident among young adults, as they produced the largest number of internal details during LC− , and similar amounts during M, UC−, LC+, and UF+ (all $p < .005$). For *external details*, this analysis revealed a between-subjects effect of group, $F(1, 55) = 5.28$, $p = .025$, $\eta^2 = .09$, indicating that, overall, older adults generated more external details than young adults (Figure 1B). No within-subject effects were found. Finally, an analysis looking only at details for *external events details* also revealed a between-subjects effect of group, $F(1, 55) = 7.13$, $p = .01$, $\eta^2 = .12$, indicating that, overall, older adults generated more details for external events than young adults (Figure 1C). No within-subject effects were found.

Discussion

The current study investigated possible differences in the phenomenological characteristics of past, future, and counterfactual mental simulations between healthy young and older adults. In addition, it explored possible effects of outcome valence and subjective likelihood in the experience of these mental simulations for both age groups. Two approaches were employed to characterize the participants' phenomenological experience during their mental simulations: a modified MCQ and an adapted version of the AI. Taken together, the results of the MCQ ratings yielded six main findings: (a) Older adults reported higher ratings of vividness, sound, overall sense of simulation, composition, and intensity than did young adults. (b) Both younger and older adults reported higher ratings of vividness, overall sense of remembering/imagining, composition, and intensity during simulation for memories than for both episodic future and counterfactual thoughts. (c) For both younger and older adults, composition ratings were higher for likely counterfactuals than for both unlikely counterfactuals and unlikely future simulations. (d) Negative counterfactuals were experienced more negatively than negative memories and negative likely future thoughts. (e) The reported imagined intensity of unlikely counterfactuals was higher than likely future and counterfactual events. (f) Young adults rated both positive and negative likely future events as more likely than did older adults, whereas older adults rated positive unlikely counterfactuals as more likely than did young adults.

The results of the AI yielded four main findings: (a) Younger adults generated on average more internal details across all mental simulations than did older adults. (b) While older adults generated more internal details for memories than for both episodic future and counterfactual thoughts, young adults produced more internal details for negative likely counterfactuals and similar amount of internal details for memories, negative unlikely counterfactuals, positive likely counterfactuals, and positive unlikely future thoughts. (c) Overall, older adults generated more external details across all conditions than did younger adults. (d) Relative to young adults, older adults generated more details for external episodes—that is, remembered or imagined events that were different from the main simulated event.

Four hypotheses were tested in the current study. First, we hypothesized (a) higher sensory and composition ratings, and (b) more internal details, across all simulations for younger than for older adults. On the one hand, Part (b) of this hypothesis was confirmed, as we did in fact find that younger adults produced on average more internal details across all simulations than did older adults. This result is consistent with previous

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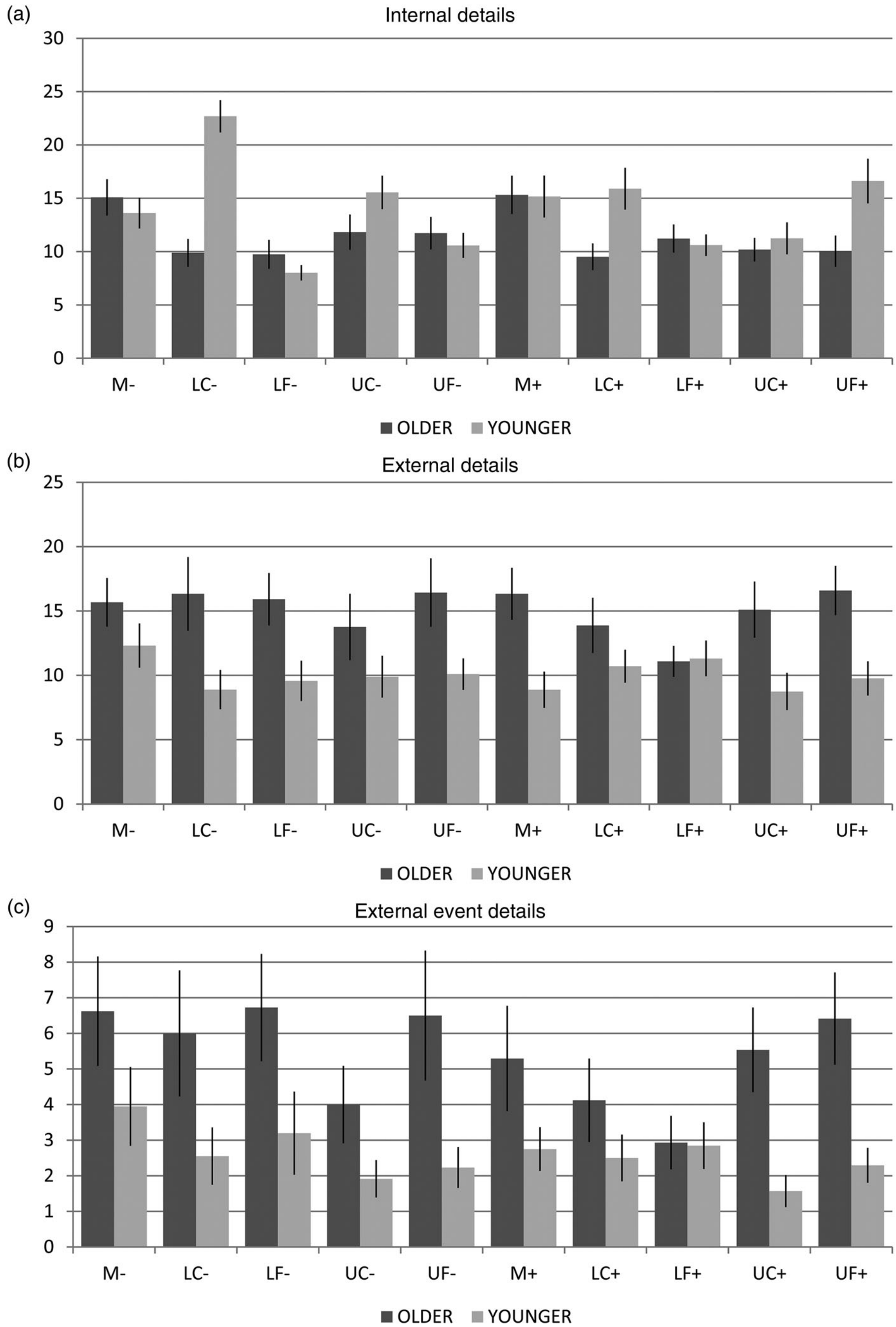

Figure 1. *Proportion of details from the adapted Autobiographical Interview. (A)* Internal details*: Mean number of internal details* (y-*axis) by condition* (x-*axis). In panel (B), y-axis corresponds to the Mean number of external details and the x-axis to the conditions. In (C), the y-axis corresponds to the mean number of external event details and the x-axis to the condition. M = memory; C = counterfactual; F = future; L = likely; U = unlikely; + Positive; − = negative. Error bars indicate standard error of the mean.*

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studies that have found more internal details in younger adults than in older adults for both episodic autobiographical memories (B. Levine et al., 2002) and episodic future thoughts (Addis et al., 2008; Addis, Pan et al., 2009; Gaesser et al., 2011). Also consistent with these studies, our results showed that older adults generated on average more external details than young adults across all conditions. Previous results have been interpreted as suggesting an age-related reduction in episodic specificity for both episodic memories and future thoughts. We believe that the current results extend this observation to episodic counterfactual thoughts as well.

On the other hand, Part (a) of the hypothesis—that is, higher sensory and composition ratings in younger than in older adults—was not confirmed. In fact, the opposite between-subjects effect was found: Relative to younger adults, older adults self-reported higher ratings of vividness, sound, overall sense of simulation, composition, and intensity across all conditions. However, this result need not be interpreted as conflicting with our claim that there is an age-related reduction in episodic specificity for episodic memory and future and counterfactual thinking. Instead, we believe that it may be due to the fact that older adults often inflate their subjective ratings of phenomenological characteristics. Although the precise reasons as to why this may occur are not altogether clear, one possible explanation has to do with reappraisal. For instance, Comblain, D'Argembeau, and Van der Linden (2005) showed that, relative to young adults, older adults were more likely to reappraise emotional memories, which in turn increased their subjective ratings of phenomenological details (for similar examples of bias in the use of rating scales by older adults, see Comblain et al. 2005; McDonough & Gallo, 2013; Schlagman, Kliegel, Schulz, & Kvavilashvili, 2009). We believe that a fruitful avenue for future research is to assess the reliability of the MCQ across the lifespan and for simulations that differ in valence and subjective likelihood.

The second hypothesis tested in this study was that, consistent with the results reported by De Brigard and Giovanello (2012), we would find higher ratings for sensory and composition factors for memories than for both episodic future and counterfactual simulations, in both younger and older adults. This hypothesis was indeed confirmed by our results, and it is consistent with previous studies comparing episodic memories and future thinking, where sensory and contextual details consistently receive higher ratings during retrieval tasks than during prospection (D'Argembeau & Van der Linden, 2004; Szpunar, 2010). These results also agree with previous findings showing that memories of real events receive higher ratings for sensory and contextual details than memories of imagined events (Johnson et al., 1988; McGinnis & Roberts, 1996). In line with previous interpretation of these kinds of results (Addis et al., 2010; Addis et al., 2008; D'Argembeau & Van der Linden, 2004; De Brigard & Giovanello, 2012; Spreng & Levine, 2006), we take the current results as supporting the claim that episodic memories involve less recombination of stored memorial details than do imaginations. This, in turn, renders memories to be experienced as more vivid and spatially cohesive than imaginative simulations, even when such simulations draw heavily from autobiographical components, as is the case with episodic future and counterfactual thoughts.

This last point relates to the third hypothesis tested by the current study, namely that, given the neural similarities between episodic recollection and likely as opposed to unlikely counterfactual thinking (De Brigard, Addis et al., 2013), unlikely simulations would receive lower ratings in sensory and composition factors on the MCQ, as well as more external details in the adapted AI, than would likely simulations. This hypothesis was only partially confirmed by our results. Although it was the case that both younger and older adults gave higher composition ratings for likely counterfactuals than for both unlikely future and counterfactual simulations, there was no difference in their vividness or other sensory ratings. Additionally, there were no differences in the number of external details for likely versus unlikely simulations, although young adults did generate more internal details for negative likely counterfactuals than for all other conditions. Previous research

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has shown that episodic future simulations that are located in temporally close (D'Argembeau & Van der Linden, 2004) as well as familiar settings (Szpunar & McDermott, 2008) are associated with clearer experiences of composition and spatial coherence than simulations placed in unfamiliar settings and remote times. Relatedly, Szpunar, Chan, and McDermott (2009) showed similar level of activation in brain areas associated with spatial processing during episodic memory and episodic future tasks involving familiar settings, but not during episodic future tasks involving unfamiliar settings. This observation offers a plausible interpretation for the aforementioned result: Given that likely counterfactuals involve minimal variation relative to the memory content from which they are derived, and given that memory contents tend to be experienced with greater spatial coherence and composition than other imaginative simulations, then counterfactual simulations that involve less deviation from memories are going to receive higher ratings of spatial coherence and composition as well. However, mental simulations that are perceived as less likely may involve a greater deviation from the memory content they are derived from and, as a result, may be associated with lower rates of spatial coherence and composition. Still, further research is needed to fully understand the factors involved in the experience of space in episodic simulations (De Brigard & Gessell, in press).

The fourth hypothesis tested in this study was that positive unlikely simulations would be rated as less positive than likely ones in the MCQ. Our results did not confirm this hypothesis, as no effects were found for positive simulations. Instead, it was found that negative counterfactuals were experienced more negatively than negative memories and future thoughts. It is possible to interpret this result as reflecting the participant's natural tendencies toward loss aversion, specifically as they relate to the so-called "status quo bias": the tendency to overvalue our status quo because the disadvantages of giving it up loom larger than the advantages (Kahneman, Knetsch, & Thaler, 1991; De Brigard, 2010). This effect, a sort of counterfactual version of regret avoidance—that is, the tendency to avoid risky choices for fear of experiencing possible future regrets—may underlie our tendency to consider possible nonactualized negative outcomes as being worse than actual past ones, for in addition to the negativity associated with the possible outcome itself, counterfactual losses involve imagining a further change in the status quo. Although this explanation is, at best, speculative, we think studying the interactions between loss aversion—of which status quo and regret avoidance biases are subspecies—and episodic future and counterfactual thinking is a fruitful avenue for future research (Schacter et al., 2015).

At this point it is worth noting the other three results found in this study about which we did not have prior hypotheses. First, both younger and older adults reported that unlikely counterfactual events would have been felt more intensely than likely future and counterfactual thoughts. One possibility is to interpret this result as a case of "retroactive" intensity bias, a sort of backward-looking version of the more familiar intensity bias in future forecasting. It has been noted, for instance, that when people simulate possible future experiences with more components from actual experienced events they report lower levels of forecasted intensity than when they simulate possible future events that are less based in reality (Buehler & McFarland, 2001). Assuming that simulating unlikely counterfactuals involves more deviation from actual experienced events than likely counterfactuals, a similar intensity bias may be expected. However, it is important to note that the construct of intensity bias has been recently questioned, as many of the previous results seem to be largely due to participants' misunderstandings (L. J. Levine, Lench, Kaplan, & Safer, 2012). Further research would be needed to understand this phenomenon.

A second result that is worth mentioning is the finding that young adults rated both positive and negative likely future events as more likely than did older adults, whereas older adults rated positive unlikely counterfactuals as more likely than did young adults. This finding may simply reflect the fact that younger adults estimate that they have much more time ahead than older adults, and, as

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a result, they overestimate the probability of any possible event happening. Another possibility, not incompatible with the first one, is that older adults are more settled into a routine and as a result consider that possible future events that deviate from that routine are rather rare. However, we also believe that this finding should be interpreted with caution, as it is probably highly dependent on the precise events that were included in the PAEQ. Studying subjective probability in episodic future and counterfactual simulations based on autobiographical information is challenging, not only because it is difficult to keep constant the level of perceived likelihood across participant and conditions, but also because we are only starting to explore different ways to measure this construct. Further research is certainly needed to fully understand the factors that influence age-related changes in judgments of likelihood during episodic future and counterfactual simulations.

One last finding that is worth discussing is that older adults generated more external details across all conditions than did younger adults. This result is entirely consistent with previous studies (Addis et al., 2008; Addis, Musicaro et al., 2010; Gaesser et al., 2011) on episodic simulation of past and future events in which older adults tend to produce higher number of external details than do younger adults. However, when looking at the specific contents of these external details, we find that in addition to semantic components, older adults generated more details for external episodes than did younger adults—that is, older adults remembered or imagined more events and/or more event details of episodes that were different from the main event they were asked to simulate. The finding that simulating episodic future and counterfactual events gives rise to generating simulations of other, unrelated episodes, both imagined and remembered, is not entirely unexpected, as a similar finding was reported by De Brigard and Giovanello (2012) with young adults. What is unexpected, however, is the fact that older adults generated these external details at a rate that was almost three times greater than that for younger adults. This result suggest that older adults' impoverished narratives of the main simulated event may not be necessarily due to an impairment in retrieving episodic details, but rather in relating them all to create a coherent narrative of a single event during the length of the task. If this interpretation is on the right path, then this result may speak to the more generalized finding that older adults often have difficulties keeping relational information in mind during retrieval (Giovanello & Dew, 2015; Old & Naveh-Benjamin, 2008). Another possibility, not necessarily incompatible with the previous one, is that older adults show reductions in inhibitory control over their verbal output, which in turn may lead them to "go off in a tangent" and deviate from the main narrative task at hand (Hasher & Zacks, 1988; West, 1996). Exploring these possible explanations might be a fruitful avenue for future research.

Finally, it is important to acknowledge some limitations of our current study. First, by selecting as cues for the likely and unlikely simulations those statements from the PAEQ that were clearly rated as either unlikely (1–3) or likely (5–7), we attempted to motivate participants to imagine events that they did, in fact, consider either likely or unlikely to a similar degree. However, being a subjective scale, it is possible that some participants may have taken these values to be less or more extreme than other participants did. Comparing relative judgments of subjective probability among statements is methodologically challenging, and we think it is worth pursuing alternative methods to assess subjective likelihood to corroborate the results reported here. A second shortcoming of the current study is the fact that participants only produced one observation per condition. This is partly because it was not easy to generate enough statements with extreme ratings to populate all the conditions, but also because the paradigm became too taxing for some participants, particularly older adults. As such, we think that caution should be exercised when interpreting the within-subject effects found in the current study. However, the main hypothesis of the present study involved a between-subject comparison, where this concern is less pressing.

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Taken together, the results of the current study further strengthen the evidence that episodic memory and future and counterfactual thinking share similar cognitive operations, and that age-related deficits that have been previously reported during episodic future thinking (Addis, Musicaro et al., 2010; Gaesser et al., 2011) are also evident in episodic counterfactual thinking. However, despite their similarities, episodic future and counterfactual thinking are also different in important respects (Schacter et al., 2015), and we have reported some ways in which ageing may affect these two kinds of simulations differentially. We hope that the results reported here can contribute to further the research on mental simulation of episodic future and counterfactual thinking across the lifespan.

Supplemental material

Supplemental content is available via the "Supplemental" tab on the article's online page (http://dx.doi.org/10.1080/17470218.2015.1115529).

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APPENDIX A MEMORY CHARACTERISTICS QUESTIONNAIRE

1. Clarity (1 = dim; 7 = clear).
2. Color (1 = black and white; 7 = full color).
3. Visual detail (1 = none; 7 = a lot).
4. Sound (1 = none; 7 = a lot).
5. Smell (1 = none; 7 = a lot).
6. Touch (1 = none; 7 = a lot).
7. Taste (1 = none; 7 = a lot).
8. Vividness (1 = vague; 7 = very vivid).
9. Composition (1 = sketchy; 7 = very detailed).
10. Clarity of location (1 = vague; 7 = clear).
11. Clarity of spatial arrangement of objects (1 = vague; 7 = clear).
12. Clarity of spatial arrangement of people (1 = vague; 7 = clear).
13. Clarity of time of day (1 = vague; 7 = clear).
14. Do you remember how you felt during the event? (1 = not at all; 7 = definitively).
15. Emotion during the event (1 = negative; 7 = positive).
16. Intensity of emotion during the event (1 = not intense; 7 = very intense).
17. Emotion as you are remembering now (1 = negative; 7 = positive).

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18. Intensity of the emotion as you are remembering now (1 = not intense; 7 = very intense).
19. Overall, how do you remember this event? (1 = hardly; 7 = very well).
20. Field/observer/none?

Autobiographical counterfactual characteristics questionnaire

1. Clarity (1 = dim; 7 = clear).
2. Color (1 = black and white; 7 = full color).
3. Visual detail (1 = none; 7 = a lot).
4. Sound (1 = none; 7 = a lot).
5. Smell (1 = none; 7 = a lot).
6. Touch (1 = none; 7 = a lot).
7. Taste (1 = none; 7 = a lot).
8. Vividness (1 = vague; 7 = very vivid).
9. Composition (1 = sketchy; 7 = very detailed).
10. Clarity of location (1 = vague; 7 = clear).
11. Clarity of spatial arrangement of objects (1 = vague; 7 = clear).
12. Clarity of spatial arrangement of people (1 = vague; 7 = clear).
13. Clarity of time of day (1 = vague; 7 = clear).
14. Can you imagine how would you've felt during the event? (1 = not at all; 7 = definitively).
15. What would have been your emotion? (1 = negative; 7 = positive).
16. What would have been the intensity of your emotion? (1 = not intense; 7 = very intense).
17. Emotion as you are thinking now (1 = negative; 7 = positive).
18. Intensity of the emotion as you are thinking now (1 = not intense; 7 = very intense).
19. Overall, how do you imagine this event? (1 = hardly; 7 = very well).
20. What's the probability that this event would have occurred as suggested? (1 = not probable; 7 = highly probable).
21. Field/observer/none?

Future characteristics questionnaire

1. Clarity (1 = dim; 7 = clear).
2. Color (1 = black and white; 7 = full color).
3. Visual detail (1 = none; 7 = a lot).
4. Sound (1 = none; 7 = a lot).
5. Smell (1 = none; 7 = a lot).
6. Touch (1 = none; 7 = a lot).
7. Taste (1 = none; 7 = a lot).
8. Vividness (1 = vague; 7 = very vivid).
9. Composition (1 = sketchy; 7 = very detailed).
10. Clarity of location (1 = vague; 7 = clear).
11. Clarity of spatial arrangement of objects (1 = vague; 7 = clear).
12. Clarity of spatial arrangement of people (1 = vague; 7 = clear).
13. Clarity of time of day (1 = vague; 7 = clear).
14. Can you imagine how you will feel during the event? (1 = not at all; 7 = definitively).
15. Emotion during the event (1 = negative; 7 = positive).
16. Intensity of emotion during the event (1 = not intense; 7 = very intense).
17. Emotion as you are imagining now (1 = negative; 7 = positive).
18. Intensity of the emotion as you are imagining now (1 = not intense; 7 = very intense).
19. Overall, how do you imagine this event? (1 = hardly; 7 = very well).
20. What's the probability that this event will happen? (1 = not probable; 7 = highly probable).
21. Field/observer/none?

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