A long time ago in a galaxy far, far away: How temporal are episodic contents?

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ABSTRACT

A prominent feature of mental event (i.e. 'episodic') simulations is their temporal orientation: human adults can generate episodic representations directed towards the past or the future. Here, we investigated how the temporal orientation of imagined events relates to the contents of these events. Is there something intrinsically temporal about episodic contents? Or does their temporality rely on a distinct set of representations? In three experiments (N = 360), we asked participants to generate and later recall a series of imagined events differing in (1) location, (2) time of day, (3) temporal orientation, and (4) weekday. We then tested to what extent successful recall of episodic content (i.e. (1) and (2)) would predict recall of temporality and/or weekday information. Results showed that recall of temporal orientation was only weakly predicted by recall of episodic contents. Nonetheless, temporal orientation was more strongly predicted by content recall than weekday recall. This finding suggests that episodic simulations are unlikely to be intrinsically temporal in nature. Instead, similar to other forms of temporal information, temporal orientation might be determined from such contents by reconstructive post-retrieval processes. These results have implications for how the human ability to 'mentally travel' in time is cognitively implemented.

1. Introduction

Human minds are not tethered to the present. We spend a large proportion of our daily lives thinking about other times (Smallwood & Schooler, 2015). This ability depends on 'episodic simulation', the capacity to generate imaginative constructions of events (for reviews see e.g. Addis, 2018, 2020; Cheng, Werning, & Suddendorf, 2016; Michaelian, 2016; Schacter & Addis, 2020; Schacter, Addis, & Buckner, 2008). Such mental event representations figure in many cognitive capacities from discounting future rewards (Boyer, 2008; Bulley & Schacter, 2020) to causal reasoning (Gerstenberg, Goodman, Lagnado, & Tenenbaum, in press). What allows episodic simulations to fulfil such a large variety of cognitive functions? One important component of such simulations is their temporality, that is, their temporal orientation towards the future or the past (e.g. Redshaw, 2014; Redshaw & Suddendorf, 2020). Episodic simulations can be future- (e.g. Szpunar, Spreng, & Schacter, 2014) or past-directed (e.g. De Brigard, Addis, Ford, Schacter, & Giovanello, 2013). Evidence, however, suggests that the processes generating the contents of both future- and past-directed event representations relies on the same mechanisms (for review see Schacter et al., 2012; Addis, 2020). As a result, a number of authors have concluded that, if episodic simulation produces the same kind of content for both past and future event representations, this content is unlikely to be intrinsically 'temporal' (Boyle, 2020; D'Argembeau, 2020; De Brigard & Gessell, 2016). Instead, the temporal orientation of these

simulations might be determined by mechanisms distinct from those generating the contents of a given event simulation (Mahr, 2020).

To illustrate this, take an example from the well-known Star Wars movie series. Even though each of these movies famously begins with the line "a long time ago in a galaxy far, far away" (thereby placing the events of the movies in the distant past), presumably nothing about the events of Star Wars would change if it were set in the distant future. That is, the content of a Star Wars movie is neutral with regard to its temporal orientation. Here, we ask whether episodic representations relate to their temporal orientation in a similar way. Are the contents of episodic simulations intrinsically temporal? Or does an event representation's temporality rely on processes distinct from those generating its contents?

1.1. Temporal information in episodic memory and episodic simulation

There is a rich literature examining when the ability to think about different times appears in human development and whether non-human animals have the ability to think about different times at all (e.g. Friedman, 2003, 2004, 2005; Hoerl & McCormack, 2019; Martin-Ordas, 2020; McCormack, 2015; Redshaw, 2014). However, less attention has been paid to the cognitive mechanisms that enable this capacity in human adults. Most research on episodic simulation has focused on the similarities between past and future event simulations irrespective of their temporal orientation (e.g. Eacott & Easton, 2012; Schacter et al., 2012). A prominent finding in this literature has been that differences in neural activation patterns underlying past and future event simulations – rather than being explained by the opposing temporal orientations of these representations – can be attributed to the differing constructive demands they place on the episodic simulation system (Addis et al., 2007, 2009; Benoit & Schacter, 2015).

Conversely, research on the cognitive role of temporal information in adult episodic thinking has traditionally not taken into account the deep similarities between episodic memory and other forms of episodic simulation. On the one hand, research in this domain has so far primarily focused on how episodic memories are 'dated', that is, how people are able to retrieve the specific place in time of a given memory (e.g. Friedman, 2004, 1993). Here it is commonly found that 'when' a given memory occurred is not encoded or retrieved as part of that memory. Instead, such dating relies on reconstructive mechanisms at the post-retrieval stage making use of general knowledge (such as when certain kinds of events typically occur), temporal landmarks (Shum, 1998), and the content of the event representation in question. In other words, 'when' specifically the events of a given memory occurred is not part of the content of that memory itself but has to be inferred from that content based on one's general autobiographical and world knowledge. However, episodic memories are just one type of output of the episodic simulation system and much less is known about how such simulations achieve their general temporal orientation in the first place. In fact, Tulving (2002) viewed the 'sense of subjective time' (or as he called it 'chronesthesia') accompanying episodic memory as a feature shared by all forms of 'mental time travel'.

On the other hand, there has been some research specifically investigating the construction of simulations of the future with respect to their temporal features (e.g. D'Argembeau & Demblon, 2012; D'Argembeau & Mathy, 2011; De Brigard, Gessell, Yang, Stewart, & Marsh, 2020; Ernst & D'Argembeau, 2017; Ernst, Scoboria, & D'Argembeau, 2019). Similar to the dating of episodic memories, the specification of the future time of episodic simulations seems to draw on hierarchically organized layers of general autobiographical knowledge (Conway, 2005; Conway, Justice & D'Argembeau, 2019; Conway & Pleydell-Pearce, 2000; D'Argembeau, 2020). For example, in a think-aloud procedure, Malek, Berna, and D'Argembeau (2017) found that participants primarily engaged in reconstructive strategies to determine the temporal locations of both past and future events. In doing so, participants made use mostly of knowledge about life periods and facts about the world, themselves, and others. In spite of results like these suggesting that people often engage in such reconstructive strategies in determining the 'date' of an event, it remains unclear what role temporality, independently of more specific temporal information, plays in episodic simulations.

Moreover, while there has been some research on the temporal properties of episodic simulations of the future and episodic memories of the past, simulations of the past that are not memories are commonly not investigated in this context. One exception to this rule is a study by De Brigard et al. (2020), who found that the general temporal orientation (past/future) of imaginations was better recalled than more specific temporal information (day/month).

Thus, in the present study we aimed to extend previous research in two directions. First, while previous work on the role of temporal information in episodic simulation has focused mostly on episodic memory and future simulations, we investigated the role of such information in imagined events more generally. Second, while there is evidence that temporal information such as specific dates are not part of the content of episodic simulations, it remains unclear whether the same is true for the temporal orientation of such simulations.

1.2. Why temporal orientation is not just another date

There are several reasons to suspect that determining an episodic simulation's general orientation towards the past or the future might require different mechanisms than those responsible for placing these representations at a more specific point in time. First, the general temporal orientation of an event simulation seems to fundamentally contribute to the cognitive role played by that simulation. Future- and past-directed simulations fulfill different functions (Epstude & Roese, 2008; Schacter, Benoit, & Szpunar, 2017). For example, episodic imaginations of the past (i.e. episodic counterfactuals; De Brigard & Parikh, 2019) play a role in causal reasoning (Gerstenberg et al., 2021) and enable regret (Hoerl & McCormack, 2016), while imaginations of the future support planning (Atance & O'Neill, 2001; McCormack & Atance, 2011), problem solving (Jing, Madore, & Schacter, 2016; Sheldon, McAndrews, & Moscovitch, 2011), and the discounting of future rewards (Bulley, Henry, & Suddendorf, 2016). In contrast, while the specific date of an episode can have important consequences in specific circumstances, it is unlikely to impact the functional role of the representation in question.

Second, as many have pointed out (e.g. Campbell, 1996, 2006; Friedman, 2003; Hoerl & McCormack, 2019), specifications of temporal orientation make conceptual requirements that specifications of dates do not make. Specifying a date primarily requires familiarity with the relevant temporal reference frames (i.e. days, months, years etc.). Because these reference frames are cyclical (e.g. every week has a Monday), dates merely require one to understand time as a cyclical domain. Understanding of temporal orientation, however, makes different conceptual demands, arguably relying on an understanding of time as linear and event independent, as well as an understanding of causality (e.g. Campbell, 1996, 2006; McCormack, 2015). Redshaw (2014) even suggests that the capacity to generate episodic simulation with temporal orientation might be a uniquely human, metarepresentational capacity. In any case, someone might be able to place an event within specific reference frames (i.e. as occurring on Mondays) without being able to determine its temporal orientation and vice versa. Third, the ability to place events at points within cyclical reference frames and the ability to determine their temporal orientation might facilitate each other. The ability to think of time equipped with an understanding of temporality should, for example, lead one to treat every Monday as unique in spite of its reoccurring nature.

1.3. How might temporality relate to the contents of episodic simulations?

Temporality might relate to episodic contents in one of two ways (Mahr, 2020). On the one hand, temporality might be part of episodic contents themselves. In that case, we would expect there to be distinct processes for generating 'past' and 'future' contents. For example, an imagination of eating toast for breakfast tomorrow would not, primarily, be an imagination of 'eating toast' but, instead, of 'eating toast *in the future*'. Such an imagination would, therefore, have a fundamentally different content from an imagination of having eaten toast for breakfast yesterday. If temporality were part of episodic contents, retrieving the content of an episode without also becoming aware of its temporal orientation should be unlikely.

On the other hand, temporal orientation might depend on mechanisms not involved in the generation of episodic contents themselves. For example, temporality could depend on a dedicated 'tagging' mechanism (Mahr, 2020). Such a mechanism would predict that the temporal orientation of a given simulation can be stored and retrieved without its contents being available. Nonetheless, even in this case, (while content and temporality should be clearly dissociable) we would expect there to be some association between content retrieval and the retrieval of the respective temporal tag. Alternatively, temporal orientation might depend on reconstructive post-retrieval mechanisms similar to more specific forms of temporal information (e.g. Friedman, 2004). Even though every Star Wars movie begins with the famous "A long time ago…", most people seem to assume that Star Wars is set in the distant future. After all, it includes futuristic technological marvels like laser guns and space ships. Thus, from the inclusion of futuristic technologies in Star Wars one might *infer* that it takes place in the future. Likewise, episodic representations may include more or less information about their temporal orientation and, as a result, temporal information might be easier or harder to infer on the basis of the contents of any given event.

Importantly, each of these potential mechanisms could lead temporal orientation to relate to episodic contents differently than information about more specific dates. For one, we know that episodic contents are neither intrinsically 'dated' nor 'tagged' with such a date (Friedman, 1993), while this has not yet been established for temporal orientation as such. However, even if temporal orientation information, like date information, is reconstructed post-retrieval, it might be that episodic contents simply include more information about temporality than about more specific times. While one might (wrongly) infer from its contents that Star Wars is set in the future, its futuristic space battles will tell you little about the exact year or day of the week of any given Star Wars event. Similarly, regarding one's own imagination, the fact that a given event involves oneself as a child might provide more information about the temporal orientation of that simulation (i.e. the event is set in the past) than about other temporal features (e.g. the time of year or day of the week the event occurred).

These accounts of how temporal information relates to episodic contents make different predictions about the availability of temporal information when episodic content is retrieved. Episodic contents display an associative structure such that retrieval of one content element facilitates the retrieval of other content elements (Horner & Burgess, 2013). Hence, the degree to which content recall is associated with recall of temporal orientation provides information about the extent to which temporality is itself another element of such contents. As a result, we will phrase our predictions primarily in terms of the 'degree of integration' between different content elements and temporal information.

2. Experiment 1

To address the question of how temporality relates to episodic contents, we adapted an experimental design by McDonough & Gallo (2010, 2013; for similar procedures see De Brigard et al., 2020; McLelland, Devitt, Schacter, & Addis, 2015; for related work on multi-element event recall see Horner & Burgess, 2013). These authors asked participants to generate and later recall episodic memories and future imaginations. They were interested in which of these representations would be more distinctive and therefore easier to identify in recall. Results suggested that future simulations were in fact more distinctive than episodic memories. In contrast to McDonough & Gallo's design, we did not pit memories of the past and imaginations of the future against one another. Because we were interested in how participants would recall the temporal orientation of their simulations, crossing past and future events with imagined and remembered events would have introduced a confound into our design (past and future events could have been distinguished simply by recalling whether an event was imagined or remembered or whether it actually occurred or not). Instead, our design focused on recalling temporal orientation of imagined future and past events and on the extent to which this correlates with the recall of event content.

Participants imagined events differing along four dimensions: (1) Location (indoors/outdoors), (2) Time of Day (daytime/

nighttime), (3) Temporality (future/past), and (4) Weekday (Monday/Friday). Location and time of day are both canonical content elements.[1] We therefore expect (and later verify) recall accuracy for location and time of day to be strongly correlated, reflecting their integration in the content of the episodic representation. If information about temporality is similarly integrated with the content of participants' imaginations, recall of temporal orientation should be predicted by whether participants are able to recall the two canonical content elements. Moreover, if temporality is part of the contents of such imaginations, the predictive relationship between content-recall and temporality-recall should be comparable to that between recall of the other two content elements (location and time of day). If, however, temporality is not part of the contents of such imaginations, we would expect either (1) no predictive relationship between temporality and content recall, or (2) a significantly smaller predictive relationship between temporality and content recall compared to the relationship between location and time of day recall.

Finally, if temporal orientation and other, more specific temporal information relate differently to the contents of episodic simulations, we would expect differences in the predictive relationship between content recall and recall of the temporality and weekday elements respectively. That is, if temporality information is more closely integrated with simulated content than weekday information, we would expect recall of temporal orientation but not weekday to be predicted by recall of content. If, however, temporality and weekday are equally distinct from simulated content, we would expect neither recall of temporal orientation nor weekday to be predicted by content recall. Finally, if recall of temporality and weekday are equally closely integrated with simulated content we would expect recall of both elements to behave similarly in terms of their predictive relationship to content recall.

In addition to these predictions, we were interested in how reported event characteristics would relate to the recall of different event elements. Previous studies have shown differences in ratings of difficulty, detail, emotional arousal, or novelty between remembered and imagined events (e.g. Berntsen & Bohn, 2010; D'Argembeau & Van der Linden, 2004; De Brigard et al., 2020; Johnson, Suengas, Ann Foley, & Raye, 1988; McDonough & Gallo, 2010). However, fewer studies have investigated whether a similar difference can be found between past and future imaginations. Addis, Pan, Vu, Laiser, and Schacter (2009) did not find differences between future and past imaginations in terms of amount of perceptual detail or emotionality. Similarly, De Brigard et al. (2020) reported no difference in vividness between simulations of past counterfactuals and future imaginations. Nonetheless, even if event ratings would not differentiate between different types of simulations they might still predict recall of different elements of these simulations and thereby provide insight into what information participants rely on in recalling different simulation elements. If recall of a given event element is predicted by differences in reported event characteristics at encoding, this might indicate that recall of that element depends on content-dependent post-retrieval reconstruction mechanisms. Notably, McLelland et al. (2015) found that detail, emotionality, and familiarity ratings were predictive of later recall of (future-oriented) events. Therefore, we might similarly expect these ratings to predict content recall here. However, since previous studies have not investigated the predictive relationships between event characteristics and recall of temporal orientation, we did not make specific predictions on this point.

2.1. Methods

2.1.1. Participants

We recruited 120 native-English speaking participants via Testable Minds (Rezlescu, Danaila, Miron, & Amariei, 2020). We arrived at this sample size by doubling McDonough and Gallo (2010) original sample of 60 to account for potentially greater noise caused by online data collection. Three participants had to be excluded because they did not fulfill the language inclusion criterion. Thus, 117 participants were included in the final sample for Experiment 1 (M_{Age} = 30.59 years, SD_{Age} = 10.06 years, 81 females).

2.1.2. Procedure

The procedure for Experiment 1 is depicted in Fig. 1 and can be accessed here. The experiment consisted of two parts. In Part 1, participants completed a *'Simulation Encoding Task'* in which they were asked to generate imaginations related to different object word cues. In each of 42 trials, participants were presented with a different 'target' word cue. These cues consisted of common nouns high in imageability (*M* = 6.6) and concreteness (*M* = 6.5; Scott, Keitel, Becirspahic, Yao, & Sereno, 2019). Participants completed two practice trials before being presented with 32 test trials and 8 filler trials (serving as a buffer before the upcoming memory test). Only the 32 test trials were subsequently included in the memory test in Part 2.

For each target word cue in Part 1, participants were asked to imagine an event differing along four dimensions: (1) *'location'* (whether the event takes place indoors or outdoors), (2) *'time of day'* (whether the event takes place during the day or at night), (3) *'temporality'* (whether the event takes place in the past or the future), and (4) *'weekday'* (whether the event takes place on a Monday or Friday). To instruct people about what kind of event they should imagine, target cues were presented together with four 'imagination instruction cues' (i.e. 'indoors'/'outdoors'; 'daytime'/'nighttime'; 'future'/'past'; 'Monday'/'Friday'). Participants were instructed to imagine events 'through their own eyes' (i.e. from a field perspective) and to generate novel events (i.e. events that had not actually occurred). That is, events were to be imagined and not remembered: participants were asked to generate past counterfactuals and possible future events. Further, events were supposed to be set within the next (in the future case) or the last (in the past case) five years of participants' lives, to be unrelated across trials, and to occur at one place and at one time (i.e. over a span of a few minutes to a few hours).

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[1] One reason why location and time of day might be taken to be closely integrated with episodic contents concerns their visual properties. It is therefore possible that these elements would be less clearly identifiable as content elements in episodic simulations that are less visual in character (e.g. simulations of smell or sound).
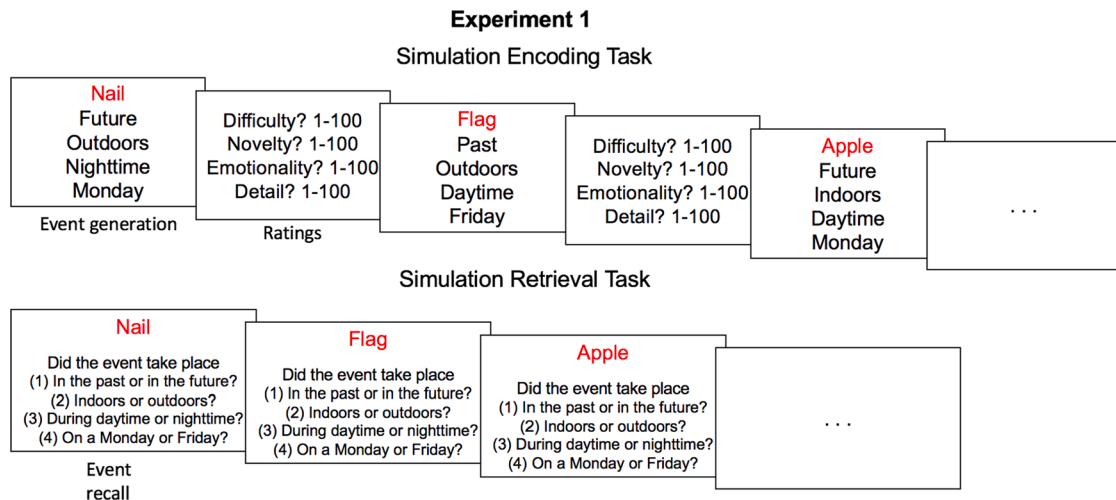
Experiment 1

Simulation Encoding Task

Fig. 1. Task structure for Part 1 ('Simulation Encoding Task') and Part 2 ('Simulation Retrieval Task') of Experiment 1.

In the 32 test trials, each participant had to imagine each combination of event types equally often (i.e. two per combination of location + time of day + temporality + weekday). Which object word cue was associated with which combination of imagination cues as well as the order of cues was randomly determined for each participant. Practice and filler trials were identical across participants.

In each trial, participants were instructed to provide a short description (one or two sentences) of each imagined event. This task was self-paced, with the constraint that participants had to spend a minimum of 15 s in each trial to provide an event description and participants were instructed to aim for spending around 30 s on each trial. Trials in which participants did not provide a description or did not describe an event (consisting at least of a noun + verb phrase) were excluded from analysis (N = 8).[2] After participants had provided an event description in a given trial, they were then asked to rate their imagination on four 100-point scales according to (1) how difficult it was to generate (0 = extremely easy; 100 = extremely difficult), (2) how many perceptual details it included (0 = extremely vague; 100 = extremely detailed), (3) how emotionally intense it was (0 = not at all emotional; 100 = extremely emotional), and (4) how familiar it was (0 = I have never experienced anything similar; 100 = I have experienced this exact event). These measures enabled analyses of the relationship between qualities of episodic content and retrieval success of different simulation elements. We excluded events that were rated maximally difficult from analysis (difficulty = 100; N = 38) because we assumed participants to have failed to generate an event in these cases.

In Part 2, participants were then presented with a '*Simulation Retrieval Task*': a surprise source memory test about each of the 32 target word cues from test trials in Part 1 (in random order). For each word cue, participants were sequentially asked to decide whether in Part 1, (1) they had imagined the event indoors or outdoors, (2) whether they had imagined the event during daytime or nighttime, (3) whether they had imagined the event in the future or the past, and (4) whether they had imagined the event to occur on a Monday or a Friday. This task was self-paced, the order of target word cues was randomly varied across participants, and the order of retrieval tasks for each target word cue was randomly varied within participants.

2.2. Results

All analyses reported here were carried out in *R* (*v 3.6.2*; R Core Team, 2019). Regression models were computed with the package *lme4* (*v1.1–21*; Bates, Maechler, Bolker, & Walker, 2015). For all mixed-effects models reported below, we only included a random effect at the participant level (with fixed slopes) because models including a more complex random effect structure (e.g. with an additional random effects at the item level) did not converge. Unless otherwise stated, all reported tests were two-sided with an alpha-level at 0.05.

2.2.1. Recall performance

To analyze participants' performance in Part 2, we conducted a one-way ANOVA comparing participants' proportions of correct recall responses across simulation elements (location, time of day, temporality, weekday; see Fig. 2). Recall performance differed across simulation elements ($F(3, 464) = 80.06$, $p < .001$): Tukey HSD post-hoc tests showed that participants recalled location (M = 0.81, SD = 0.17) more often than time of day (M = 0.72, SD = 0.15, $p < .001$), recalled time of day more often than temporality (M = 0.61, SD = 0.14, $p < .001$), and recalled temporality more often than weekday (M = 0.54, SD = 0.11, $p < .001$). A one-sample *t*-test

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[2] The following are some examples of event descriptions produced by participants: "Coming home after work and smelling freshly baked bread in the kitchen" (for the cue combination *Bread – Past, Friday, Indoors, Nighttime*) or "Collecting bread at the bakery" (for the cue combination *Bread – Future, Monday, Outdoors, Daytime*).
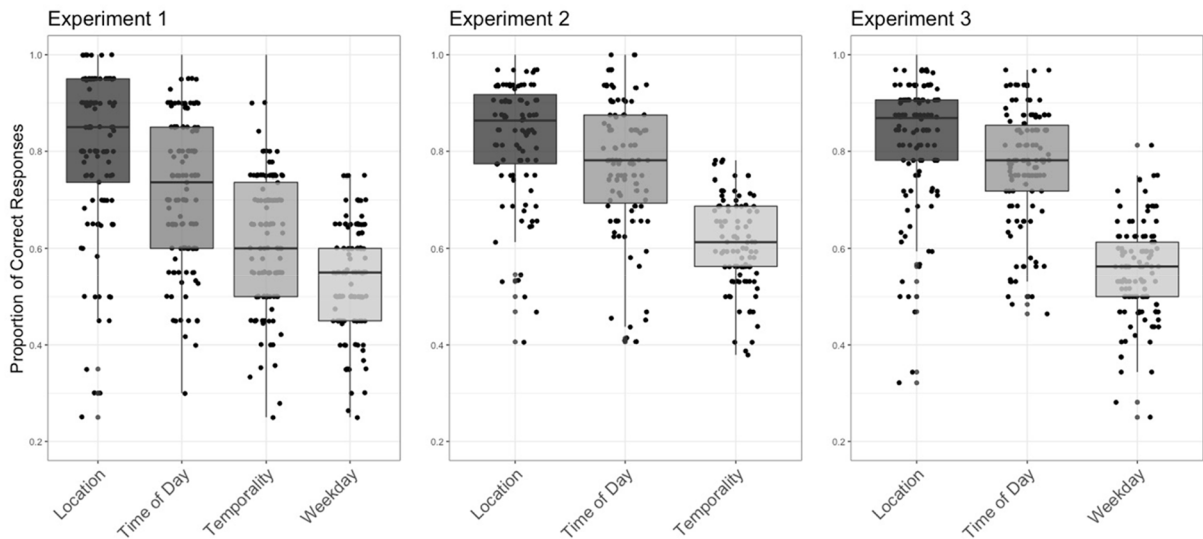
Fig. 2. Differences in recall performance for each simulation element in Experiments 1, 2, and 3. In Experiment 1, participants were asked to generate and later recall events differing in location, time of day, temporality, and weekday. In contrast, in Experiment 2, no weekday element was included and in Experiment 3, no temporality element was included. Across all experiments, participants recalled event location more reliably than time of day, time of day more reliably than temporal orientation, and temporal orientation more reliably than weekday. Scatter plots depict mean scores for each participant in recalling a given element. Boxplot middle bars represent medians, upper and lower hinges correspond to the first and third quartiles (i.e. 25th and 75th percentiles), and whiskers extend from the hinge to the largest value no further than 1.5 * IQR from the hinge in either direction (where IQR is the inter-quartile range/the distance between the first and third quartiles).

against 0.5 confirmed that participants performed at greater than chance at recalling the weekday of their simulations ($t(116) = 3.50$, $p < .001$). On average, participants successfully recalled both content elements together in 61.31% of trials (SD = 20.72%).

2.2.2. Ratings of event characteristics

Ratings of event characteristics in Experiment 1 are summarized in Table 1. To test for effects of different simulation elements on rating types, for each rating type we computed a linear regression model with predictors for Locations, Times of Day, Temporal Orientations, and Weekdays. This analysis showed that detail ratings – with the exception of a marginal effect for Temporality ($\beta = 1.2$, SE = 0.62, $p = .054$) – did not differ across values in any simulation element. Similarly, difficulty ratings only differed across Temporal Orientations ($\beta = 2.20$, SE = 0.65, $p < .001$): past events were rated as easier to generate than future events. Further, familiarity ratings differed across Times of Day ($\beta = 1.76$, SE = 0.84, $p = .035$), Locations ($\beta = 2.81$, SE = 0.84, $p < .001$), and Temporal Orientations ($\beta = 2.06$, SE = 0.84, $p = .014$) but not Weekdays. Specifically, indoor events were rated as more familiar than outdoor events, daytime evens were rated as more familiar than nighttime events, and past events were rated as more familiar than future events. Emotionality ratings did not differ across the values of any simulation element.

Next, we tested to what extent ratings predicted recall of the different simulation elements (location, time of day, temporality, and weekday). To do so, we computed binomial logistic regression models for each simulation element seeking to predict a binary variable coding for recall success of that element ("0″ = "incorrect recall"; "1" = "correct recall") on the basis of z-transformed detail, familiarity, difficulty, and emotionality ratings. While neither weekday nor temporality recall was predicted by values in any rating category, location recall was predicted by familiarity ($z = 2.96$, $p = .003$, $\beta = 0.17$, SE = 0.06) and difficulty ratings ($z = -3.04$, $p = .002$, $\beta = -0.16$, SE = 0.05), and time of day recall was also predicted by difficulty ratings ($z = -3.53$, $p < .001$, $\beta = -0.16$, SE = 0.05). Similarly, detail ($z = 3.15$, $\beta = 0.13$, SD = 0.04, $p = .002$), familiarity ($z = 4.15$, $\beta = 0.14$ SD = 0.04, $p < .0001$), and difficulty ratings ($z = 3.15$, $\beta = 0.13$, SD = 0.04, $p = .002$) predicted content recall (i.e. recall of both content elements) for a given simulation. This partially replicates a result by McLelland et al. (2015) but suggests that the amount of perceptual detail and event familiarity make event simulations more memorable irrespective of their temporal orientation.

2.2.3. Relationship between recall of location, time of day, temporality, and weekday

Are location and time of day recall mutually predictive of one another?

Fig. 3 depicts the predictive relationship between location and time of day recall in relation to the relationship between temporality and content recall as well as weekday and content recall. First, to assess whether recall of location would predict recall of time of day and vice versa, we computed two binomial mixed-effects logistic regressions. We used location recall as a binary dependent variable (1="correct", 0="incorrect") and added random intercepts for each participant with fixed slopes to the model. We then compared this 'null model' via a likelihood ratio test (LRTs) to a model including as a fixed effect a binary variable coding for whether participants' recalled the simulation's time of day. For parameter estimates, 95% confidence intervals were generated by computing a likelihood profile and finding the appropriate cut-offs based on the LRT. This analysis showed that time of day recall predicted location recall

Table 1

Means and standard deviations for ratings of event characteristics over values of Location (indoors/outdoors), Time of Day (day time/night time), Weekday (Monday/Friday), and Temporality (past/future) in Experiment 1.

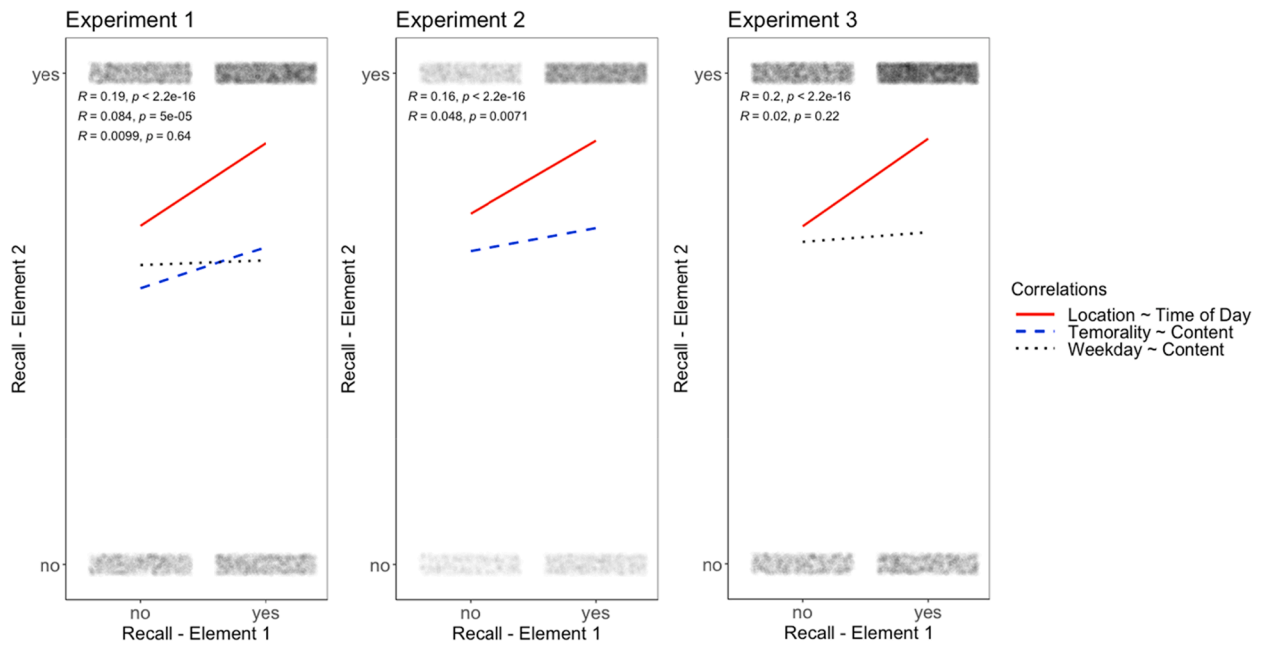| | Location | | | | Time of Day | | | | Weekday | | | | Temporality | | | |
| | Outdoors | | Indoors | | Daytime | | Nighttime | | Monday | | Friday | | Past | | Future | |
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Detail	25.7	26.1	43.8	26.4	44.5	26.4	43.2	26.1	43.5	26	44.2	26.5	45	27.6	42.8	24.8
Difficulty	27.4	26.2	23.9	25.2	24.3	25.0	25.3	26.3	24.4	25.7	25.1	25.7	22.5	24.8	27.1	26.3
Emotionality	44.4	25.6	26.9	26.2	27.2	25.9	27.0	26	26.6	25.8	27.6	26.0	26.8	26.3	27.5	25.5
Familiarity	45.5	34.8	50	37.2	48.8	35.8	45.6	36.4	46.9	36.3	47.5	36	49.1	37.2	45.3	34.9

Fig. 3. Predictive relationships between recall of location, time of day, temporality, and weekday elements in Experiment 1, 2, and 3. Regression lines depict the results of separate linear regression models for relationships between location and time of day recall (solid), temporality and content recall (dashed), and weekday and content recall (dotted). 'Content recall' was coded as successful recall of both location and time of day elements. Experiment 1 included all four elements, while Experiment 2 did not include the weekday element, and Experiment 3 did not include the temporality element. In Experiments 1 and 2 temporality recall was less strongly correlated with content recall than recall of location and time of day were with each other. Across all Experiments, temporality recall was more strongly correlated with content recall than weekday recall was.

$(\chi^2(1) = 36.83, p < .0001, \beta = 0.75, SE = 0.12, 95\% \text{ CI} = [0.51, 1])$.

Second, we repeated this analysis to test whether the reverse predictive relationship also held – that is, whether location recall also predicted time of day recall. LRT-based model comparison between a null model and a model including location recall as a predictor for time of day recall showed a significant effect $(\chi^2(1) = 49.51, p < .0001, \beta = 0.87, SE = 0.12, 95\% \text{ CI} = [0.62, 1.11])$. This finding supports the hypothesis that both the location and time of day elements are part of a simulation's contents.

Is content recall predictive of temporality and/or weekday recall?

To assess whether recall of the two content elements predicted recall of temporality or weekday, we followed the same approach as above. First, we generated a binomial logistic mixed-effects regression with temporality recall as a binary dependent variable (1="correct", 0="incorrect") and added random intercepts for each participant with fixed slopes to the model. We then compared this 'null model' via LRTs to two other models: (1) a model including as a fixed effect a binary variable coding for whether participants' recalled the content of a given simulation (1= "content fully recalled", 0 = "content not fully recalled"), and (2) a model including as a fixed effect a binary variable coding for whether participants recalled the weekday of a given simulation. A given trial was coded as an instance of 'content recall' when the participant correctly recalled *both* the location and the time of day elements.

This analysis showed that temporality recall was positively predicted by content recall $(\chi^2(1) = 13.78, p < .001, \beta = 0.34, SE = 0.09, 95\% \text{ CI} = 0.16–0.52)$ and negatively predicted by weekday recall $(\chi^2(1) = 7.55, p = .006, \beta = -0.24, SE = 0.08, 95\% \text{ CI} = -0.42$ to $-0.07)$.

Next, we applied the same approach to testing whether weekday recall would be predicted by content and temporality recall. However, since the mixed-effects models for weekday recall did not converge, we analyzed this variable using a model without random effects instead. Thus, we computed a binomial logistic regression model with a binary variable coding for success of weekday recall as the dependent variable and a binary variable coding for complete content recall as predictor variable. This analysis showed that weekday recall was not predicted by content recall $(z = 0.48, p = .635)$.

To test the relative strength of the correlations between recall of temporality and content vs. recall of weekday and content we computed a two-sided Fisher-Z-transformation test on the Pearson correlations between these variables across all participants. This analysis confirmed that recall of temporality and content were more strongly correlated $(r = 0.08)$ than recall of weekday and content $(r = 0.01, p = .011)$. This suggests that temporality was more strongly integrated with the contents of the simulations than weekday. Another Fisher-Z-transformation test assessed whether the correlation between temporality and content recall was comparable to that between recall of each of the content elements (location and time of day). This analysis showed that temporality and content recall were less strongly correlated than location and time of day recall $(r = 0.19, p < .001)$. This suggests that temporality was not as strongly integrated with simulated contents as the location and time of day elements and, therefore, likely not retrieved as part of these contents.

Controlling for recall performance

In contrast to weekday recall, temporality recall was predicted by content recall. However, these differences might have been caused by differences in recall performance. After all, participants recalled a higher proportion of temporality than weekday elements. In order to rule out this explanation, we repeated the above analysis on a sub-sample of our participants; namely, those who performed in the upper 50th percentile at recalling the weekday of their simulations (i.e., M >= 0.55; N = 64). Crucially, those participants did not differ in their performance at recalling temporal orientation (M = 0.61, SD = 0.15) and weekday (M = 0.62, SD = 0.06) as assessed by a paired-sample t-test ($t(63) = 0.1, p = .924$). Because the mixed-effects models for weekday recall also did not converge for this sub-sample, we analyzed both weekday and temporality recall with the use of separate generalized linear models without random effects for each predictive relationship. These models confirmed that also for participants with similar recall performance across these elements, temporality recall was predicted by content recall ($z = 3.02, p = .003, \beta = 0.36, SE = 0.12$, 95% CI = [0.12, 0.6]) while weekday recall was not ($z = -0.33, p = .74, \beta = -0.04, SE = 0.12$, 95% CI = [-0.28, 0.2]) .

Further, Fisher-Z-transformation tests on the Pearson correlations between temporality and content recall vs. weekday and content recall showed that temporality and content recall were more highly correlated (r = 0.09) than weekday and content recall (r = −0.01, $p = .017$) across this sub-group of participants. However, also for this sub-group, the correlation between temporality and content recall was smaller than that between location and time of day recall (r = 0.17, $p = .032$).

3. Experiment 2

Experiment 1 suggested that temporality was more strongly integrated with episodic contents than other forms of more specific temporal information such as weekday but less well integrated with more concrete elements such as location and time of day. This suggests that temporality was not retrieved as part of episodic contents themselves. However, we also found that temporality and weekday recall were negatively correlated: temporality recall seems to have made weekday recall less likely and vice versa. One reason for this finding might be that the processes participants relied on to generate or recall the temporality and weekday elements interacted. In generating or retrieving simulations differing along the lines of temporal orientation and weekday, participants might not have relied on entirely independent processes. This circumstance might have masked the extent to which either element correlated with content recall. In order to control for this interaction, we investigated the respective relationships between temporality/weekday and content recall independently in separate experiments. Experiment 2 investigated whether the predictive relationship between temporality and content recall would hold in the absence of the weekday element. In contrast, Experiment 3 investigated the predictive relationship between weekday and content recall in the absence of explicit differences in temporal orientation.

3.1. Methods

In Experiment 2, we dropped the weekday element from the design of Experiment 1. That is, participants were now asked to generate and later recall events that only differed in location, time of day, and temporality. Participants still received 32 test trials, but were now exposed four times to each of the eight possible combinations of the values of the location, time of day, and temporality elements. Instructions, materials, and procedure were otherwise identical to those of Experiment 1.

3.1.1. Participants

We recruited 120 native-English speaking participants via Testable Minds. 19 participants had to be excluded because they did not fulfill the language inclusion criterion and 2 participants were excluded due to providing a majority of invalid event descriptions in the simulation encoding task. Thus, 99 participants were included in the analysis for Experiment 2 ($M_{Age} = 34.42$ years, $SD = 10.85$ years; 47 females).

3.2. Results

Trials in which participants did not provide a description or did not describe an event (i.e. consisting at least of a noun + verb phrase; N = 15) as well as trials which participants rated as maximally difficult (difficulty = 100; N = 61) were excluded from analysis because we assumed that participants had failed to generate a simulation in these cases.

3.2.1. Recall performance

A one-way ANOVA comparing participants' average proportion of correct recall responses across simulation elements revealed a main effect of simulation element ($F(2, 294) = 86.24, p < .001, \eta^2 = 0.37$). Tukey HSD post-hoc tests suggested that participants recalled a simulation's location ($M = 0.83; SD = 0.13$) more often than its time of day ($M = 0.77; SD = 0.14; p = .003$) and recalled its time of day more often than its temporal orientation ($M = 0.61, SD = 0.09; p < .001$). On average, participants recalled both the location and time of day elements in 66.46% ($SD = 18.5\%$) of trials.

3.2.2. Ratings of event characteristics

To test for effects of differences in Locations, Times of Day, and Temporal Orientations on each rating type, we generated linear regression models for each rating type with predictors for each simulation element. This analysis showed a marginal effect of Temporality on detail ratings ($\beta = 1.31, SE = 0.77, p = .088$). Otherwise, detail ratings were unaffected by differences in Times of Day and Locations. Difficulty ratings were affected by differences in Temporality ($\beta = 1.22, SE = 0.61, p = .045$; $M_{Future} = 31.51, SD_{Future} =$

24.91; $M_{Past} = 19.28$, $SD_{Past} = 19.28$) and marginally affected by differences in Times of Day ($\beta = 1.12$, SE = 0.61, $p = .067$). Further, familiarity ratings differed between Locations ($\beta = 3.32$, SE = 0.9, $p < .001$), Times of Day ($\beta = 2.45$, SE = 0.9, $p = .007$), and Temporal Orientations ($\beta = 3.31$, SE = 0.9, $p < .001$). Specifically, indoor events (M = 51, SD = 36.82) were rated to be more familiar than outdoor events (M = 44.51, SD = 36.2), past events (M = 51, SD = 36.84) rated as more familiar than future events (M = 44.44, SD = 36.16), and daytime events (M = 50.11, SD = 36.58) rated as more familiar than nighttime events (M = 45.39, SD = 36.57). Emotionality ratings were not affected by differences in any simulation element.

As in Experiment 1, we then generated generalized linear models to examine the extent to which ratings predicted the different simulation elements (location, time of day, and temporality). That is, we computed binomial logistic regression models for each simulation element seeking to predict a binary variable coding for recall success of that element on the basis of z-transformed detail, familiarity, difficulty, and emotionality ratings. This analysis revealed that while temporality recall was not predicted by any rating category, location recall was negatively predicted by difficulty ($z = -3.85$, $p < .001$, $\beta = -0.18$, SE = 0.04) and emotionality ratings ($z = -3.08$, $p = .002$, $\beta = -0.14$, SE = 0.05), and time of day recall also was negatively predicted by difficulty ($z = -2.14$, $p = .032$, $\beta = -0.09$, SE = 0.04) and emotionality ratings ($z = -4.17$, $p < .001$, $\beta = -0.17$, SE = 0.04). Complete content recall was similarly negatively predicted by difficulty ($z = -2.58$, $p = .01$, $\beta = -0.1$, SE = 0.04) and emotionality ratings ($z = -4.69$, $p < .001$, $\beta = -0.18$, SE = 0.04). Thus, in contrast to Experiment 1 where content recall was predicted by differences in perceptual detail and familiarity between events, in Experiment 2, emotionality and difficulty predicted content recall.

3.2.3. Relationship between recall of location, time of day, and temporality

Are location and time of day recall mutually predictive of one another?

We assessed whether recall of location would predict recall of time of day and vice versa in the same way as for Experiment 1. LRT-based model comparison revealed the same pattern as in Experiment 1: time of day recall predicted location recall ($\chi^2(1) = 47.73$, $p < .0001$, $\beta = 0.71$, SE = 0.11, 95% CI = [0.49, 0.93]). Conversely, location recall also predicted time of day recall ($\chi^2(1) = 50.40$, $p < .0001$, $\beta = 0.71$, SE = 0.11, 95% CI = [0.49, 0.93]).

Is content recall predictive of temporality recall?

To test for predictive relationships between recall of location and time of day (i.e. 'content recall') on the one hand and temporal orientation on the other, we employed the same approach as in Experiment 1 (see Fig. 3): we compared binomial logistic mixed-effects models for successful recall of temporality via LRTs. This analysis showed that temporality recall was predicted by content recall ($\chi^2(1) = 6.76$, $p = .009$, $\beta = 0.21$, SE = 0.08, 95% CI = [0.05, 0.36]). However, a Fisher-Z-transformation test showed that temporality and content recall (r = 0.05) were less strongly correlated than location and time of day recall (r = 0.16, $p < .0001$) across all participants.

4. Experiment 3

Experiment 2 replicated the finding of Experiment 1 that content recall seems to facilitate recall of temporal orientation to some extent. Nonetheless, recall of temporality was significantly less strongly associated with content recall as compared to the association between recall of the two content elements suggesting that temporality was not retrieved as part of these contents. In Experiment 3, we sought to replicate the second main finding of Experiment 1, namely, that weekday recall was not associated with content recall. However, in order to avoid possible interference effects between the temporality and weekday elements, we only included the latter in the design of Experiment 3.

4.1. Methods

Whereas Experiment 2 focused on the relationship between temporality and content, Experiment 3 focused on the relationship between more specific temporal information (i.e. weekday) and simulation content. Thus, in Experiment 3 we dropped the temporality element from the design of Experiment 1. As a result, participants were instructed to generate events occurring on a Monday or Friday but could freely choose whether a given event was set in the future or the past. Otherwise, Experiment 3 was identical to Experiment 2 in instructions, materials, and procedure.

4.1.1. Participants

We recruited 120 native-English speaking participants via Testable Minds. Six participants had to be excluded because they did not fulfill the language inclusion criterion. Thus, 114 participants were included in the analysis for Experiment 3 ($M_{Age} = 31.88$ years, $SD_{Age} = 10.79$ years; 77 females).

4.2. Results

As in the previous experiments, trials in which participants did not provide a description or did not describe an event (N = 25), and trials which participants rated as maximally difficult (difficulty = 100, N = 53) were excluded from analysis.

4.2.1. Recall performance

Recall performance for each simulation element is displayed in Fig. 2. A one-way ANOVA investigating whether participants' recall performance differed between simulation elements produced a significant effect ($F(2, 339) = 167.26$, $p < .001$, $\eta^2 = 0.5$). Tukey HSD post-hoc tests indicated that participants recalled their simulations' location ($M_{Location} = 0.82$; $SD_{Location} = 0.14$) more often than their

time of day (M_{Time} = 0.77; SD_{Time} = 0.12; p = .002) and recalled the simulations' time of day more often than their weekday ($M_{Weekday}$ = 0.55, $SD_{Weekday}$ = 0.1; p < .001). A one-sample t-test confirmed that average performance in recalling the weekday element was significantly above chance-level (t(113) = 5.37, p < .001). On average, participants recalled both content elements together in 66.4% (SD = 17.5%) of trials.

4.2.2. Ratings of event characteristics

To determine whether participants' ratings differed between locations, times of day, and weekdays, we generated separate linear regression models for each rating type with predictors for each simulation element. This analysis suggested that detail and difficulty ratings did not differ across the values of any simulation element. Just as in the previous experiments, familiarity ratings differed across locations (β = 3.94, SE = 0.84, p < .001) and times of day (β = 1.92, SE = 0.84, p = .022): indoor events were again rated to be more familiar (M = 55.48, SD = 37.13) than outdoor events (M = 47.77, SD = 36.46), and daytime events (M = 53.5, SD = 36.87) more familiar than nighttime events (M = 49.75, SD = 37.03). However, events on Mondays and Fridays did not differ in how familiar they were judged to be. Finally, emotionality ratings did not differ across values in any simulation element.

In order to test whether ratings predicted accurate recall of each simulation element, we again computed separate binomial logistic regression models for each simulation element, seeking to predict a binary variable coding for recall success of that element on the basis of z-transformed detail, familiarity, difficulty, and emotionality ratings. This analysis revealed that difficulty ratings (z = 2.033, p = .042, β = 0.07, SE = 0.03) predicted weekday recall. Neither location recall nor time of day recall were predicted by any ratings in any category. Content recall (i.e. recall of both location and time of day recall) was similarly not predicted by any rating type.

4.2.3. Relationship between recall of location, time of day, and weekday

Are location and time of day recall mutually predictive of one another?

Using the same approach as in the previous experiments, LRT-based model comparison revealed that time of day recall predicted location recall (χ^2(1) = 77.73, p < .0001, β = 0.91, SE = 0.10, 95% CI = 0.70–1.1) and, vice versa, location recall predicted time of day recall (χ^2(1) = 86.65, p < .0001, β = 0.95, SE = 0.110 95% CI = 0.76–1.15).

Is content recall predictive of weekday recall?

Using the same approach as in the previous experiments to test for predictive relationships between content recall and weekday elements showed that weekday recall was not predicted by content recall (χ^2(1) = 1.16, p = .281, β = 0.08, SE = 0.07, 95% CI = [−0.06, 0.22]). Similarly, A Fisher-Z-transformation test showed that weekday and content recall (r = 0.02) were less strongly correlated than location and time of day recall (r = 0.2, p < .0001) across all participants.

In order to determine whether these results were caused by the large differences in performance between weekday recall and content recall, we repeated this analysis on only those participants who performed roughly equally in all three conditions (i.e. participants performing in the lowest 15th percentile for location recall, M < 0.71, N = 19). A one-way ANOVA for the effect of simulation element on recall performance did not produce a significant effect for this sub-sample (F(2, 54) = 1.79, p = .176) suggesting that these participants performed roughly equally in recalling all three simulation elements ($M_{Location}$ = 0.58, SD = 0.11; $M_{Time of Day}$ = 0.59, SD = 0.09; $M_{Weekday}$ = 0.53, SD = 0.07). A one-sample t-test confirmed that participants in this sub-sample continued to perform above chance in recalling the weekday element (t(18) = 2.33, p = .031).

Because the mixed-effects model for weekday and time of day recall did not converge for this sub-sample, we instead used generalized linear models without random effects for all three variables (i.e. location, time of day, and weekday) to explore the predictive relationships between recall of the different simulation elements. These models suggested that, for those participants who performed roughly equally at recalling the three simulation elements, weekday recall was not predicted by content recall (z = 0.98, β = 0.57, SE = 0.17, 95% CI = [−0.16, 0.51]). Nonetheless, location recall was still predicted by time of day recall (z = 3.31, p < .001, β = 0.57, SE = 0.17, 95% CI = [0.23, 0.91]). However, for this sub-group of participants, only a one-sided Fisher-Z-test for the difference in correlation strength between weekday and content recall (r = 0.04) on the one hand, and location and time of day recall (r = 0.14) on the other reached significance ($p_{one-sided}$ = .049).

5. General discussion

In this study, we asked two questions (1) is temporality part of the contents of episodic simulations, and (2) does temporality relate differently to these contents than other, more specific temporal elements? To answer these questions, we asked participants to generate and later recall imagined events that differed in location (indoors vs. outdoors), time of day (daytime vs. nighttime), temporality (past vs. future), and weekday (Monday vs. Friday). Our predictions centered on the extent to which recall of temporal orientation and weekday would be predicted by recall of simulated content (i.e. location and time of day).

5.1. How temporal are episodic contents?

First, note that our experiments support our assumption that the location and time of day elements are indeed closely integrated with the contents of any given simulation: recall of these elements was consistently mutually predictive across all three experiments. We thus operationalized successful retrieval of an episode's content as trials in which participants correctly recalled both the location and time of day elements. If temporality were part of the contents of episodic simulations, we would expect temporal orientation to be retrieved whenever said content is retrieved. Therefore, we tested to what extent content recall predicted successful recall of temporal orientation.

Both in Experiment 1 and 2 we found that recall of temporality was predicted by content recall. This suggests that episodic contents at least contain enough information about temporal orientation to facilitate its retrieval. However, if temporality was indeed just another content element (as location or time of day) we would expect this predictive relationship to be on par with the correlation between location and time of day recall. In both experiments which included the temporality element, this was not the case: temporality was consistently less strongly correlated with content recall than location and time of day recall were with one another. This suggests that, even though episodic contents contained information about temporal orientation, temporality was itself not retrieved as part of these contents. Our findings therefore support the idea – recently advanced by various authors (e.g. Boyle, 2020; De Brigard & Gessell, 2016; Mahr, 2020) – that episodic contents are not intrinsically temporal in nature. That is, episodic simulation does not seem to generate 'past episodes' and 'future episodes'. Instead, the pastness or futurity of a given episode relies on inference mechanisms separate from those generating an event's contents. This conclusion is also supported by the fact that content recall was predicted by differences in detail, difficulty, and familiarity ratings (Experiment 1) and difficulty and emotionality ratings (Experiment 2) whereas temporality recall was not predicted by rating differences in any experiment. However, the fact that we did not consistently replicate the relationship between specific event characteristics and content recall across all of our experiments makes it difficult to draw strong conclusions from this finding alone.

A further caveat to this conclusion concerns the extent to which different temporal orientations might be differentially integrated with episodic contents. An exploratory post-hoc analysis suggests that the predictive relationship between content recall and temporality recall differed between temporal orientations in Experiments 1 and 2. Whereas in Experiment 1 temporality recall for future (but not past) episodes correlated with content recall ($r = 0.16, p < .0001$), in Experiment 2 temporality recall for past (but not future) episodes correlated with content recall ($r = 0.075, p = .003$). These analyses, although unplanned, suggest that the integration of episodic contents with their temporality may vary depending on the specific temporal orientation.

In spite of these caveats, our results speak to the question of how temporal orientation is determined if temporality is not part of episodic contents themselves. The current results are compatible with the claim that temporal orientation in episodic simulation might rely on similar reconstructive mechanisms as other temporal features (D'Argembeau, 2020; Friedman, 2004). Temporal orientation might be reconstructed from content-specifics post-retrieval. Just as in the Star Wars scenario discussed in the introduction, participants might have reconstructed event temporality on the basis of objects, people, or places involved in the event that would indicate whether the event is in the past or future. From this perspective, the interaction between temporal orientation and content integration mentioned above might be taken to indicate that (possibly depending on context) one or the other temporal orientation might be easier to reconstruct from content elements.

However, we are not claiming that reconstruction is the only, or even the most common way that people assign temporal orientation to their simulations. Instead, the current results merely emphasize that episodic contents and their corresponding temporal orientations can be independently retrieved and forgotten. This observation suggests that such contents are not intrinsically temporal in nature. In more naturalistic contexts it could be that people often rely on metacognitive feelings (such as feelings of familiarity and fluency) in assigning temporal orientation to their simulations. Nonetheless, the interpretation of feelings of (say) familiarity as an indication of past-orientation requires an inference (e.g. Leboe & Whittlesea, 2002; Mecklinger & Bader, 2020). This idea is nicely demonstrated by feelings of déjà vu in which one has feelings of familiarity (Brown, 2003) and premonition (Cleary & Claxton, 2018) about a current event without retrieving explicit episodic content of any prior event.

Moreover, it's plausible that when people generate episodic simulations voluntarily in everyday life, they know whether the event they are simulating occurs in the past or future before they generate the episodic contents (see also Mahr, 2020). In such cases, they need not reconstruct the temporal information after the fact, as participants likely did in the present research. Future research should therefore seek to more specifically investigate the mechanims responsible for assigning temporal orientation to episodic simulations. One step in this direction would be to discriminate between a post-retrieval and a tagging mechanism for episodic temporality.

5.2. Is temporality more closely integrated with the contents of episodic simulation than other temporal features?

Regarding our second research question, the present results suggest that – while not part of these contents themselves – temporality is more closely integrated with episodic content than other forms of temporal information such as on what day of the week the event occurs. In Experiment 1, temporality recall was more strongly correlated with content recall than weekday recall was. Moreover, temporality recall was predicted by content recall in Experiment 2 whereas weekday recall was not predicted by content recall in Experiment 3. Finally, replicating a finding by De Brigard et al. (2020), participants were consistently more successful at recalling an episode's temporal orientation than the weekday on which the episode was set to occur. Both a tagging and a post-retrieval reconstruction account of temporality can explain these findings. On the tagging account, the discrepancy between temporality and weekday recall would be due to the diverging mechanisms allowing participants to determine each element respectively. On the post-retrieval reconstruction account, episodic contents simply contain more information about temporal orientation than weekday: the fact that a given event might include oneself as a child might allow one to infer that the event is set to take place in the past while it does not allow one to make similar inferences about the day of the week on which the event takes place.

5.3. Conclusion

While the present study was able to show that episodic contents are unlikely to be intrinsically temporal, it remains an open question which mechanisms enable the differing temporal orientations of episodic simulations. This is largely because the present study investigated inferences about temporal orientation in a paradigm that required participants to retrieve previously generated

imaginations. While our results are compatible with the view that determinations of temporal orientation and weekday might rely on similar reconstructive inferences in this task, we cannot definitively speak to how simulations receive their temporality when they are first generated. Therefore, future research should seek to determine what allows a given simulation to be directed towards the future or the past in the first place. Moreover, given that we found contradictory results regarding how strongly temporality recall was predicted by content recall depending on temporal orientation, future research should investigate in what contexts pastness or futurity is more strongly integrated with episodic contents. After all, these questions have important implications for understanding how the human ability to mentally traverse different times is cognitively implemented.

If temporality in episodic simulation indeed relied on the same kind of inferences as other forms of more specific temporal information, this similarity would suggest that there is no dedicated, domain-specific capacity underlying our ability to episodically 'think in different temporal orientations' as such. Instead, this ability might then be an outcome of socio-cultural learning during development similar to how we learn to place events within hours, days, weeks, months, and years (e.g. Heyes, 2018; Friedman, 2005). In light of the supposed centrality of the ability to mentally simulate different times for many cognitive capacities (such as affective forecasting, prospective memory, counterfactual thought, etc.), this result would be surprising.

CRediT authorship contribution statement

Johannes B. Mahr: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft. **Joshua D. Greene:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Daniel L. Schacter:** Conceptualization, Methodology, Supervision, Writing – review & editing, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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