



## Target article

## Autobiographical memory for spatial location is unaffected by delay

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## ABSTRACT

To examine recall of personal spatial location during a previously experienced event, Lafayette College students located themselves in a version of their incoming class photograph that was all black with each individual figure identified in white. They then subsequently identified themselves in the original version of the photograph. The distance between the initial choice in the obscured version and the individual's correct location was recorded. Participants were remarkably and equally accurate in identifying their location irrespective of whether the event occurred 2, 6, 18, 30, 38, or 42 months earlier. Although non-spatial aspects of the cue and rehearsal did not influence accuracy, objective location in the photograph partially accounted for error rates. However, none of these factors was sufficient to explain the absence of delay effects. Unlike spatial memory, recall of temporal information showed a linear decrease in accuracy with delay, but with exceptionally accurate performance by senior-class students.

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Tulving (1972) defined episodic memory as any memorial claim of "I did such and such, in such and such a place, at such and such a time." (p. 389). Since then, the *what* and the *when* of autobiographical memory have been studied extensively, but the *where* decidedly less so. Within the spatial memory literature, there is work examining navigation through space (e.g., Maguire, Burgess, & O'Keefe, 1999), but not examining memory for the self in space. The *where* component of autobiographical memory has not yet been examined in the same way that the *what* and *when* aspects of personally experienced events have been investigated.

Laboratory paradigms tend to be highly constrained and quite typically artificial; the vast changes in spatial location between encoding and retrieval common in everyday experience are often not captured by these tasks. Furthermore, the intervals examined are relatively short, typically minutes or sometimes days, not the months or years that would be relevant to questions of autobiographical recall. The study of autobiographical spatial information is further complicated by different, equally valid levels of analysis (e.g., I am simultaneously sitting at my desk, in my office, in Oechsle Hall, on the Lafayette campus, in Easton, PA, USA). This nested structure allows for an individual's response to vary in specificity as a function of mnemonic accessibility or for non-mnemonic factors such as the inferred familiarity of the experimenter with the location. Therefore, data about long-term autobiographical recall of spatial location is lacking.

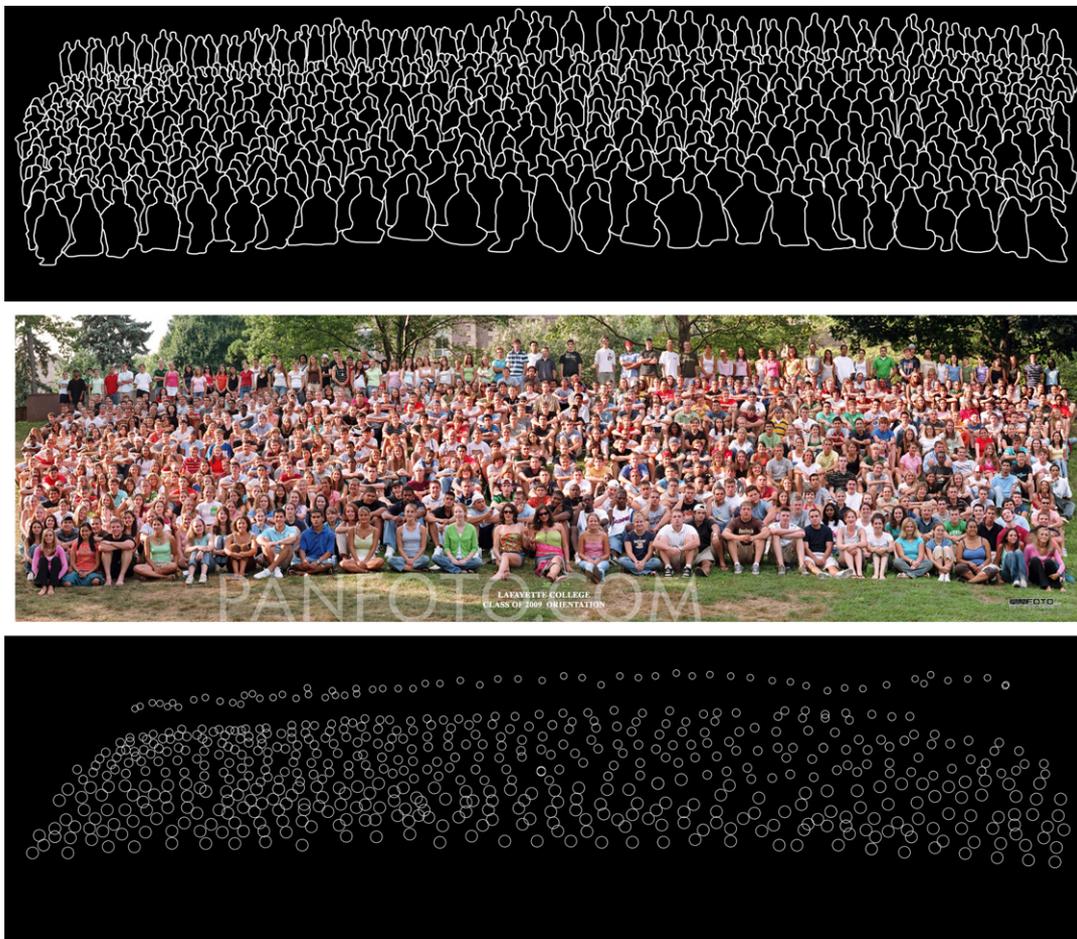
One possible exception is Whittman and Healy (1995) who had college students recall the what, where, and when components of semester schedules from approximately 12–36 months previously. Consistently, recall of where a class was held was more accurately recalled than what the class was named, who taught it, or when it started. However, although these data were from everyday experience, the authors argue that performance is based on proceduralization of the information through repeated experience throughout the semester, not on episodic recall. Therefore, there is still no comparison among the components of recall of a unique autobiographical event.

Flashbulb memory research does commonly ask participants "where were you (and what were you doing) when you heard the news about X?" The vast majority of participants in these studies provide highly confident, highly detailed responses to this question (Julian, Bohannon, & Aue, 2009; Talarico & Rubin, 2009). However, like most studies of autobiographical memory, these studies suffer from a lack of verifiability as they examine events encoded outside the control of an experimental session. Diary studies similarly rely on consistency between entries made hours after the event and reports provided days or months later as an indirect measure of accuracy. Furthermore, these test–retest procedures necessitate increased attention drawn to the event of interest online or soon after, possibly inflating later memory.

By asking undergraduates where they were seated during the taking of their college class photograph, the accuracy of one's autobiographical memory for spatial location during a specific, personally experienced event that occurred years ago and for which there have been no more prior retrieval attempts than would be expected for any other autobiographical memory can be

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**Fig. 1.** Samples of the stimuli. Obscured photographs (top and bottom) were created with Adobe Photoshop CS 9.0.2. Original photographs (middle) courtesy of and reproduced with permission of Panfoto LLC. Note that the bottom photograph is not of the same class as pictured in the other two photographs; this stimulus was created to reduce the amount of non-spatial information available during figure selection to the second group of freshman Fall participants.

determined. A Lafayette College tradition, taking the incoming class photograph is integrated into the first-year orientation experience and is a vividly remembered event for most students (Talarico, 2009). The photographs themselves are displayed in the student union and other administrative buildings throughout the students' 4 years on campus. Copies are also available for purchase, but a minority of students do so.

The taking of these photographs are useful to-be-remembered stimuli. The location of the photographic event is the same for all incoming students, yet one's specific, self-selected seat among approximately 600 classmates is unique. Therefore, for each participant, spatial location during the taking of the class photograph represents a component of a prototypical autobiographical memory while simultaneously controlling the specificity of responses. Furthermore, the use of photographs allows for a direct measure of accuracy. For all of these reasons, asking individuals to identify their spatial location during a unique event that transpired a number of years ago can provide us with novel information about autobiographical memory for spatial location.

## 1. Method

### 1.1. Participants

Lafayette College students (aged 18–22) participated for extra credit in psychology courses or for a token reward. As the photographs were taken during each students' first year, those students

in Spring semester of their freshman, sophomore, junior, and senior year represent delays from the time of the event of approximately 6, 18, 30, or 42 months, respectively ( $n = 30$  from each class; 7, 10, 8, and 9 males, respectively). Another group of 30 freshmen (including 4 males) was run in a subsequent Fall semester within 2 months of having had their class photograph taken.

### 1.2. Procedure

Participants were shown an obscured version of their incoming class photograph measuring 63 cm  $\times$  18.5 cm and they pointed to the figure they believed represented themselves. This version was created in Adobe Photoshop CS 9.0.2 and was all black with each individual figure outlined in white (see Fig. 1, top panel). The time taken by the participant to point to him- or herself, in seconds, was recorded using a stopwatch. Following this identification, the researcher outlined the photograph and the selected figure on a sheet of tracing paper overlaid on the photograph. After completing a questionnaire about the event and the participant's memory for it (described below), the participant identified him- or herself on the actual class photograph (see Fig. 1, middle panel). After visual confirmation of the accuracy of this identification by the experimenter, the corresponding figure was subsequently traced on the same piece of paper.

First, linear distance (in cm) between the two figures from nose to nose was examined. This measure is appropriate if the task-at-hand is remembering a 2-dimensional photograph. However,

the photograph distorts vertical distance; the horizontal axis accurately preserves distance relationships among individuals, but, due to visual perspective, the vertical axis is compressed. In these photographs, the faces of individuals in the first row are approximately twice as large as faces of individuals in the back row. Therefore, the same amount of 2-dimensional space includes more individuals if it is closer to the top of the photograph than if it is near the bottom. To account for this distortion and provide a more representative measure of distance in 3-dimensional space, an adjusted distance measure was calculated. First, the absolute horizontal and vertical distances (in cm) between individuals were measured. Next, the slope of the hillside on which the photograph was taken (an average of .32 rad) was subtracted to get the angle between the vertical photographic plane and the hillside (1.25 rad). Then each vertical distance measurement was divided by the cosine of that angle to get an adjusted vertical distance between individuals. The Pythagorean theorem was used with that adjusted vertical distance and the linear horizontal distance to calculate an adjusted distance between individual figures. Both linear and adjusted distance measures were included in all subsequent analyses.

An event-memory questionnaire was completed between the two figure-identification tasks. First, open-ended questions were asked about what time the photograph was taken, what the participant was wearing, what the weather was like at the time, and who he or she was seated near.<sup>1</sup> For time, participant responses were constrained by “\_\_\_\_\_:\_\_\_\_\_ am/pm” formatting on the questionnaire. This time estimate was compared to the start time of the taking of the class photograph as listed in the orientation schedule for each class. With this question, we can compare relative accuracy for *when* and *where* responses over the same delays.

Participants were then asked a series of rating-scale questions, including several measures of rehearsal: frequency of talking about the photograph or the event of taking the photograph (rated on a scale from 1 *not at all* to 7 *more than any other photo/event*) as well as recency (1 – *not since it was taken* to 7 – *within the past week*) and frequency (1 – *not at all* to 7 – *almost every day*) of looking at the publicly displayed photographs and students’ personal copies (where applicable). Participants were also asked to rate the current vividness of their memory (1 – *not at all* to 7 – *as clear as if it were happening now*), how emotional the event was at the time and now, and how significant the event was at the time and now (all 1 – *not at all* to 7 – *more than any other memory*).

## 2. Results

A one-way between-subjects analysis of variance among the groups for both linear and adjusted distances between initial choice and correct location was calculated. Students from each class were equally accurate in identifying their location whether using the linear,  $F(4, 149) = 1.38, p = .25$ , or adjusted distance measure,  $F(4, 149) = 1.95, p = .11$ . Moreover, the lack of a delay effect was because participants were remarkably accurate. Fig. 2 shows boxplots for the linear and adjusted distance measures by delay. Maximal linear error distance was approximately 60 cm across all photographs (e.g., measuring from the top, leftmost figure to the bottom, rightmost figure). An average error distance might be estimated at 30 cm

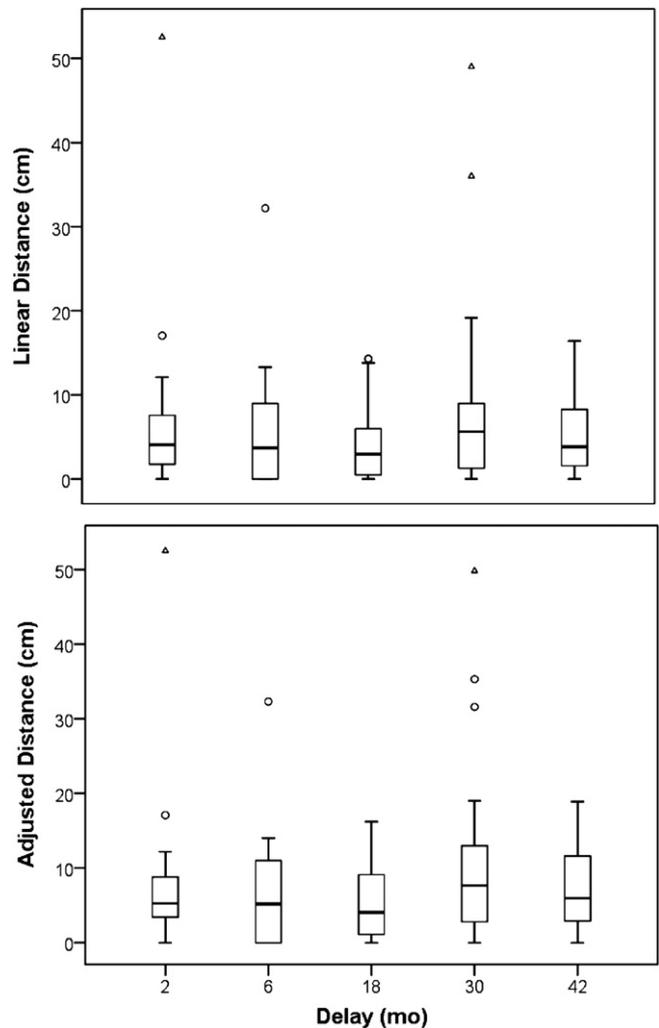


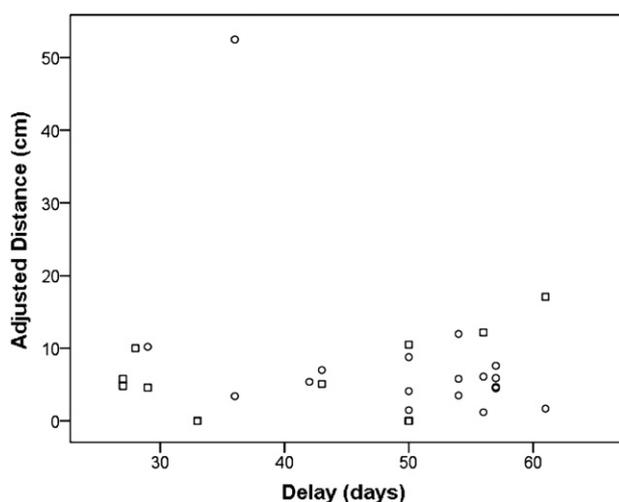
Fig. 2. Linear distance (top) and adjusted distance (bottom, square root of absolute horizontal distance squared plus (absolute vertical distance divided by cosine (1.25 rad)) squared) between participants’ identification of themselves in the obscured photograph and their actual location by delay interval. Circles indicate outliers within 3 interquartile ranges (IQR) of the 3rd quartile (Q3); triangles indicate outliers more than 3 IQR above Q3.

(e.g., measuring from the center figure to any corner) or even half of that (15 cm) if one assumes that the participant could narrow down their response to a given quadrant of the photograph. Observed error distance for all class years was well below these expected error rates.

Given the surprising absence of a delay effect, the data of the freshmen tested within 2 months of having had their photograph taken were more closely examined. There was no relationship between delay and accuracy in these data either,  $r(28) = -.10$  and  $-.095$ , both  $p > .60$  for linear and adjusted distance, respectively. Fig. 3 shows a scatterplot of the adjusted distance data to demonstrate the null effect. If the participant whose distance was more than three inter-quartile ranges above the 3rd quartile is removed, there is still no relationship,  $r(27) = .12$  and  $.14, p > .48$  for linear and adjusted distance, respectively.

Converging evidence for the accuracy of these spatial recollections is the fact that each class had some participants who chose their exact location in the obscured version of the photograph ( $n = 4, 8, 7, 2$ , and 2 for each group in ascending order of delay). There was a trend such that participants whose pictures were taken more recently were more likely to be 100% accurate than those whose pictures were taken longer ago,  $\chi^2(4, N = 150) = 8.01, p = .091$ .

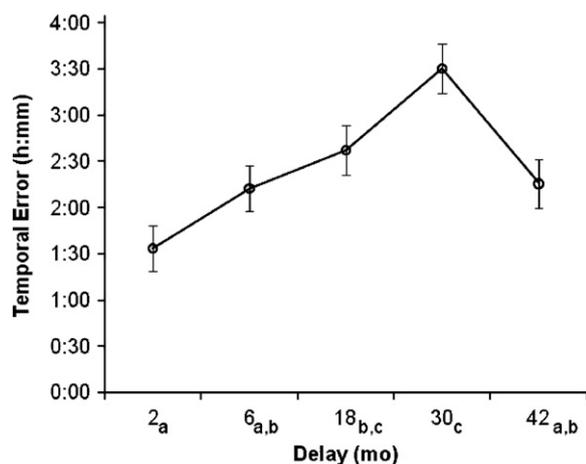
<sup>1</sup> Unfortunately, tremendous variability and lack of specificity precluded coding the latter two questions for accuracy. For example, historical data regarding temperature, cloud cover, wind speed, and precipitation were difficult to reconcile with descriptive terms like “nice” or “hot and muggy” and similarly saying that “there were some football players in front of me” or “I sat next to my roommate but didn’t know anyone else yet” could not be systematically translated to a quantitative accuracy score. Information about what participants were wearing was also surprisingly unavailable given that most individuals in the photograph were obscured, at least in part, by those around them.



**Fig. 3.** Adjusted distance between participants' identification of themselves in the obscured photograph and their actual location for freshmen who were tested within 2 months of the taking of the photograph only. Delay interval is the number of days between the taking of the photograph and when participants were tested in the laboratory. Squares indicate participants who were located on the edge of the group in the photograph; circles indicate participants who were not on the edge (i.e., those in the vast middle of the group).

However, the first-semester freshmen had fewer individuals who chose their exact location than would be expected if recency alone predicted accuracy. As a more liberal accuracy criterion, the number of participants who selected an individual directly adjacent to their correct location in the image was calculated. An adjacent individual was operationally defined as anyone for whom a straight line drawn nose-to-nose between the selected figure and the correct figure did not intersect another individual's head. There was no difference among groups in the number of participants who were no more than one individual away from their correct location,  $\chi^2(4, N=150)=1.50, p=.83$  ( $n=9, 9, 9, 6,$  and  $10$  for each group in ascending order of delay).

The pattern observed for spatial memory is different from that for temporal memory (see Fig. 4). There was a significant effect of delay on accuracy or the time that the photograph was taken,  $F(4, 144)=7.23, p<.001$ . For the 2–30 month delay groups, there is a linear increase in error with delay. However, the group tested



**Fig. 4.** Mean difference between the actual start time of the taking of the photograph (as provided by the orientation schedule) and the time provided by participants as a function of delay. Error bars represent standard error of the mean. Delay intervals sharing the same subscript are not significantly different from one another according to post hoc Tukey HSD tests.

in their senior year was not significantly different from the two freshman groups (both  $p>.35$  according to Tukey HSD). It appears that those students approaching graduation demonstrated better memory than would be expected given the absolute delay from the time that the photograph was taken. It is possible that transitional events like those from the start of college take on additional significance as the transition marking the end of college nears. That this added salience enhances accuracy is consistent with findings from flashbulb memory (Berntsen, 2009).

Within any memory study, failure to find a delay effect is surprising. One potential explanation is that actual location in the photograph may have aided some participants' recall and therefore led to the ceiling effect in spatial accuracy seen here. Specifically, a location on the edge of the group may have been easier to identify relative to the vast middle. An edge location was operationally defined as anyone who was seated in the front row, the left- or rightmost edge of any given row, the last row, or who was standing in the row at the back. An edge location was significantly related to identifying one's location exactly,  $\chi^2(1, N=150)=30.62, p<.01$ . Of the 23 participants who knew exactly where they were in the photograph, 20 of them were on an edge. However, there were 54 total participants who were located on an edge, and the majority did not locate themselves exactly. Using the more liberal criterion of choosing a figure no more than one individual away from one's exact location, a similar pattern emerges,  $\chi^2(1, N=150)=10.27, p<.01$ . Twenty-four of 54 participants located on an edge were within one individual away from their correct location and 19 of 96 individuals not on the edge were equally as accurate. The scatterplot in Fig. 3 showing the adjusted distance measures for freshman participants tested in the Fall differentiates between those participants who were located on an edge (in squares) and those who were not (in circles) to further illustrate this relationship.

Another alternative explanation for this pattern of data could be reliance on non-spatial aspects of the figure outlines to recognize oneself in the photograph. To address this, the procedure described above was replicated but with circles marking each head instead of outlining each figure (see Fig. 1, bottom panel). Participants ( $n=30, 8$  of whom were male) were drawn from a class year that had not been previously tested and run at an approximate 38 month delay interval (i.e., in Fall of their senior year). There were no differences in the accuracy between this group ( $M=6.32$  and  $8.03, SD=7.56$  and  $7.48$ ) and the 42 month delay group ( $M=5.47$  and  $7.00, SD=4.82$  and  $5.29$ ) in linear or adjusted distance, respectively,  $t(58)=.52$  and  $.62$ , both  $p>.54$ . Similarly, there was no difference in the number of individuals who correctly recalled their exact location ( $n=2$  in both groups) or who were no more than one individual away from their exact location ( $n=9$  for the circle group and  $10$  for the figure group,  $\chi^2(1, N=60)=.08, p=.78$ ).<sup>2</sup> Therefore, these factors cannot account for the observed data.

Prior rehearsal is another potential explanation for the high spatial accuracy rates. Correlations between each accuracy measure and any measure of rehearsal were calculated for the four groups tested in Spring semester.<sup>3</sup> The only significant relationship was between adjusted distance and the last time the individual looked at the publicly displayed photograph,  $r(118)=-.19, p=.03$ , indicating that having recently viewed the image increased accuracy in identifying one's location in the image. There was no other evidence of practice effects due to frequency of talking about the photograph,

<sup>2</sup> There was also no statistically significant difference in temporal accuracy between the senior students tested in Spring ( $M=2:16, SEM=:16$ ) and those tested in Fall ( $M=2:28, SEM=:17$ ),  $t(58)=.51, p>.61$ .

<sup>3</sup> For the majority of freshmen students tested in the Fall, the personal and public photos were not available prior to testing.

talking about the event of taking the photograph, looking at the publicly displayed photograph, largest  $r = -.15$ , all  $p > .10$ .

Next, I examined the possibility that owning a personal copy of the photograph would increase accuracy. Still looking only at participants tested in Spring, there was no difference in accuracy between those who owned a personal copy of the class photograph ( $n = 45$ , linear distance  $M = 7.45$  ( $SD = 9.00$ ); adjusted distance  $M = 8.82$  ( $SD = 9.71$ )) and those who did not ( $n = 75$ , linear distance  $M = 4.92$  ( $SD = 5.56$ ); adjusted distance  $M = 6.51$  ( $SD = 6.05$ )),  $t(118) = -1.90$ ,  $p = .06$  for linear distance and  $t(118) = -1.61$ ,  $p = .11$  for adjusted distance. If anything, the trend was for those with a personal copy of the photograph to be less accurate than those without. Perhaps the personal copies were not kept by the students in their campus residences, but instead that they were kept elsewhere and were not as readily accessible as one might initially assume. Those with a personal copy did not rate the event as more emotional or more personally significant than those without, largest  $t(118) = 1.67$ ,  $p = .099$ . Similarly, the freshmen tested in the Fall who had placed an order for a photograph also did not rate the event as more emotional or more personally significant (then or now) than those who had not ordered a personal copy, largest  $t(28) = .33$ ,  $p = .75$ .

Although there was no evidence of delay or practice effects on spatial memory, there was an inverse relationship between accuracy and speed among participants; the faster individuals selected their location in the obscured version,<sup>4</sup> the more accurate they were,  $r(148) = .15$ ,  $p = .07$  for linear distance and  $r(148) = .18$ ,  $p = .03$  for adjusted distance. Neither linear distance nor adjusted distance was correlated with emotion at the time of the event or emotion felt now (largest  $r(148) = .09$ ,  $p > .29$ ). A relationship between accuracy and the personal significance of the event then or now was also absent (largest  $r(148) = -.13$ ,  $p > .10$ ). Participants who rated their memories as more vivid were moderately more accurate in identifying their location when using the adjusted distance measure,  $r(148) = -.21$ ,  $p = .047$ , with a trend in the same direction for the linear distance measure,  $r(148) = -.14$ ,  $p = .09$ . Vividness was also correlated with temporal accuracy,  $r(148) = -.19$ ,  $p = .018$ . Similar to spatial accuracy, there was no relationship between temporal accuracy and emotion or significance ratings now or then (largest  $r(148) = -.07$ ,  $p > .39$ ).

### 3. Discussion

This task required remembering a particular event that occurred once at a specific time and place. Therefore, one might have expected performance to mimic the power function forgetting curve seen in studies of autobiographical and event memory (Rubin & Wenzel, 1996); that performance showed little to no decrease over time was surprising. However, there is some evidence that people demonstrate excellent recall of the location of things even if encoded incidentally, such as the place on a page where information had been presented (Rothkopf, 1971; Zechmeister & McKillip, 1972). Wagenaar (1986) recalled where he was 76% of the time (at most) after a delay of 1–5 years, similar to what is shown here with a very different metric. He required responses to be equally precise (e.g., “at home” was incorrect if the original description was “in our kitchen” p. 232) when judging consistency over time in the study of his own memory in order to address the complications of measuring accuracy and specificity within autobiographical memory. In the present study, high accuracy for *where* information was demonstrated over 4 years with some evidence of exact recall of location being influenced by delay interval.

One potential explanation for the enhanced accuracy may be the lack of interference from similar events which can be particularly disruptive to retrieval of spatial information (da Costa Pinto & Baddeley, 1991). Bahrack (1979) found approximately 60% forgetting of the spatial layout of town/campus after 14 months and little to no retention after 44 months (if rehearsal was held constant) with initial overlearning of the information. Remembering one’s personal location may be better preserved than generic spatial information. Support for this assertion comes from Whittman and Healy (1995) who found that recall of where previous classes were held was more accurately recalled than the when or what aspects of a semesters’ schedule. The accuracy of spatial recall in their paradigm was partially explained by the procedure of showing participants a campus map and having them point to the particular building in which a class had been held. This effectively constrained participants’ responses much like the finite number of figures in the class photograph procedure here restricted overall distance error. However, the errors made here did not approach this upper limit.

Temporal information was similarly constrained in both procedures, yet did not show a similar pattern of sustained accuracy. Burt (1992) demonstrated that errors in dating past events recorded in a diary could be explained by strategic efforts to estimate date information and were influenced by the boundaries set forth by the experimenter. This is consistent with other evidence suggesting that determining when personally experienced events occurred is a highly reconstructive process based on deductive reasoning (Friedman, 2004). All of the Lafayette students here knew roughly that the photograph was taken in the afternoon, just as Wittman and Healy’s (1995) participants knew well the conventions of class start times. Yet, temporal recall was less accurate than was spatial recall in both cases.

There are other parallels between temporal and spatial remembering. Participants in more easily identifiable edge locations were more likely to choose their exact location; this may be analogous to a benefit in accurately dating temporal landmarks (Shum, 1998). Strategic spatial reasoning (e.g., narrowing the field by determining if one was on the left or right, front or back of the group) may have reduced the error distance, especially if spatial location was estimated (Huttenlocher, Hedges, & Duncan, 1991). The relationship between speed and accuracy supports that idea that most participants employed a strategy that honed in on their general location and then refined their choice to a particular figure from there. In other words, those participants who were quite confident of their location chose quickly and accurately whereas those who were less sure and more likely to reconstruct an estimate of spatial location were slower. Although this kind of reasoning may have served to restrict error generally, the lack of an increase in error over such lengthy delays remains impressive.

The considerable accuracy in retrieving one’s spatial location over a 4-year delay brings to mind anecdotal flashbulb memories of remembering “exactly where you were” when hearing an important piece of news for years after the event. However, empirical studies of flashbulb memories have demonstrated that they are often less accurate than participants believe them to be (Talarico & Rubin, 2003). Spatial location in isolation has not been systematically investigated in the flashbulb memory literature. Instead, most investigators examine a composite measure of where the participant was, what he or she was doing, who else was present, and other idiosyncratic details of the reception experience. However, there is limited evidence that some details may be more reliably recalled than others (Christianson, 1989; Tekcan, Ece, Gulgoz, & Er, 2003) with location always being included among those details which are recalled consistently over time. It may be that accurate recall of spatial location leads to reconstruction of other details resulting in vivid and confidently held memories.

<sup>4</sup> To maintain task consistency, data from participants who saw only circles in the obscured version are omitted here.

Evidence from temporal accuracy tentatively supports this interpretation as well. Memory accuracy for when the photograph was taken showed a linear decrease with delay until the longest delay interval; Participants in their senior year had accuracy rates similar to freshman students. The enhanced accuracy of seniors is consistent with Berntsen's (2009) theory of flashbulb memory which suggests that events salient to one's social identity are better remembered than everyday autobiographical experiences. Students approaching graduation may be particularly aware of their identity as Lafayette College students and especially sensitive to the fact that this identity is nearing its end. Memory for taking the class photograph displays other characteristics of flashbulb memories such as enhanced vividness (Talarico, 2009) and this vividness was correlated with increased accuracy of spatial and temporal aspects of the event. Tracking the accuracy in alumni groups further removed from conceptions of themselves as college students and/or determining if accuracy can be influenced by priming Lafayette identity are potentially fruitful tests of the social identity hypothesis that would not rely on test-retest consistency as a proxy for accuracy.

As autobiographical memory theorists (e.g., Rubin, 2006) begin to take seriously questions of the attributes of memory (Underwood, 1969) and to investigate the neural underpinnings of these attributes, understanding memory for spatial location becomes particularly important. Since Scoville and Milner (1957) we have known that damage to the hippocampus results in pervasive loss of autobiographical memory. Given that spatiotemporal specificity distinguishes autobiographical memory from semantic and procedural aspects of memory, many models have emphasized a role for the hippocampus as an explicit, recollective memory system (Fortin, Wright, & Eichenbaum, 2004; Morris & Frey, 1997; Moscovitch, Nadel, Winocur, Gilboa, & Rosenbaum, 2006; Rubin, 2006). There is also evidence of hippocampal involvement in human spatial navigation (Maguire et al., 1998; Maguire, Nannery, & Spiers, 2006) and in non-human animal memory for allocentric spatial location (Burgess, Becker, King, & O'Keefe, 2001; Holdstock et al., 2000). As the current task required participants to transpose their perspective from the time of the event to the time of recall, it can be considered an allocentric task and a particularly difficult task at that as relevant spatial landmarks (e.g., trees or buildings) were not available in the obscured version of the photograph. Yet, despite this, our participants achieved remarkable accuracy regardless of delay.

The number and variety of activities that rely on reliable retrospective reporting of personally experienced events mean that understanding autobiographical memory is of the utmost practical importance. An essential part of this is examining the individual aspects of autobiographical experience and how they coordinate to produce a rich, recollective phenomenon. Hopefully, studies like this encourage future research in this area.

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