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Memory of where predicts confidence in when: the role of spatial information in dating autobiographical events

Samantha A. Deffler[a], Megan Itagaki[b], Madeline Valdez[c] and Sharda Umanath[c]

[a]Department of Psychology, York College of Pennsylvania, York, PA, USA; [b]Department of Psychology, Scripps College, Claremont, CA, USA; [c]Department of Psychological Science, Claremont McKenna College, Claremont, CA, USA

ABSTRACT

How do we know when a remembered event took place? Contemporary theories suggest that temporal landmarks, conventional time patterns, transitions, and lifetime periods, among other strategies, help reconstruct the date of an event. Spatial information plays a privileged role in participants' experiences of reliving and vividness during remembering. Given its influence on these key properties, we conducted two experiments with undergraduate students ($n_{Study\ 1}$ = 151, $n_{Study\ 2}$ = 141) to test whether spatial information may also contribute uniquely to confidently dating a memory. Results from the two experiments revealed (1) higher levels of spatial details while remembering predicted greater confidence when dating memories and (2) spatial information is used to reconstruct dates of events by extending prior work that previously subsumed spatial information into the broader category of contextual details (e.g., Ben Malek et al., 2017). Participants utilised spatial information to date 26.6% of their memories; confirming previous work, they also utilised temporal landmarks, lifetime periods, and contextual details often to date events. Overall, spatial information is an important factor in dating autobiographical memories that had not been explored independently until this investigation. We discuss the implications for theories regarding the dating of memories and event memory.

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Introduction

Autobiographical memory consists of past events from one's life, or more generally, memories of the self (Brewer, 1986; Conway & Pleydell-Pearce, 2000; Rubin, 1986; Rubin & Umanath, 2015; c.f. Pillemer et al., 2015 for a discussion of vicarious memories). Using the terminology coined by Tulving (1972, 1993), remembering a personal event can be "episodic," in that it is of a single event, is retrieved voluntarily, and comes with a sense of reliving and a spatial context (Rubin et al., 2019; Rubin & Umanath, 2015). These events are likely to be associated with a particular location, informing one of *where* to "mental time travel" or relive the event (Suddendorf & Corballis, 1997). For example, when reminiscing about their first week of college, a student might mentally time travel and imagine standing in their first dorm room or sitting in their first college classroom. This spatial information drives the experiences of reliving, vividness, and belief in the accuracy of the memory (Rubin et al., 2019), key phenomenological properties of autobiographical memory. Date estimations of when autobiographical memories took place, which is often reconstructed using multiple strategies, have also been linked to these phenomenological properties (Ben Malek et al., 2017; Larsen et al., 1996). Given these connections, spatial information may also contribute to confidently dating a memory. Yet, previous literature on dating autobiographical memories subsumed spatial information into the broader category of contextual details (e.g., Ben Malek et al., 2017), preventing the analysis of the unique contribution of spatial information. Compared to other cues and strategies, the potential singular influence of spatial information on the process of (Study 2) and confidence in date estimation (Study 1 and 2) has not yet been fully considered in light of recent developments in the theoretical understanding of event and autobiographical memory (Rubin et al., 2019; Rubin & Umanath, 2015). To address this shortcoming, the current studies investigate the particular contribution of spatial information in dating autobiographical memories using a sample of undergraduates ($n_{Study\ 1}$ = 151, $n_{Study\ 2}$ = 141) each providing four memories.

Autobiographical memories are not randomly stored in our memory system but are temporally organised to form a life narrative, or a coherent story of one's own life (Friedman, 1993). Some have compared its organisation to that of a book (McAdams, 2001; Rubin & Umanath, 2015; Thomsen et al., 2016) with "life story chapters," which are important periods of time in one's life with a specific start and end (Thomsen et al., 2016). Certain themes throughout one's life are formed by drawing connections

CONTACT Samantha A. Deffler sdeffler@ycp.edu 441 Country Club Road, York, 17403 PA, USA
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between various chapters, such as the development of a certain personality trait from kindergarten to college. Since autobiographical memories often contain temporal information, each memory has a relationship with previously experienced memories, as well as memories that have yet to be experienced (Tulving, 1972). These temporal and thematic relationships create a cohesive life story, developing one's self-concept through a personal timeline of interconnected memories (McAdams, 2001). This ultimately represents the "self" function of autobiographical memory, assisting in the maintenance of self-continuity across the life span (Pillemer, 1992). As a result, autobiographical memories are frequently defined in relation to the self (Brewer, 1986; Rubin & Umanath, 2015).

Just as authors can organise a book in various ways, from adjusting the length of a chapter to switching between character perspectives, the organisation of autobiographical memory has been theorised in many ways, from hierarchical (Conway & Pleydell-Pearce, 2000) to temporally-based (Shum, 1998). Here, we focus on the temporal organisation of memories, which may aid individuals in dating specific autobiographical memories (Brown et al., 2016; Larsen et al., 1996; Shimojima, 2004; Shum, 1998; Skowronski et al., 2007).

Retrieval of temporal information

How do we date our memories? Friedman (1993) classifies three underlying processes for dating memories: distance, order, and location, which are likely not mutually exclusive (Friedman, 1993; Friedman, 2004; Janssen et al., 2006). Distance-focused theories suggest that temporal information is recalled by gauging the distance between the time of an event and the present (Friedman, 1993, 2004). In contrast, order-based theories posit that recalling one event leads to the activation of another event, which creates a temporal relationship between the two events (Friedman, 1993, 2004). This relationship is recalled when an individual is attempting to determine which event occurred first, such as in a judgment of recency (JOR) task (Skowronski et al., 2003; Skowronski et al., 2007).

Lastly and most relevant for present consideration, location theories can be broken down into time-tagging theories and reconstructive theories (Ben Malek et al., 2017; Friedman, 1993, 2004). Time-tagging theories assume that temporal information is automatically encoded along with an event (Larsen et al., 1996; Skowronski et al., 2007). Conversely, reconstructive theorists argue that just as remembering is a reconstructive process, determining the date when an event occurred also involves inferential processing based on details of the encoded event (Brown et al., 1986; Larsen et al., 1996; Rubin & Umanath, 2015). Thus, temporal information is reconstructed using dating strategies, such as contextual details, to infer when the event occurred. That is, when trying to date a memory, an individual might think about what season it was, or what other events were going on at that time in an attempt to recall temporal information about the event in question. For example, if an individual remembers it was snowing, that will narrow down the month of the event to sometime during the winter season. Spatial information, such as the location or layout of an event, may also provide critical contextual information to aid in the date estimation process. However, recent theories of how memories are dated do not specifically account for spatial information as a separate cue or strategy, perhaps because it is only recently that the fundamental importance of spatial information to event memories, in general, has been theorised and established (Rubin et al., 2019; Rubin & Umanath, 2015). Since many individuals "mentally time travel" back to an event when remembering contextual details such as the weather or who they were with, they are simultaneously utilising information about *where* the memory took place (Rubin et al., 2019; Rubin & Umanath, 2015). We therefore hypothesise that spatial information may be particularly helpful in reconstructing temporal information.

Dating memories using reconstructive strategies

As mentioned above, people often use strategies to date past and future events rather than directly dating them, emphasising the reconstructive aspect of the dating estimation process (Ben Malek et al., 2017; Brown, 1990). Past literature on dating autobiographical memories has explored many different reconstructive strategies, such as lifetime periods, temporal landmarks, contextual details, factual knowledge, and conventional time patterns (Ben Malek et al., 2017; Bohn & Habermas, 2016; Brown, 1990; Brown et al., 2016; Burt, 2008; Janssen et al., 2006; Larsen et al., 1996; Shum, 1998; Skowronski et al., 1995). The two most widely studied and frequently reported strategies are temporal landmarks and lifetime periods. Temporal landmarks (or landmark events; Shum, 1998) are unique, personally important events such as a graduation or 21st birthday that function as reference points within one's timeline of personal memories (Ben Malek et al., 2017; Bohn & Habermas, 2016; Brown et al., 2016; Burt, 2008; Larsen et al., 1996; Skowronski et al., 1995). These landmarks can serve as transition events, helping to organise autobiographical memory by marking the beginning and end of extended events or lifetime periods (Brown et al., 2016), which represent larger spans of time, usually within the same environment, in which one has established a sense of stability and routine (Ben Malek et al., 2017; Brown et al., 2016; Skowronski et al., 1995). For example, when attempting to recall information about high school, an individual may use temporal landmarks, such as the beginning of freshman year or graduation, to locate the lifetime period in which to search. When a temporal landmark marks a transition, it "produces an enduring change in the fabric of daily life" (Brown et al.,

2016, p. 261), signalling the end of a lifetime period and the beginning of another.

Ben Malek et al. (2017) observed that using lifetime periods was the most frequent dating strategy, followed by general knowledge about one's self and the world. The importance of temporal landmarks has also been observed in the ordering and dating of autobiographical memories (Burt, 2008; Shum, 1998). Nevertheless, reconstructive strategies are not always used exclusively or independently, as past research has found that 53% of autobiographical memories were dated using multiple reconstructive strategies (Ben Malek et al., 2017), possibly indicating the need to verify the date of a past event using multiple methods. This overlap of reconstructive strategies may contribute to masking the particular role and importance of spatial information in dating autobiographical memories.

"Spatial" as a reconstructive strategy

Importance of spatial information in event memory

Rubin and Umanath (2015) provide a neurocognitive theory of event memory, defined as "the mental construction of a scene, real or imagined, for the past or the future" (p. 1). When constructing a given scene – the foundation of the event memory, one does so at a given location and time, generating a specific perspective from which the scene will be viewed. The "self" is situated in a particular spatial location relative to other beings and objects within the scene. Indeed, Gardner et al. (2015) found that 98% of participants' autobiographical memories contain at least one detail corresponding to spatial features. This spatial organisation and mental scene construction is required, but not necessarily sufficient, to generate a sense of reliving, a key phenomenological property of autobiographical memories (Rubin et al., 2019).

When recalling a past event, one may re-live the event through "mental time travel" to that same perspective by using a specific spatial orientation, which may also provide useful information in producing a date estimation – the question at hand. Thus, mentally constructing a scene of a past event, which provides information about spatial context and location, may aid in dating autobiographical memories. In fact, Friedman (2004, p. 593) says "Often, remembering where the event occurred or some other detail can be combined with general knowledge of time patterns to determine when the event must have taken place." It is also important to note that transitions often involve relocation, or a change of place, as the individual no longer encounters familiar, repeated components such as people or places (Brown, 2016; Brown et al., 2016). Thus, a change in location (or defining aspects of a location) may indicate a transition and aid in the temporal organisation of autobiographical memory.

Nevertheless, the importance of spatial context as a reconstructive strategy for date estimation has not been examined directly, as this variable is typically subsumed under the broader category of contextual details. Spatial characteristics point to not only *where* to mental time travel to, but possibly *when* as well. Furthermore, spatial information also predicts reliving while remembering and the vividness of a memory (Rubin et al., 2019), which has been previously linked to better date estimations (Ben Malek et al., 2017; Larsen et al., 1996). Thus, we analyse these two key phenomenological properties in relation to the dating estimation process, as spatial information may predict similar characteristics in the context of dating memories. Given that memories consisting of greater levels of spatial information were correlated with higher ratings of reliving and vividness (Rubin et al., 2019), we aim to replicate these results. Spatial information may aid in the recollection of a memory, as demonstrated by its close association with these phenomenological properties. Therefore, we seek to modify the previously established theories of date estimation by separating and introducing the key role of "spatial" as a reconstructive dating strategy.

Our study: aims and hypotheses

Given the dearth of empirical evidence examining the specific contribution of spatial information in dating autobiographical memories, we explore this novel area of memory research through the examination of dating strategies, particularly those related to spatial information. We focus on how the rememberer determines *when* to travel by investigating whether participants' confidence in their dating of memories and their stated dating strategies are related to also remembering spatial information about the event. Thus, note that we are not evaluating the *accuracy* of dating when a memory occurred but instead, we are interested in the extent to which spatial information bolstered people's confidence in deciding when an event occurred. As such, we conducted two studies in which undergraduate participants recalled four autobiographical memories each, rated memory characteristics, dated the memories, and rated confidence in their dating of the memories. During the second study, participants also explained how they dated their memories. Both studies were approved by the Claremont McKenna College Institutional Review Board and the York College of Pennsylvania Institutional Review Board for ethically conducted research with human participants.

We had three main aims that are associated with three *a priori* hypotheses.

First (Aim 1), we aimed to explore what might drive participants' confidence in their dating of memories, with a specific focus on whether spatial information was brought to bear when determining dating confidence. This gave rise to Hypothesis 1: Given the importance of spatial information for mental time travel and event memories, participants' confidence in their dating of memories would significantly predict how well they remembered the event's spatial layout, above and beyond the predictive

power of other characteristics such as emotional intensity or knowing the contents of a memory (Study 1 and 2). Although not a specific *a priori* hypothesis, we also explored the lack of significant effect of temporal specificity on dating confidence because we had expected that events that had only happened once would be more confidently dated than those that happened multiple times, as location is unique to single events but shared by general events.

Second (Aim 2), given that components of mental time travel have been previously linked to better date estimations (Ben Malek et al., 2017; Larsen et al., 1996), we sought to replicate our previous work on mental scene construction (Rubin et al., 2019) that demonstrated a relationship between an event's spatial layout and one's ability to mentally time travel while remembering. Specifically (Hypothesis 2), we predicted that participants' sense of reliving and vividness while remembering would be positively related to how well they remembered the event's spatial layout (Study 1 and 2).

Finally, (Aim 3), we sought to replicate and extend prior work on date reconstruction strategies (Ben Malek et al., 2017; Bohn & Habermas, 2016; Brown et al., 2016; Burt, 2008; Janssen et al., 2006; Shum, 1998; Skowronski et al., 1995) by investigating whether participants would utilise spatial information to date their memories in addition to previously well-established strategies such as lifetime periods or temporal landmarks. Specifically, we predicted (Hypothesis 3) that participants would explicitly use a "spatial" strategy, which encompasses the importance of layout, location, and scene construction (Rubin et al., 2019; Rubin & Umanath, 2015) in dating autobiographical memories (Study 2).

Study 1

Method

Participants

A total of 160 participants signed up for the online study through their college's introductory psychology participant pool for course credit, but 9 were removed for taking more than 1 h to complete the study (indicating they were multitasking or otherwise not fully attending to the task) or rating two or more memories with the same numerical rating on all Likert scales. The sample analysed is composed of 151 undergraduate students from York College of Pennsylvania ($n = 101$) and Claremont McKenna College ($n = 50$) who provided four memories each (the online survey required a response to all four prompts). Table 1 shows complete demographics information. *a priori*, sample size was determined using a power analysis for a stepwise multiple regression with small effect size of the predictor of interest, calculated by G*Power 3.1 (Faul et al., 2007); our target *N* was 163 participants for a total of 652 memories.

Table 1. Demographics information.

	Study 1	Study 2
N	151	141
YCP	101	87
CMC	50	54
Age *M* (*SD*)	18.97 (1.15)	18.79 (1.03)
Gender *n* (%)		
Male	48 (31.8)	43 (30.5)
Female	99 (65.6)	96 (68.1)
Another gender	1 (0.7)	0 (0)
Did not report	3 (2.0)	2 (1.4)

Note: YCP stands for York College of Pennsylvania. CMC stands for Claremont McKenna College.

Materials and measures

Cues. To cue memories of specific events that would vary in emotionality and temporal specificity, we selected four concrete nouns quasi-randomly from a list compiled by Rubin (1980): lake, friend, candy, and fire. We opted for concrete nouns to increase the likelihood that participants would remember specific events that had happened to them, as opposed to general lifetime periods or feelings (Clark, 1973).

Autobiographical memory questionnaire (AMQ). We modified the original Autobiographical Memory Questionnaire (AMQ; Rubin et al., 2003) to include measures from our previous work (Rubin et al., 2019) examining spatial information and reliving. Specifically, we utilised multiple rating scales of spatial layout and setting name, as well as reliving and vividness measures for conceptual replication of that work (see Table 2). Given our interest in the dating of autobiographical memories, we asked participants to indicate separately the day, month, and year that the event occurred. Critically, they also rated their confidence in each of those estimates. Participants were told to guess the date if they did not know, and put "1" for the day if they thought it was the beginning of the month, "15" for the middle, and "30" for the end. Furthermore, because the frequency of an event's occurrence may impact their ability to confidently date their specific memory, we also asked them to rate how often the event occurred and the degree to which it was a general (happened often) versus specific (happened once) event in their lives. Replicating our prior analytical method (Rubin et al., 2019), we created composite variables for reliving ($\alpha = .86$), vividness ($\alpha = .85$), layout ($\alpha = .82$), content ($\alpha = .71$), and temporal specificity ($\alpha = .58$) by averaging together the items corresponding to each construct (see Table 3). We also created a composite for date confidence by averaging each participant's confidence in their month, day, and year estimates ($\alpha = .83$).

Procedure

Participants accessed the survey through Qualtrics (Provo, Utah, USA). After participants provided consent, they were cued with a word and asked to provide an autobiographical memory elicited by that cue (Crovitz & Schiffman, 1974; Galton, 1879) with explicit instructions that "This memory

Table 2. Autobiographical memory questionnaire.

Items
Date Confidence
How confident are you in this answer? [1 (not at all) to 7 (extremely confident)]; Asked separately for month, day, and year; these ratings were then averaged to create composite score
Reliving
Living Again: While remembering, it is as if I am living the occurrence again. [All reliving items: 1 (not at all) to 7 (as if it were happening now)]
Time Travel: While remembering, it is as if I am mentally travelling back to the time and place of the occurrence.
Same Feelings: While remembering, it is as if I am experiencing the same feelings, emotions, and/or atmosphere again.
Vividness
See: While remembering, I can see everything in my mind. [All vividness items: 1 (not at all) to 7 (as vivid as if it were happening now)]
Vivid: While remembering, the actions, objects, and/or people that are involved in the memory are as clear now as they were when the event occurred.
Layout
Setting Layout: While remembering, I experience a scene in which the elements of the setting are located relative to each other in space. [Rated from 1(not at all spatially organised) to 7(a clear spatial layout)]
Event Layout: As I remember, I can describe *where* the actions, objects, and/or people are located in the memory. [Rated from 1 (not at all) to 7 (as if it were happening now)]
Content
Setting Name: While remembering, I can identify or name the setting where the memory occurred, although I might not be able to describe it clearly. [Setting name and event contents rated from 1(not at all) to 7 (definitely)]
Event Content: As I remember, I can identify the actions, objects, and/or people that are involved in the memory, though I may not be able to clearly say where they are in relation to each other.
Emotion
Valence: How positive or negative is this memory? [1(extremely negative) to 4(neutral) to 7(extremely positive)]
Intensity: While remembering, the emotions I feel are intense. [1(not at all) to 7(extremely)]
Temporal Specificity
Less Often: How often has this event or something very similar to it occurred in your life? [1(not at all) to 7(very often); reversed scored for congruence with *Single Event*]
Single Event: The memory is of a general situation that happened many times in my life, rather than of a specific occurrence with its own details that let me know the memory was of a single event. [1(definitely a general class of events)] to 7(definitely a specific event)]

should be of a *specific event that happened to you at one point in time*." Participants provided a brief phrase to describe the event they recalled. They repeated this cuing and nominating of memories four times, providing a new, specific event each time.

Once they provided all four memories, participants completed the AMQ for each memory. The brief phrase they had provided during the cuing phase was used to remind them of the events they had nominated. Participants then responded to demographics questions.

Analytical method. For all statistical tests described below, we used a critical *p*-value of 0.05. Because participants were screened for inclusion in the dataset (see Participants section), each participant provided four memories rated on the AMQ.

Because of nesting in our data (four Level 1 memories nested within each of our Level 2 participants), we utilised multilevel modelling[1] using SPSS Mixed and maximum likelihood estimation (to allow for model comparison) to test Hypotheses 1 (layout predicts dating confidence) and 2 (layout predicts reliving and vividness). Because our survey protocol required participants to respond to and rate each of the four memories, there was no missing data. For each of the three dependent variables, null models with three parameters (fixed intercept, random intercept, and residual) revealed that similarity within participants should be accounted for through MLM, Wald's Z's ≥ 4.45, p's $< .001$, ICC $\geq .24$. All predictors were group-mean centred to control for individual differences (Heck et al., 2014; Radenbush & Bryk, 2002), as these were not the focus of our current investigation. The full models contained fixed effects for all predictors plus the null model parameters. The size of the effect of a predictor, or the proportion of unique variance accounted for by each significant predictor, was quantified as a ΔR^2_w, calculated by comparing the full model to a "covariate model" that did not contain that predictor; this can be interpreted as a semi-squared partial correlation. Model parameters and fit indices are reported in Table 4.

Table 3. Descriptive statistics for autobiographical memory questionnaire.

	Study 1		Study 2	
Properties	*M*	(*SD*)	*M*	(*SD*)
Date confidence	4.50	(1.91)	4.46	(1.89)
Month conf.	4.86	(2.25)	4.79	(2.21)
Day conf.	3.68	(2.30)	3.62	(2.29)
Year conf.	4.97	(2.12)	4.96	(2.11)
Reliving	4.64	(1.58)	4.37	(1.51)
Living again	4.47	(1.84)	4.24	(1.70)
Time travel	4.88	(1.67)	4.65	(1.64)
Same feelings	4.56	(1.86)	4.20	(1.75)
Vividness	4.89	(1.58)	4.45	(1.59)
See	4.96	(1.65)	4.68	(1.68)
Vivid	4.81	(1.75)	4.22	(1.74)
Spatial	5.09	(1.57)	4.62	(1.48)
Setting layout	5.10	(1.74)	4.70	(1.64)
Event layout	5.08	(1.67)	4.53	(1.62)
Content	5.50	(1.42)	5.23	(1.48)
Setting name	5.77	(1.58)	5.52	(1.69)
Event content	5.24	(1.64)	4.95	(1.65)
Valence	5.17	(1.85)	5.34	(1.66)
Intensity	3.99	(1.98)	3.81	(1.86)
Specific	4.67	(1.81)	4.61	(1.69)
Less often[a]	4.50	(2.10)	4.42	(1.95)
Single event	4.84	(2.20)	4.80	(2.12)
Age of memory[b]	81.33	(2.57)	81.67	(2.65)

Note. Study 1: $n = 604$ separate memories from 151 participants. Study 2: $n = 564$ memories from 141 participants.

[a]*Less Often* variable was reverse-scored.

[b]*Age of Memory* is reported in months and was calculated by subtracting the estimated date of the memory from the date that the participant completed the study.

Study 1 Range: 255 (Min = 0; Max = 255); Study 2 Range: 237 (Min = 0; Max = 237).

Results and discussion

Data and supplementary MLM information for this and subsequent studies are available online at https://osf.io/yfxbq/?view_only=06c37f26fc9c47c9888ef629b8c908d8.

Table 4. Multilevel models predicting confidence in date, reliving, and vividness.

	Dating confidence			Reliving			Vividness		
Predictors	*B* (*SE*)	Δ-2LL	ΔR^2_W	*B* (*SE*)	Δ-2LL	ΔR^2_W	*B* (*SE*)	Δ-2LL	ΔR^2_W
Study 1									
Layout	.33 (.08)***	17.93	.04	.42 (.04)***	104.74	.21	.44 (.04)***	105.71	.21
Content	.15 (.09)			.18 (.04)***	16.19	.04	.39 (.05)***	69.84	.05
Intensity	.06 (.05)			.30 (.03)***	116.57	.23	.13 (.03)***	23.76	.05
Valence	.17 (.04)***	14.40	.03	.05 (.02)*	5.37	.01	-.01 (.02)		
Temp. Specific	-.02 (.05)			.01 (.02)			.02 (.02)		
Study 2									
Layout	.25 (.07)***	11.51	.03	.32 (.04)***	72.05	.16	.56 (.04)***	175.49	.34
Content	.36 (.07)***	24.17	.06	.23 (.04)***	39.02	.09	.20 (.04)***	28.29	.06
Intensity	.14 (.06)*	6.54	.02	.31 (.03)***	115.17	.24	.16 (.03)***	27.57	.06
Valence	.14 (.05)**	9.26	.02	.05 (.02)*	4.76	.01	.03 (.02)		
Temp. specific	.00 (.05)			.02 (.02)			.02 (.02)		

Note. *$p < .05$, **$p < .01$, ***$p < .001$. Models computed using SPSS Mixed. Full Models (8 parameters: fixed effects for all predictors, fixed intercept, random intercept, and residual) reported here. Δ-2LL and ΔR^2_W (Radenbush & Bryk, 2002) computed by comparing covariate model not containing the significant predictor (e.g., 7 parmeters) to the full model. Δ-2LL is interpret here as a χ^2 test with 1 *df*. ΔR^2_{within} represents change in variance accounted for by predictor at the memory-level, controlling for other predictors.

We first addressed Aim 1 by directly testing Hypothesis 1 that spatial layout would predict average confidence in date, even when controlling for other measures such as basic details or emotional characteristics of the memory. We used multilevel modelling; the descriptive statistics for the AMQ are reported in Table 3. All predictors were entered into the Full Model; the statistical significance, effect size, and variance explained by a given predictor were established through comparison with a Covariate Model that did not contain that predictor. Spatial layout significantly predicted variance in dating confidence, above and beyond the variance explained by other predictors, $\chi^2(1) = 17.93$, $p < .001$. The final model, with all predictors entered in the Full model, is shown in Table 4. The proportions of variance in dating confidence uniquely predicted by a given variable for this final model ($\Delta R_w{}^2$) indicate that spatial layout and valence are the *best* unique predictors of dating confidence in the model. Therefore, spatial information is important to consider when examining how individuals place their events not only in space but also in time. In other words, when mentally time travelling and confidently dating one's memories, the location in which an event occurred offers an important piece of information to reason one's way to the date of occurrence.

After confirming Hypothesis 1, we further explored Aim 1 by considering the lack of significant result for temporal specificity. Initially, we expected that temporally specific events would be more confidently dated than general events because location is unique to single events but shared by general events (therefore making it more difficult to use location to determine the date of a repeated event). The lack of significance of temporal specificity was not due to the inclusion of predictably dated holiday events cued by "candy", as separate multiple regressions computed for each cue word did not reveal a significant effect of temporal specificity for any individual cue, β's range from −.02 to +.03, *p*'s > .05. To test if our lack of significant effect was replicable, we used the same cue words in Study 2. In Study 2, we also further explore the role that holidays may play in dating *other* events, as holidays serve as both temporal landmarks and also denote conventional time patterns due to their cyclical nature (Skowronski et al., 1995).

Does simple awareness of an event's location allow one to determine when it occurred, or is the spatial layout necessary? To address this more specific question related to Aim 1, we computed follow-up MLMs that entered *setting name* and *event contents* separately (previous analyses had these averaged as the composite variable *contents*), along with all other predictors, to test whether simple awareness of the setting also predicted dating confidence; neither event contents ($B = .12$, $SE = .08$) nor setting name ($B = .03$, $SE = .07$) were significant predictors, *t*(453)'s < 1.73, *p*'s > .05. Therefore, spatial layout is important for dating confidence; merely being able to identify where something took place is not.

Finally, in accordance with Aim 2, we tested Hypothesis 2 and replicated our previous work (Rubin et al., 2019) by analysing whether participant's reported degree of spatial layout predicted the higher-level phenomenological characteristics of reliving and vividness through computation of MLMs predicting reliving and vividness, respectively, with layout, content, valence, intensity, and specificity. As expected, a higher degree of spatial layout was strongly associated with both reliving and vividness while remembering (Table 4).

These higher-level phenomenological characteristics of reliving and vividness, which are likely downstream products of more basic memory components (Rubin, 2006), were strongly correlated with the confidence that individuals had when dating their memories (averaged confidence in month, day, and year; correlations with reliving and vividness were .392 and .400, respectively), which provides more ancillary support for Hypothesis 1 that confidence in the date of an event is driven in part by the spatial characteristics of the memory of the event.

To summarise, spatial layout showed unique predictive power for participants' confidence in their date estimates for events. However, the unique effect of layout alone ($\Delta R^2_W = .04$) is rather small, perhaps because other factors

Table 5. Coding of participants' descriptions of memory dating in study 2.

Code	Description	Reliability	Example
Spatial	Reference to location in any way (could include spatial layout/mental imagery about where they were)	.93	I remember exactly the date on which my friend came to visit me in New York.
Temporal landmarks[a,b]	Use of specific event to date memory for which the precise temporal location is known	.86	I remembered … the year my mother passed away in relation to this event.
Lifetime periods[a]	Use of lifetime periods or extended events for attempting to locate the event in time (includes age of self or other, grade in school, etc.)	.88	I just kind of remember it was sometime in middle school, so I estimated what years I was in Middle School.
Contextual details[a]	Use of event details, including visual components of the scene (not including spatial layout), sounds, activities, weather, particular people, and environment	.91	… I do not remember snow on the ground at the time, so I chose a month in the summer …
Conventional time patterns[a]	Dates memory based off its temporal relation to conventional time patterns (seasons, calendar dates, days of the week, externally instituted dates)	.90	It was trick-or-treat in our new neighbourhood, so it would have been a few days before Halloween, which is October 31 …
Emotion	Reference to emotional valence or intensity (specific to the participants emotions)	.97	I know exactly when this was because it was honestly heart wrenching.
Repeated events	Explicit reference to the event being a repeated occurrence	.94	We always went to the lake around the time school ended.
Recency	Explicitly refers to the event as just having happened recently	.99	It was few hours ago so I clearly remember the date
Just know[a]	Knowing the exact date of the event without use of other temporal strategies	.98	I just know for a fact it was in 2018 and in the middle of February sometime.
Guessed	Guessed when the event occurred (includes I don't know, I don't remember)	.95	I actually have no clue the date on when this event occurred …

[a]Based on Ben Malek et al., 2017.
[b]Based on Shum, 1998.
Note. Reliability calculated as correlation between two raters' responses. A third rater settled disagreements.

already identified are also contributing to confidence in date estimates. Furthermore, confidence in the date does not capture the strategies that participants may be using to date a memory. As discussed in the Introduction, prior work indicates that there are many different cues (e.g., temporal landmarks, conventional time patterns, contextual details; Ben Malek et al., 2017; Brown, 1990; Shum, 1998) that are used to reconstruct when a particular event occurred. Spatial information may predict confidence in the date decided upon, but does it also explicitly factor into people's reasoning process in determining when an event occurred (Aim 3)? In Study 2, we begin to address this critical question.

Study 2

Prior work has extensively studied how individuals organise (e.g., Brown et al., 2016; Larsen et al., 1996; Shum, 1998) and ultimately, date (e.g., Ben Malek et al., 2017; Bohn & Habermas, 2016; Brown et al., 2016; Burt, 2008; Janssen et al., 2006; Larsen et al., 1996; Shum, 1998; Skowronski et al., 1995) their autobiographical memories. However, as mentioned above, spatial information is typically integrated into other categories (particularly, as another contextual detail, Ben Malek et al., 2017; Brown, 1990; Friedman, 2004) instead of being measured separately.

Study 2 re-examines the question of how people date their event memories in the context of current theories of explicit memory (Rubin & Umanath, 2015) by investigating whether, during mental time travel, people actively use spatial cues to orient themselves not only in space but also in time. Specifically, In Study 2 we seek to (1) replicate findings related to Aims 1 and 2 in Study 1 with the same procedure and AMQ questions and (2) address Aim 3 by asking participants to describe *how* they are dating these events in an open-ended question. This second component explicitly was coded not only for those factors identified by previous researchers as important for dating events but also separated references to spatial information being used to reason through when an event occurred.

Method

Participants

One-hundred forty-one undergraduates from York College of Pennsylvania ($n = 87$) or Claremont McKenna College ($n = 54$) participated online for course credit by providing four memories each (the online survey required a response to all four prompts). Using the same removal criteria as Study 1, 12 additional participants were excluded from the dataset. Sample size was determined using the same power analysis as Study 1. Demographics are provided in Table 1.

Materials and measures

Cues. The same cues were used as in Study 1 to provide a corpus of memories varying in emotionality and temporal specificity.

Autobiographical memory questionnaire (AMQ). The same AMQ as in Study 1 was used (see Table 2), with one addition. After providing date estimates and confidence ratings for month, day, and year, participants also answered the following open-ended question: "How did you figure out when this event occurred? That is, what kinds of things did you think about to help you decide when this event happened? We are not asking you to further describe the event. Instead, we are interested in how you came up with the date that you gave above." Composite variables for reliving (α = .87), vividness (α = .84), layout (α = .79), content (α = .73), temporal specificity (α = .57), and dating confidence (α = .82), were again created by averaging the items for each subscale.

Coding of open-ended responses. To address Aim 3, a coding scheme was created to quantify the dating strategies mentioned by participants. To capture the dating strategies previously identified by other researchers, we relied heavily on the work of Ben Malek et al. (2017) and Shum (1998), both of which focused on the role of temporal landmarks and lifetime periods (Ben Malek et al., 2017; Shum, 1998). It is important to acknowledge that although we relied on these two sources to create the coding scheme, these concepts also have roots in the work of others (e.g., Brown et al., 2016; Conway, 1996; Friedman, 2004). Table 5 contains the codes used, their definitions, inter-rater reliabilities (i.e., correlation between raters), and examples of responses related to each code. Specifically, *temporal landmarks* was based on Shum's (1998) work defining "landmark events" as personal reference points within one's timeline of personal memories that help one determine the dates of other, nearby events; this strategy was also addressed by Ben Malek et al. (2017). From Ben Malek et al. (2017) coding scheme, we included *lifetime periods*, *just know* [referred to by Ben Malek et al. (2017) as "direct event dating" and also related to Friedman's (2004) properties of memory for time], *conventional time patterns,* and *guessed* (referred to by Ben Malek et al., 2017 as "uncategorised").

We then modified Ben Malek et al.'s (2017) code of *contextual details* by removing mention of the use of spatial information, as the main focus of this study was to isolate the role of spatial cues. Spatial information was coded as *spatial;* the use of any non-spatial mental imagery was considered as contextual details.

In addition, based on the responses participants provided and the patterns of data from Study 1, we developed a few other codes:

Recency refers to participants' awareness of a date because it had just happened; this strategy was a by-product of our study design, whereby the cues sometimes elicited very recent memories for participants.

Emotion was added as a possible dating strategy because of the predictive power of valence and intensity in Study 1 when exploring confidence in date.

Repeated events was created to elucidate why participants' dating confidence was not related to their rated temporal specificity of an event. Additionally, repeated events play a role more globally in event memory (Rubin & Umanath, 2015) and are not always temporal landmarks or repeated cyclically (like a conventional time period).

Two of the authors (MI & MV), who helped to develop the coding scheme, rated each response as referencing or not referencing a particular dating strategy. Because multiple strategies could be used to date memories, each response could have more than one code. For example, a participant might write "This event occurred while we still lived on *Walnut Street* (spatial) but *before Barack Obama was elected* (temporal landmark)." The corpus of responses was rated for one type of information at a time (e.g., all responses were rated on whether each contained spatial information; next, they were rated on whether they contained information about lifetime periods). After the coders each rated a dimension fully across all memories, the memory order was resorted before coders began coding the next dimension. An initial random subset of 30 responses was used to established inter-rater reliability; the correlation between the two raters was very high ($r = .933$) for these 30 responses. Disagreements were discussed and the coding scheme was revised before coding the rest of the responses (the 30 responses in the initial subset were coded again given the updated coding scheme). Final reliability between raters (correlation between raters; shown in Table 5) was high for all codes. Discrepancies were resolved by the last author (SU).[2]

Procedure

The procedure was identical to Study 1, but with the additional open-ended question described above.

Analytical method. For all statistical tests described below, we used a critical *p*-value of 0.05. Because participants were screened for inclusion in the dataset (see Participants section), each participant provided four memories rated on the AMQ.

A MLM framework was again used to account for nesting, with the same procedure and models computed as in Study 1 to investigate Aims 1 and 2; computation of the null models revealed this approach was necessary due to similarity within participants, Wald's $Z \geq 3.14$, p's < .001, ICC's > .14.

Results and discussion

Replication of study 1

We first set out to confirm our main result of Study 1, which aligned with Aim 1 and provided evidence for Hypothesis 1 by showing that spatial layout while remembering predicts confidence in participants' date estimates for the event. As was done in Study 1, we used MLM. The full model is reported in Table 4 along with the unique variance explained by significant predictors (calculated by comparison with a Covariate Model not containing that predictor). Spatial layout again significantly predicted variance in dating confidence, above and beyond the variance explained by other predictors, $\Delta R^2_w = .03$. The significant effect of valence was also replicated, $\Delta R^2_w = .02$, and, contrary to Study 1, a significant effect of content, $\Delta R^2_w = .06$ and intensity, $\Delta R^2_w = .02$, was also found. Although spatial layout and valence were not the "best" predictors of dating confidence when examining the ΔR^2_w for each parameter, they were the only predictors that were consistently significant across both studies. Affirming Hypothesis 1, spatial layout is utilised when assessing the confidence one has in a dating estimate. Temporal specificity was again not a significant predictor of confidence; this result gives credence to the idea that some repeated events might be very easy to date whereas others might be difficult. In other words, temporal specificity might not function uniformly with singular events always being easier to date, perhaps because single events may have fewer memory traces or potential cues.

Once again, we also tested Hypothesis 2 and replicated our previous work (Rubin et al., 2019) by demonstrating the role of spatial layout in reliving and vividness of autobiographical memory (Table 4).

As mentioned above, the multilevel models predicting confidence in date estimates provide important evidence that spatial information may be used by individuals to date their memories. However, these AMQ data do not capture the process by which individuals come to determine the date of their memories. To further explore the role that spatial information plays in dating events, we also analysed participants' open-ended responses explaining how they dated each memory they provided in an investigation of Aim 3.

Analysis of open-ended responses

We coded participants' open-ended response explanations of how they dated their memories for references to several different dating strategies. The percentages of explanations referencing these strategies are provided in Figure 1. In line with the work of other researchers (Ben Malek et al., 2017; Brown, 2016; Shum, 1998; Skowronski et al., 1995), our participants referenced temporal landmarks, lifetime periods, and conventional time patterns relatively often when dating their memories – these dating strategies were each referenced in over 30% of the dating explanations. Of greatest interest to the current investigation was a test of Hypothesis 3 that spatial information, including the place of occurrence, would be referenced as a dating strategy. Again, in previous work (Ben Malek et al., 2017; Brown, 1990; Shum, 1998) this information has been subsumed within "contextual details." Now, when separately considered, "spatial" was referenced as a dating strategy in 26.6% of responses. Thus, on its own, spatial information plays an important role in the dating of autobiographical memories and should be considered separately from other contextual details, which were referenced in 22.5% of memories. Only 8.3% of responses referenced both of these strategies.

The raw percentages of individuals utilising a given dating strategy do not fully investigate Aim 3, nor does it capture the importance of a given dating strategy. For example, was spatial information a unique source of dating information, or was it likely to be used in concert with other dating strategies? We first examined how many different dating strategies participants used and found that participants utilised an average of 2.09 ($SE = .05$; Range = 6; Min = 0; Max = 6) strategies while dating their memories. Interestingly, the more strategies that a person used, the less confidence they had in their date estimates, as evidenced by a small negative correlation with average dating confidence, $r = -.117$, $p = .005$, particularly driven to confidence in day, $r = -.134$, $p = .001$ and year, $r = -.134$, $p = .001$. As shown in Table 6, there was a small negative correlation between the number of strategies and the recency strategy, suggesting that other dating strategies are not necessary when an event is recent. Use of the strategies of temporal landmarks, contextual details, lifetime periods, conventional time patterns, repeated event, or spatial was moderately positively correlated with the total number of strategies a person used; in other words, participants often used multiple dating strategies to determine when an event occurred.

Were certain strategies more likely to be used in concert? To answer this question, we computed the Pearson r correlation coefficients between the different dating strategies; larger positive correlations indicate that two strategies were likely to be used together. The significance of the correlation values was determined using a p-value of .006 (Bonferroni correction for 9 comparisons). A matrix of correlation coefficients is reported in Table 6. Overall, the dating strategies were not strongly correlated, which suggests that participants were not systematically using the same dating strategies for a given event. The clearest pattern was for recency. Supporting the idea that recency as a dating strategy requires no additional strategies, recency was negatively correlated with the temporal landmarks, contextual details, lifetime periods, and conventional time patterns dating strategies; when participants noted that an event happened recently, they were less likely to use these other strategies. For the

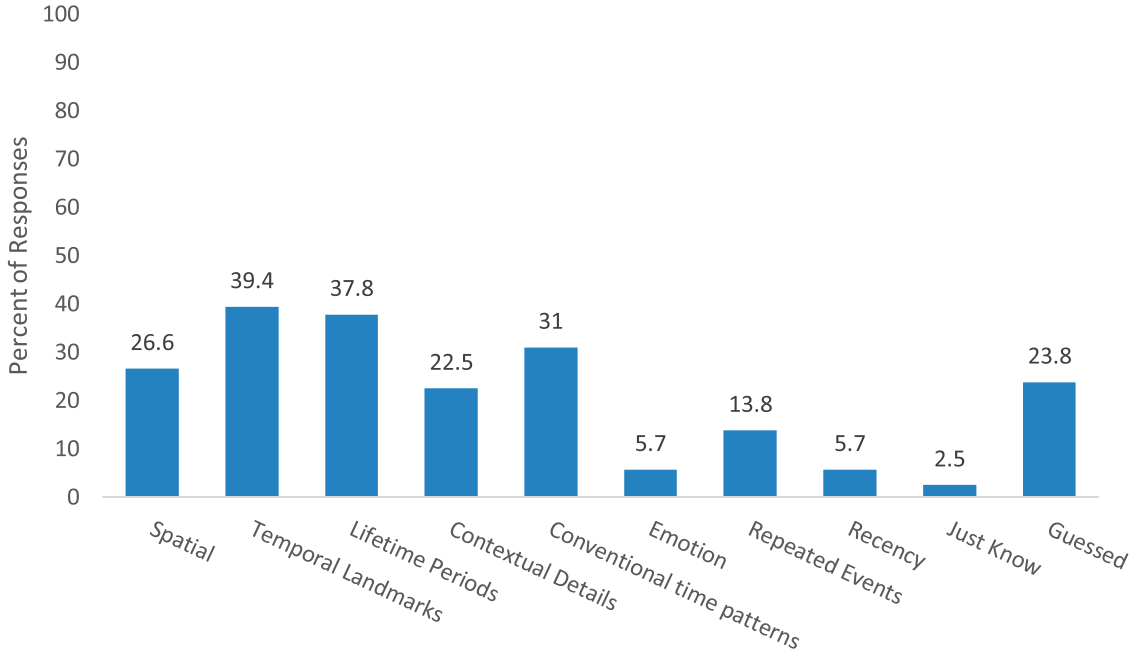

Figure 1. Percent of responses referencing each dating strategy.

spatial strategy, participants were also likely to utilise temporal landmarks and other contextual details while dating, as evidenced by small but significant positive correlations of .123 and .127, respectively (although, as noted above, only 8.3% of responses showed evidence of both the spatial and contextual details strategies). They were also likely to say that an event was a repeated event while using a spatial strategy, $r = .108$. To be clear, these correlations are small (less than .200); their size suggests that, although there is some overlap in strategy, these strategies present unique sources of information that participants are not systematically combining when dating their memories.

In alignment with Aims 1 and 3 and given the role of spatial information for self-reported confidence in date, we next examined the relationship between the use of a spatial dating strategy and reported confidence in an event's date by computing an independent samples *t*-test with the mere presence or absence of a spatial dating strategy as the independent variable and average confidence in date as the dependent variable. The results of this analysis were not significant.[3] Confidence ratings when participants mentioned using a spatial strategy ($M = 4.53$; $SE = .14$) were no higher than ratings when participants did not mention a spatial strategy ($M = 4.43$; $SE = .10$). Remembering spatial information (some of which was likely cued by the AMQ questions) is different than explicitly noting spatial information is a dating strategy. Furthermore, an individual's confidence in an estimated date is, as noted above, not the same as actually (accurately) dating an event.

To extend others' prior work (Aim 3; e.g., Ben Malek et al., 2017), we also investigated the relationship between participants' other dating strategies and average confidence in date by computing additional independent samples *t*-tests.[4] As with the correlational analysis, we corrected for familywise error by adjusting the critical *p*-value using a Bonferroni correction ($p_{crit} = .006$). Participants that utilised lifetime periods as a dating strategy were less confident on average ($M = 3.78$, $SE = .12$) in their dating estimates than participants who did not ($M = 4.87$; $SE = .10$), $t(488.25) = 7.07$, $p < .001$; $d = .60$. The

Table 6. Correlations between dating strategies.

	# of strategies	1	2	3	4	5	6	7	8	9
1 Spatial	.473***									
2 Temporal Landmarks	.258***	.123*								
3 Lifetime Periods	.461***	.028	−.096							
4 Contextual Details	.350***	.127*	−.061	.070						
5 Conventional Time Patterns	.497***	.056	−.109	.173***	.033					
6 Emotions	.087	−.061	−.025	−.001	−.004	−.049				
7 Repeated	.319***	.108*	−.028	−.047	−.019	.109	−.032			
8 Recency	−.137**	−.044	−.151**	−.191***	−.114	−.115	−.060	−.098		
9 Just Know	−.032	−.044	−.082	−.101	−.086	−.082	−.039	−.064	−.039	
10 Guessed	.317***	−.119	−.134*	.124*	−.091	.139**	−.083	.030	−.119*	.072

Note. Bonferroni correction for multiple comparisons applied to critical *p*-value. *$p < .005$, **$p < .001$, ***$p < .0001$.

opposite pattern emerged when comparing participants who used temporal landmarks ($M = 5.00$; $SE = 1.55$) compared to those who did not ($M = 4.10$; $SE = 2.01$), $t(546.04) = 6.00$, $p < .001$; $d = .50$, and, not surprisingly, those participants who reported that an event was recent ($M = 6.40$; $SE = .21$) compared to those who did not ($M = 4.34$; $SE = .08$), $t(41.02) = 9.20$, $p < .001$; $d = 1.32$. Also not surprisingly, participants who reported guessing the date of an event ($M = 3.15$; $SE = .14$) were less confident overall than those who did not ($M = 4.87$; $SE = .09$), $t(562) = 9.91$, $p < .001$; $d = 1.00$. No other comparisons were significant.

General discussion

Remembering autobiographical events often involves estimating the date of occurrence using several different reconstructive strategies (Ben Malek et al., 2017; Brown, 1990), as well as experiences of reliving, vividness, and belief, which are known to be driven by the degree of spatial information contained within the memory (Rubin et al., 2019). Previous work examining how individuals date events did not focus on spatial information as a potentially important strategy in dating memories, in part because theory and supporting research establishing spatial information as an important basis for event memory and driver of related phenomenological processes (Rubin et al., 2019; Rubin & Umanath, 2015) had not yet been completed. Here, we establish in two studies that spatial information helps individuals to determine when an event occurred and feel confident in their date estimate. We confirmed our hypotheses related to the dating of autobiographical memories: (1) given the importance of spatial information for mental time travel, participants' confidence in their dating of memories was predicted by how well they remembered the event's spatial layout (Aim 1; Study 1 and 2); and (2) in addition to well-established date reconstruction strategies (Ben Malek et al., 2017; Bohn & Habermas, 2016; Brown et al., 2016; Burt, 2008; Janssen et al., 2006; Shum, 1998; Skowronski et al., 1995), participants also use a "spatial" strategy, which encompasses the importance of layout, location, and scene construction (Rubin et al., 2019; Rubin & Umanath, 2015) in dating autobiographical memories (Aim 3; Study 2). We explore the implications of these two key results in turn below.

In two separate studies, spatial layout, as measured by the AMQ, predicted variance in participants' confidence in their date estimates. These significant results were found despite variability in temporal specificity and potential differences across memories cued by different words. Memory of the spatial layout of a remembered scene not only locates a person in an event memory (Berntsen & Rubin, 2006; Butler et al., 2016; McIsaac & Eich, 2002; Nigro & Neisser, 1983; Rice & Rubin, 2011), but also appears to help locate that individual in time. Prior work (Rubin et al., 2019), replicated here (Aim 2), already established the privileged role of spatial information in driving the phenomenological properties of reliving, vividness, and belief in the accuracy of an event memory. Constructing a scene using spatial information underlies phenomenological properties that serve as evidence that an event was experienced as remembered and should therefore be believed (Rubin & Umanath, 2015). Detailed scene reconstruction was closely associated with confidence in date; simply identifying the name of the setting in which the event occurred was not sufficient for confident date estimates, nor did the temporal specificity of the event matter (perhaps because individuals often recall multiple events of the same type as if they were a single event; Rubin & Umanath, 2015). Spatial information drives detailed scene construction, which in turn supports belief not just in its veracity, but also in confidence for its estimated date of occurrence.

Self-reported confidence in a date estimate, however, does not directly measure whether or not one consciously utilises spatial information when determining the date of occurrence. Perhaps spatial information triggers the use of other reconstructive strategies, but does not serve as an independent source of information when determining the date that an event occurred. We expand upon previous work (e.g., Ben Malek et al., 2017; Brown et al., 2016; Friedman, 2004; Shum, 1998) on dating memories by amending and adding onto previous coding schemes to include an explicit focus on spatial information as a potential dating strategy.

Using participants' explanations of how they dated their memories, we examined which strategies they used to determine the date. Given previous work (Ben Malek et al., 2017; Brown et al., 2016; Friedman, 2004; Shum, 1998), we expected to find that landmark events, lifetime periods, and conventional time patterns would be the most frequent strategies used; we confirmed this finding (Figure 1). Differing from prior work (e.g., Ben Malek et al., 2017), we coded "spatial" separately from other contextual details. Our results add to the existing literature with a novel finding: People use spatial information separately from other contextual details and other strategies to determine the date when an event occurred. Our newly-coded "spatial" dating strategy was a frequent dating strategy (used by participants 26.6% of the time) that was utilised independently from other contextual details, with which it had previously been aggregated (Ben Malek et al., 2017, p. 1406 shows roughly 20% of responses used a broader "contextual details" as a dating strategy; this included information about location). Given that there was little overlap between spatial and contextual details as dating strategies (only 8.3% of responses used both), these two strategies should be considered separately going forward, similar to how spatial information should be considered independently from memory contents when analysing phenomenology of autobiographical memories (Rubin et al., 2019).

Memory of *where* an event occurs may help to determine *when* that event occurs, perhaps because the location of an event triggers other event components, including temporal information (Brown, 1990, 2016), while also providing information about where that event fits in the timeline of one's life. Location may also cue the use of other reconstructive dating strategies, such as lifetime periods, conventional time patterns, or temporal landmarks (e.g., Ben Malek et al., 2017; Brown, 2016; Friedman, 2004; Larsen et al., 1996). For example, the first author has a vivid memory of her father entering the family backyard with a new puppy one summer. To determine *when* this event occurred, she draws on three sources of information: (1) it occurred in the backyard of the house (*location*) she lived in from ages 4–18 (*lifetime period*); (2) there is no pool in the backyard (*spatial layout*), indicating it happened before the pool was installed (*temporal landmark*); (3) her brother was not born yet (*temporal landmark*). These three sources of information help to confidently pinpoint the event as occurring in the summer of 1994; without the setting and spatial information, the remaining source of information would locate the event as occurring before the birth of her brother, but, given their age gap, would not provide sufficient information to confidently date the event. Instead, the location allows for the identification of a lifetime period and the spatial information helps to identify a temporal landmark. For some other events, location (or, *re*-location during a transition, Brown, 2016) and other spatial information may mark the beginning or end of a lifetime period by signalling a transitional event or other temporal landmark (Bohn & Habermas, 2016; Brown, 2016; Brown et al., 2016; Larsen et al., 1996; Shum, 1998).

If, however, spatial information typically triggers the recall of other dating strategies, we expected to find several indications of a connection between strategies that were not present in the current set of studies. Although many strategies were used together, as shown by the correlations between the total number of strategies and the individual strategies, no clear pattern of strategy "sets" emerged. This may be because such a connection is not present or due to the limitations of our design, which asked participants to explain their own reasoning. Individuals are often unaware of their own memory processes (e.g., Talarico & Rubin, 2003); dating of memories could happen, at least in part, unconsciously, meaning that participants' responses do not fully capture how dating occurs. Additionally, dating an event may lead to an attenuation of search as, once the goal is satisfied (i.e., the date is determined), the use of further dating strategies is unwarranted.

There are likely also individual differences in how people date events. Previous research has demonstrated that individuals vary in the qualities of their autobiographical memories (Berntsen et al., 2019; Rubin, 2021; Sheldon et al., 2016). More specifically focusing on the use of spatial information, detailed scene construction is a stable individual difference (Rubin, 2020), and people differ on their use of spatial imagery during remembering and subsequently, how vivid and detailed their memories are (e.g., Hebscher et al., 2018; Sheldon et al., 2017). Further investigation of people's tendencies to rely on spatial-based dating strategies across event types could elucidate whether dating strategies also vary between-subjects, perhaps through more targeted questions asking participants if and how they use spatial information to date their memories, or think-aloud dating protocols (e.g., Brown et al., 2016) analysed at the person-level.

Further exploration is also needed to determine the relationship between dating strategies and confidence in date estimate. Despite a relationship between spatial layout, as measured by the AMQ, and dating confidence, we found no relationship between reports of the spatial dating strategy and participants' confidence in their date estimate. Additionally, our results show that use of lifetime periods to date events were associated with less overall confidence in one's date estimate, as measured by aggregating confidence in day, month, and year. Given that lifetime periods are typically longer periods of time, it is likely hard to pinpoint an exact day, month, and/or year an event within that period occurred. However, this result is counter to that of Ben Malek et al. (2017), who measured dating certainty using a 7-pt Likert scale and found no relationship between dating using lifetime periods and dating certainty. Research on dating accuracy (Skowronski et al., 1995) demonstrates a relationship between use of lifetime periods to date and accuracy. It is possible that confidence and accuracy could be linked here as well, with individuals relying on lifetime periods suspecting they are less accurate, which is reflected in their confidence ratings.

Confidence in the date, however, is not accuracy about the date. This disconnect between confidence and accuracy in memory has been demonstrated quite starkly in prior work on flashbulb memories, wherein participants' confidence in their memories' accuracy remained quite high despite their actual accuracy declining precipitously (Talarico & Rubin, 2003). Because we were interested primarily in the phenomenological characteristics related to dating event memories, we focused on confidence in date estimates as well as participants' reported strategies to determine the date of occurrence. Given our research method, an examination of accuracy is not possible here (nor is it necessarily warranted, given the rich history of examining autobiographical memory using cues to elicit reconstructed memories; see Rubin, 2005, for a review). Because spatial information may drive a number of different memory properties, a logical future extension would be to examine the relationship between spatial information and the accuracy of a date estimate, as well as how other dating strategies could influence accuracy. Use of "prototypic information," or

knowledge, is associated with dating accuracy (Skowronski et al., 1995); as such, spatial information may be a type of specific knowledge that aids in accurate recall of a date. The accuracy of dating events is higher for events that are well-remembered, including those that produce high mental involvement (Betz & Skowronski, 1997; Friedman, 2004), which could include reliving and vividness. These two phenomenological properties are linked to the recall of spatial information, suggesting then that spatial information may support accurate dating of event memories.

Limitations and future directions

Although the present work provides evidence for the important role of spatial information in the process of and confidence in dating memories, there are limitations in our design that we hope will be addressed in future research. First, future research should aim to replicate the current findings with different and more diverse sets of cue words for generating memories to obtain a wider subset of observations. It is plausible that our selection of cue words may have influenced the results and prompted the recall of a specific subset of emotional memories. For example, the cue word, "candy," may have elicited more holiday-related memories related to Halloween or Christmas, which could possibly influence the frequency with which certain dating processes were used. Furthermore, several studies have shown that events cued by affective or emotional words tend to be more recent (Fitzgerald, 1980, p. 1981; Fitzgerald & Lawrence, 1984; Maki et al., 2013; Robinson, 1976; Rubin, 1982) and have longer response latencies (Fitzgerald, 1981; Fitzgerald & Lawrence, 1984; Robinson, 1976; Rubin, 1982). Moreover, Maki et al. (2013) found that the type of cue word (neutral, emotion-provoking, and emotional) can affect the phenomenological ratings of the recalled memories with events cued with both emotional and emotion-provoking words resulting in significantly higher ratings on every item on the AMQ except for *real/imaginary* and *see*, indicating stronger belief in the accuracy of the memory, memory components, and recollective experience than events cued by neutral words. Given the evidence suggesting an association between the amount of spatial information in a memory and its phenomenological properties (Rubin et al., 2019), it is possible that one or more of the cue words used in the current study elicited memories with stronger phenomenological properties and a higher degree of spatial information.

Future work can also explore the relationship between spatial layout and accuracy in dating memories. Accuracy was not a core variable of interest in the present studies, but research on accuracy in relation to the type of strategy used and confidence in dating a memory can build our understanding of how the type of strategy, specifically the use of spatial information, may play a role in both the subjective (confidence) and objective measures of accuracy.

Finally, future work can consider the perhaps critical role of spatial layout in dating memories in the context of the COVID-19 global pandemic. More than ever, there is an opportunity to observe how spatial information contributes to the dating of memories. People changed location less often during the pandemic as they worked from home and reduced local, national, and international travel. With these changes to daily life, spatial information, in some ways, is essentially controlled for or severely reduced compared to pre-pandemic life; this lack of location-based transitions could have implications for dating events.

Theoretical implications

As discussed in the Introduction, the way in which we date our memories has been understood via multiple theories: distance, order, and location, the last of which is most relevant to the current studies (Friedman, 1993, 2004; Janssen et al., 2006). Though the results of our current studies do not allow us to draw conclusions about the validity of distance and order theories, our findings do provide support for location theories, which can be classified as time-tagging or reconstructive (Ben Malek et al., 2017; Friedman, 1993, 2004). Our "just know" dating strategy provides some support for time-tagging theories, as participants reported simply knowing the exact date of the event without the use of other temporal strategies. However, this strategy was used the least often, indicating that time-tagging may not be automatic or the tag may not be stored for all memories. Rather, the majority of our data supports reconstructive theories, suggesting several key theoretical implications. First, our findings are consistent with previous work (Ben Malek et al., 2017), which suggests that individuals often use multiple dating strategies to arrive at a date estimation; the use of multiple strategies emphasises the reconstructive nature of this process, as various types of information are used in combination to arrive at an informed date estimation. Second, our findings also support the theoretical underpinnings of Transition Theory (Brown, 2016), which posits that event components, including places, form networks that represent memorable events and aid in the creation of temporal links between events. Not only do the current findings corroborate previously established reconstructive theories of memory dating, but also make an important contribution by demonstrating the pivotal role that spatial information plays in date reconstruction. The importance of spatial information as a separate dating strategy should be considered in future research on date reconstruction, as it may provide important information on the nature and use of reconstructive dating strategies.

Turning to event memory theory (Rubin & Umanath, 2015), the present work provides further support for the critical importance of spatial information, particularly the

spatial layout of an event in memory, for event reconstruction and phenomenology. We have already demonstrated that recalling the spatial layout is distinctly separate from the contents of a memory and that this distinct component of event memories helps give rise to the experience of mental time travel that is part of reliving, the vividness of memories in one's mind's eye, and the belief in the accuracy of the memory (Rubin et al., 2019). Other recent work suggests that memory of one's location within an event may remain robust after the event occurred is forgotten (Bauer et al., 2017), and that changing spatial locations (or, displacement) leads to the recall of more event details, compared to not changing locations (Jeunehomme et al., 2018), perhaps because spatial information helps to scaffold or organise event memories (Rubin & Umanath, 2015). Now, we can extend event memory theory to include the contribution of spatial information to inference of the date of an event memory's occurrence, along with confidence in that date estimate. Beyond its contribution to key phenomenological characteristics of autobiographical memories, spatial information helps one to recall where in the timeline of one's life that event resides.

To conclude, we conceptually replicated findings related to the dating of memories, by demonstrating with a different methodology that individuals utilise lifetime periods, temporal landmarks, and conventional time patterns as dating strategies. More importantly, we presented a pair of studies that provide two novel findings: (1) spatial layout predicts confidence in date estimates of autobiographical event memories; and (2) spatial information is used to determine the date that an event occurred, independent of the use of other contextual details. Researchers should continue to explore the influence of spatial information on event memories, with a focus on how these details influence downstream properties, including confidently and ultimately, accurately dating events.

Notes

1. We thank an anonymous reviewer for the suggestion that we utilise a multilevel modelling approach to account for nesting in our data.
2. Because participants did not consent to open access to their written responses, this data is not available on OSF.
3. A second, multivariate ANOVA separating average dating confidence into its individual month, day, and year confidence ratings was also non-significant.
4. *t*-tests with adjusted *df* indicate that the Levene's tests for equality of variances were significant.

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