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EMPIRICAL ARTICLE

They Forgot Their "Baby"?!: Factors That Lead Students to Forget Their Cell Phone

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Remembering intentions is critical for daily life, yet errors happen surprisingly often, even when there are fatal consequences (e.g., forgetting a baby in a car). To understand how people can forget personally important intentions, we took 192 students' cell phones while they participated in an unrelated experiment. We examined (a) how often students forgot to retrieve their cell phone when they left the lab compared to an experimenter-relevant task that required returning an activity tracker that we attached to their clothes to "monitor their amount of fidgeting" during the experiment and (b) whether it mattered if the instructions were explicitly encoded or not. Students only forgot the tracker 10%–13% more often than their cell phone, and explicit encoding did not reduce forgetting; neither did longer, more distracting ongoing tasks. Between 60% and 70% of participants said the intention "popped into mind." We suggest that prospective memory intentions are "autonomically" encoded, yet even explicitly encoded, personally important tasks are forgotten at surprising rates.

General Audience Summary

How do people forget personally important intentions, like forgetting your sleeping baby in the back seat when you leave the car (or forgetting to turn off appliances or bring your cell phone, keys, etc. with you, for that matter)? We suggest that such intentions are *autonomically* encoded by the mind and brain by default, yet even when intentions are explicitly encoded forgetting happens surprisingly often, and it is not clear why. To understand what causes forgetting, we took ∼200 students' cell phones from them when they came into our labs to participate in an unrelated experiment. Students forgot their cell phones at surprising rates compared to a control condition, and it did not matter (a) how students formed or "encoded" the intention, (b) how long and involved the other experiment tasks were, or (c) if they said they thought of the intention during their other, ongoing tasks. Students who said the intention spontaneously "popped into mind" at the right time were less likely to forget than those who did not. This study suggests that forgetting occurs when environmental cues fail to elicit spontaneous retrieval at the appropriate moment, regardless of whether or not intentions are explicitly encoded. This study should help inform the public and judicial system about what does and does not cause such prospective memory errors to happen—even those with tragic consequences.

Keywords: prospective memory, implicit, encoding, naturalistic, forgetting

Supplemental materials: https://doi.org/10.1037/mac0000110.supp

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Nathan S. Rose played a lead role in conceptualization, funding acquisition, investigation, methodology, project administration, resources, supervision, validation, writing–original draft, and writing–review and editing and a supporting role in data curation, formal analysis, software, and visualization. Abigail C. Doolen played a lead role in data curation and visualization and an equal role in conceptualization, formal analysis, software, writing–original draft, and writing–review and editing. Andrea

continued

Remembering to perform intentions—*prospective memory* (PM)—is critical for daily life. Yet, PM forgetting happens often, constituting 50%–80% of everyday memory failures (Crovitz & Daniel, 1984; Haas et al., 2020; Niedźwieńska et al., 2020; Terry, 1988). Most errors, like forgetting something at the market, are minor annoyances. However, many errors, such as forgetting one's cell phone on the table at a café or leaving the stove on, can have harmful outcomes (e.g., theft, fire). Some errors, like forgetting one's sleeping baby in the back seat of a vehicle, can be fatal. Since 1998, over 477 children have died in the United States alone because their caregiver forgot them in the car (Epstein, 2016, https://nhtsa.gov, https://noheatstroke.org). This does not include unreported close calls in which caregivers forgot a child in the car, but remembered before the event turned fatal. Approximately 25% of parents with children under 3 report that they have momentarily forgotten that their child was in the car with them at some time during a drive (Public Opinion Strategies, 2014).

How could a caregiver forget about their most important responsibility? Expert testimony suggests that forgetting a baby in a car is fundamentally a PM error that can happen to anyone; it does so irrespective of sex, age, race, and socioeconomic status (Diamond, 2019). Remembering to perform a PM intention (e.g., dropping a child off at daycare) involves multiple cognitive processes that support four phases: encoding the intention, retaining the intention while engaged in ongoing activities (e.g., driving to work), detecting cues that signal when to switch from ongoing activities (e.g., approaching the street to turn for daycare), and executing the intention (e.g., turning left to drop the child at daycare rather than right to proceed to work). Problems at any stage can cause PM failures (Kliegel et al., 2011; Kvavilashvili & Rummel, 2020). For example, the absence of salient visual and auditory cues from a child who is sleeping in the back seat creates a scenario conducive to forgetting the child in the car. This idea is supported by the fact that forgetting babies in cars was uncommon until the 1990s and then skyrocketed when laws mandated that car seats were to be in the back seat (Mckenzie (2018) https://kidsandcars.org).

It may seem odd to consider remembering to bring one's baby with them a PM task because caregivers are unlikely to explicitly encode their intention to do so every time. We argue that such intentions are formed at a *latent* level by default. Yet, even when intentions are explicitly/consciously encoded (remember to drop the baby off at daycare), forgetting still occurs. Hardly any empirical research exists to understand how PM forgetting can happen in a situation analogous to forgetting a baby in a car. Prior PM research mainly involves abstract or "one-off" computer tasks (e.g., push the spacebar anytime you see the word "spaghetti" during a word-rating task; McDaniel & Einstein, 2000) that are usually introduced explicitly, not personally important, and have little consequence to the participant if forgotten (for exceptions, see Kvavilashvili, 1987; Sellen et al., 1997). Some research has shown that manipulating the importance of the PM intention affects performance (Walter & Meier, 2014). For example, monetary incentives can enhance real-world PM performance (Aberle et al., 2010). However, some studies have shown that explicitly encoding and monitoring for PM cues is not always necessary for task completion (Kvavilashvili et al., 2013; Scullin et al., 2018).

The Present Study

We designed a naturalistic procedure to measure how college students could forget something they are really attached to—something that could have real consequences if forgotten. When we asked colleagues what they thought was the equivalent of a college student's "baby," most were quick to respond—"their cell phone!" Although nothing is of comparable importance as remembering to care for one's baby, the task of remembering one's cell phone has several notable similarities. The typical student brings their cell phone with them everywhere. If forgotten, even briefly, there can be serious consequences. In addition to the cost and inconvenience of losing the phone and its data, it often includes ID, debit, or credit cards.

In the present study, students came to our labs to participate in a separate, unrelated experiment (see Figure 1). Before beginning that experiment, we asked them to give us their cell phone and gave them an activity tracker to attach to the back of their waistband. One group was told to remember to ask for their cell phone back and return the tracker after the experiment; the other group was not. Upon completion, we gave them a debriefing sheet and guided them to the exit. The experimenters pretended to go on with their business and surreptitiously watched to see if and when the participant remembered to get their phone or return the tracker.

The hypotheses we aimed to address in this study and their rationale were as follows:

1. Because personally important tasks are prioritized during encoding (Peter & Kliegel, 2018), and task importance has been shown to reduce PM forgetting (Walter & Meier, 2014), we hypothesized that there would be less forgetting of the personally relevant task of retrieving one's cell phone than the experimenter-relevant task of returning the tracker.

2. We compared forgetting rates following explicit-encoding and non-explicit-encoding to test the hypothesis that explicitly encoding an intention would enhance the ability to detect PM cues and retrieve the intended action; we expected that people who explicitly encoded the tasks would forget less than those who did not. We were wrong.

3. Because the other experiment varied in length, we could test the hypothesis that there should be an association between forgetting and delay. According to the preparatory

E. O'Rear played an equal role in conceptualization, data curation, formal analysis, writing–original draft, and writing–review and editing.

All dependent variables or measures that were analyzed for this article's research questions have been reported. All levels of all independent variables and all predictors and manipulations, whether successful or failed, have been reported. The total number of excluded observations and the reasons for making those exclusions have been reported.

The data are available at https://doi.org/10.7274/3197xk84j07.

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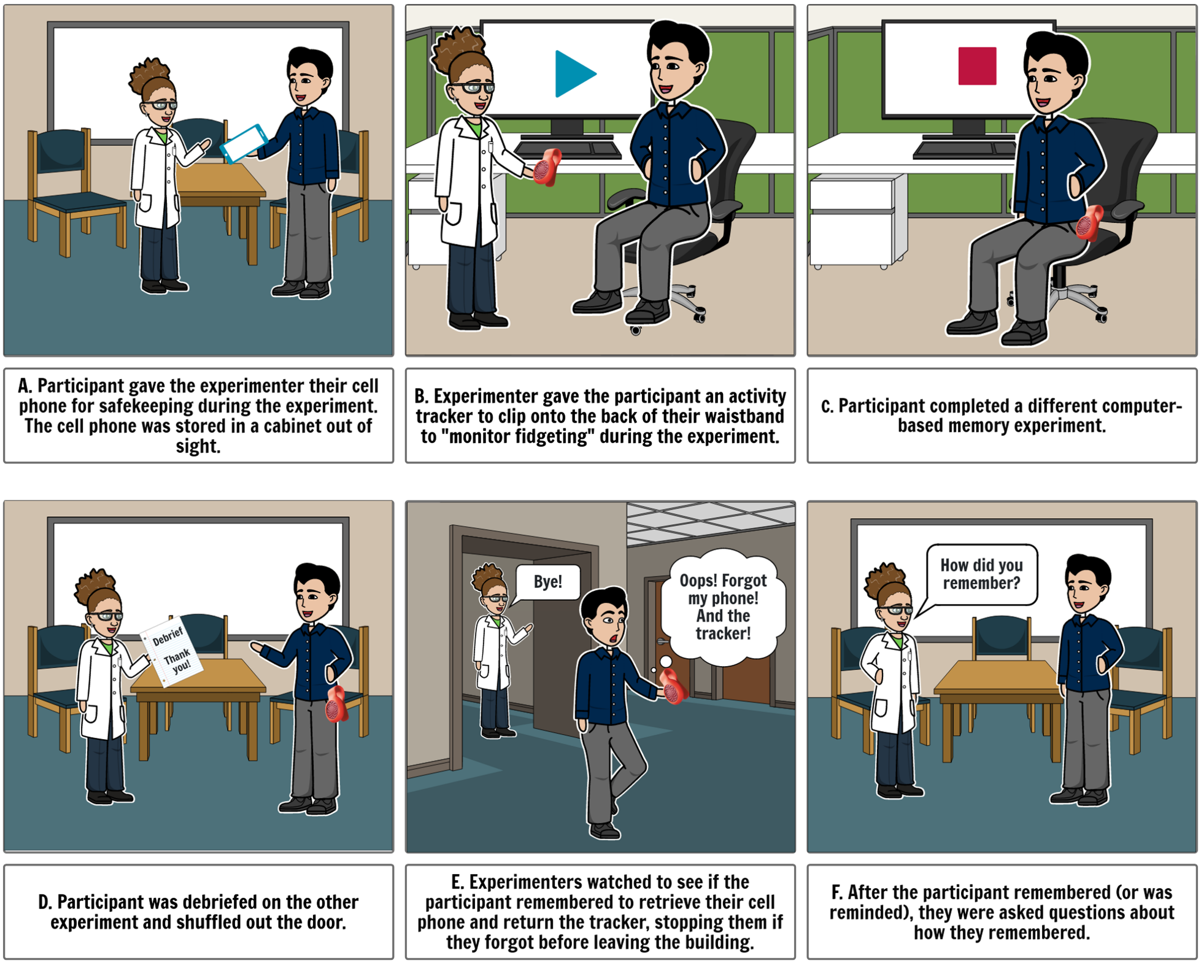
Figure 1
Depiction of the Experimental Procedure



Note. See the online article for the color version of this figure.

attentional and memory processes (PAM) theory, successful PM requires continuous conscious monitoring for cues in the environment (Smith, 2003), which should be more difficult for longer delays, so PM failures should become more frequent with longer delays. In contrast, the multiprocess model suggests that there should be no association because people also rely on spontaneous retrieval processes that cause the intention to "pop into mind" at the appropriate moment (McDaniel & Einstein, 2000).

4. We also evaluated the strategies and cues that participants used to help them remember. The PAM theory predicts that people will monitor for the tasks between intention formation and execution of action and that this monitoring would be beneficial for success in performing the tasks. We did not have strong predictions about what would cue participants in this atypical situation, but we suspected that participants would frequently report that the task "popped into mind," especially for their cell phone compared to the tracker and that they "thought about" or monitored for the tasks more often in the explicit- than the non-explicit-encoding condition.

5. Last, when presenting these data, we received questions about whether men or women were more likely to forget. The expectations seemed to be driven more by (sexist) gender stereotypes than evidence-based theories about biological sex differences in cognition. Although we had no a priori predictions regarding any effect of biological sex on forgetting rates, we report the lack of a difference between men and women in this study to combat such sexist, preconceived stereotypes about sex differences in PM.

Method

Participants

One hundred ninety-two students from the University of Notre Dame participated (non-explicit-encoding condition: n = 108

[76 female]; explicit-encoding condition: n = 84 [47 female][1]). Participants were recruited for participation in this study when they arrived at our laboratories to participate in another, unrelated experiment. All procedures for this study were approved by the university's institutional review board (17-05-3899).

Design and Materials

The study had a 2 (task-relevance: personally relevant [cell phone] vs. experimenter-relevant [tracker], within-subjects) × 2 (encoding condition: non-explicit-instruction vs. explicit-instruction, between-subjects) mixed design. Within each group, half the participants encoded the personally relevant task outside the testing room and the experimenter-relevant task inside the testing room, and the other half of participants did the opposite (for details, see the Supplemental Material). A Jawbone Up (San Francisco, California) clip-on activity tracker was used for this experiment.

Procedure

When participants arrived at the laboratories for their testing session, they gave informed consent for the other experiment. We then asked them if they would like to participate in this add-on experiment, which we told them was to "track how much people fidget during experiments." Willing participants signed a separate consent form that indicated that the experiment was about remembering intentions, without referencing the cell phone and tracker tasks (full details were disclosed to participants during debriefing). Either before or after entering the testing room, the experimenter asked for the participant's cell phone so that they were not "distracted or tempted to check their phone" during the other experiment and later stored it out of their sight in a cabinet. Then, either before or after entering the testing room, the experimenter gave the participant an activity tracker and asked them to clip it onto the back of their waistband, shirt, or dress so that it was out of sight.

The locations where the cell phone was taken and the tracker was attached were always different; one task was encoded outside the testing room, while the other was encoded inside the testing room. Manipulating the location (and order) of intention formation between subjects was done to reduce interference between the encoding of both intentions and to assess the effect of having a match versus mismatch between intention formation and retrieval because both items were to be retrieved outside the testing room. We also wanted to assess forgetting rates when there was a match or mismatch between the locations where the items were encoded and they were to be retrieved, and whether remembering would occur when students passed through doorways. Because the measures lacked sufficient psychometric properties for valid statistical inferences, we refrained from analyzing and interpreting these data. Interested readers are referred to the Supplemental Materials for more details about the motivation, predictions, and results regarding these hypotheses, as well as suggestions about how future research could better test these hypotheses.

Participants in the nonexplicit condition did not receive an explicit instruction or reminder to remember either object. The procedure for the explicit-encoding condition was identical except that participants were explicitly instructed to remember the tasks. They were told, "Don't forget to retrieve your cell phone and return the tracker after the experiment" after both tasks were introduced.

Participants then completed the other experiment. The other experiments involved either learning words, sentences, or stories and taking memory tests or playing a Virtual Reality game and performing naturalistic PM tasks; the length ranged ~5–197 min, M = 49.3 (SE = 3.2), M = 32.6 (SE = 3.1) and M = 70.74 (SE = 5.33) for the two encoding conditions; partial correlation analyses controlling for the experiment duration did not change interpretation of the effects of encoding on forgetting the cell phone or tracker.

When the participant finished the experiment and opened the door to exit the testing room, the experimenter debriefed them on that experiment and guided them out of the lab. The experimenter pretended to be busy with other paperwork. A confederate experimenter outside the lab surreptitiously watched to see if and where they remembered each item and marked the participant's location on a floor plan (Figure 2). If participants did not retrieve their phone or return the tracker before they reached a stairwell to exit the building, an experimenter stopped them and said, "Excuse me, did you forget something?" If that did not prompt the participant to remember either object, the experimenter told them what they forgot and then took the person back to the lab to get the object(s). If the participant remembered just one of the two objects, the experimenter did not mention the second one. The experimenter either took the tracker or returned the cell phone, whichever one was remembered, and then allowed the participant to proceed to the exit before asking, "Did you forget something else?," if necessary. When the participant retrieved their phone and returned the tracker, they were debriefed about the experiment and asked the following questions about their memory for the tasks:

1. Non-explicit-encoding group only: When we took your phone and attached the tracker, did you make a mental note to remember to retrieve your cell phone or return the activity tracker later? (The response options were "yes" or "no" for each item separately.)

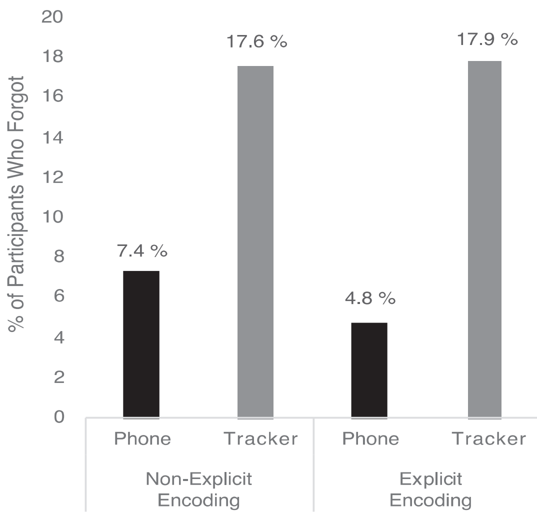
2. Did you think about your phone or the tracker during the experiment? (The response options were "yes" or "no" for each item separately and, if it was "yes," they were asked to estimate the number of times.)

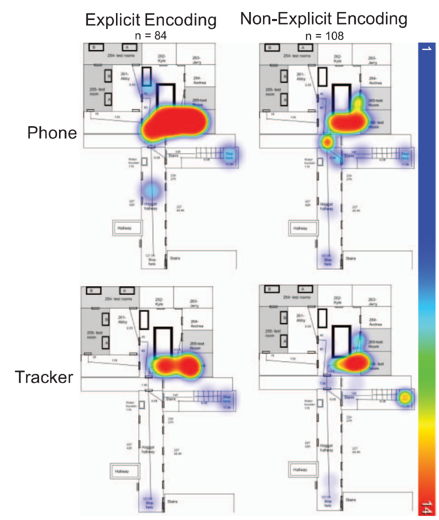
3. What made you remember to get your phone or return the tracker? (The responses were open-ended; we grouped them into five categories: "experimenter" [e.g., seeing the experimenter at the end of the experiment cued them to remember], "other PM task" [remembering one of the tasks, e.g., their cell phone; cued them to remember the other task, e.g., the tracker), "needed to use" [having to use

[1] Because an effect size from a similar study did not exist, an a priori power analysis could not be conducted. A post hoc power analysis using G*Power estimated that the achieved power to detect at least a medium-sized effect between the encoding groups was >95%. The difference in sample sizes is because data were collected for the non-explicit-encoding group first; then, to see if the forgetting rates could be reduced or eliminated, data were collected for the explicit-encoding group second. Before the sample sizes could be equated, the Psychology Department closed and moved to a new building. Future studies should randomize and equate enrollment in conditions with and without explicit-encoding instructions.

Figure 2

Percent of Participants Who Forgot to Retrieve Their Cell Phone or Return the Activity Tracker Before Leaving to Exit the Building in the Non-Explicit-Encoding and Explicit-Encoding Conditions (Left), and the Locations Where Participants Remembered—Or Were Stopped When They Forgot (Right)





their cell phone cued them to remember it], "popped into mind" [they spontaneously retrieved the intention, seemingly in the absence of any environmental cue], or "felt" [either they had a general "feeling that something was off" or they physically felt that their phone was missing (not in their pocket) or that the tracker was attached to their clothes]).

Data Analysis

Forgetting was deemed to have occurred if the student had to be stopped before they started to leave the building. The results, separated by whether participants forgot, but then remembered after leaving the lab (i.e., a less extreme form of forgetting), or whether they forgot the other item, are in Supplemental Tables 1 and 2. The numbers and percentages of participants who reported that remembering one item cued them to remember the other item split by the conditions are reported in Supplemental Table 3. Chi-square and logistic regression analyses with Wald tests were conducted to analyze whether there were differences between the two tasks or two conditions for this bivariate measure of memory accuracy (Cohen et al., 2013). We also computed the distance from the location in the lab where the tasks were to be remembered and the location where the participant stopped to ask for their phone or return the tracker. This was to assess performance using a less stringent/categorical definition of memory success; however, the psychometric properties did not allow valid inferences using this measure (Supplemental Material). McNemar's chi-square tests were used to examine potential differences between the conditions in the distribution of responses to the postexperiment questions. Bayes factors (BFs) were calculated using default priors and the Cauchy distribution to assess the strength of evidence favoring the null or alternative hypothesis for *t* tests (Rouder et al., 2009; Rouder & Morey, 2011), regressions (Rouder & Morey, 2012), and analyses of variance (Rouder et al., 2012).

Results

Personal Relevance and Type of Encoding

The frequency with which students forgot to ask for their cell phone back or return our activity tracker before leaving to exit the building is shown in Figure 2 for the non-explicit-encoding and explicit-encoding conditions. Students forgot to return our tracker only 10%–13% more often than they forgot to ask for their cell phone back. This difference was small, but significant (McNemar's $\chi^2 = 12.41$, $p < .001$) for both the non-explicit-encoding ($p = .04$, Bayes factor [BF_{01}] = 6.94) and explicit-encoding ($p = .002$, $BF_{01} = 1.12$) groups, although BFs favored the null. Surprisingly, explicit instructions did *not* reliably reduce forgetting. A logistic regression analysis showed that the type of encoding did not significantly predict whether participants would remember either their cell phone, $\beta = 0.770$, Wald (1, 192) = 1.234, $p = .267$, Nagelkerke's $r^2 = .02$, $BF_{01} = 6.43$, or the tracker, $\beta = -0.013$, Wald (1, 192) = .002, $p = .962$, Nagelkerke's $r^2 < .001$, $BF_{01} = 1.096$. The location where the items were encoded did not affect memory, so these results collapsed over that factor (see Supplemental Materials, for details).

Delay

Next, we assessed potential associations between memory success and the retention interval between when the intention was formed and when it was to be performed. Logistic regression analyses revealed that there was no association between memory success and the retention interval for either the cell phone in the non-explicit-encoding, $\beta = -0.01$, Wald (1, 192) = .42, $p = .52$, Nagelkerke's $r^2 = .008$, $BF_{10} = 2.09$, or explicit-encoding, $\beta = -.01$, Wald (1, 192) = .87, $p = .35$, Nagelkerke's $r^2 = .04$, $BF_{10} = 43.21$, conditions, or the tracker for the explicit-encoding condition, $\beta = -.01$, Wald (1, 192) = 3.23, $p = .07$, Nagelkerke's $r^2 = .07$, $BF_{10} = 820.70$. The one exception was for the tracker in the non-explicit-encoding condition, β = −.02, Wald (1, 192) = 5.58, $p = .02$, Nagelkerke's $r^2 = .08$, $BF_{10} = 2241.78$. As discussed below, this suggests that the amount of time that passes before a personally relevant task is to be performed may not influence whether or not it will be remembered. That is, forgetting can be very rapid for some, while little forgetting may occur over longer delay intervals for others.

Reported Strategies and Cues

Next, we examined the participants' responses at the end of the experiment regarding the strategies and cues that helped them remember. Participants in the non-explicit-encoding condition were queried to see if they had intentionally encoded the need to retrieve their cell phone or return the activity tracker. Only 17.4% reported that they did so for their cell phone; 43% did so for the tracker. Chi-square tests on participants in the non-explicit-encoding condition revealed that, compared to participants who did not intentionally encode the intention, participants who self-generated an explicit intention were not more likely to remember to ask for their cell phone before they left the lab, $\chi^2 < 1.0$, $p = 1.0$. Participants who explicitly encoded the tracker were slightly more likely to remember (18.92% vs. 12.25% forgetting), $\chi^2 = 4.61$, $p = .04$, $BF_{01} = 2.482$, but BFs favored the null. Therefore, although some participants in the non-explicit-encoding condition did explicitly encode the intentions, doing so did not make them less likely to forget. That is, self-generated intentions did not improve memory relative to pure, non-explicit-encoding.

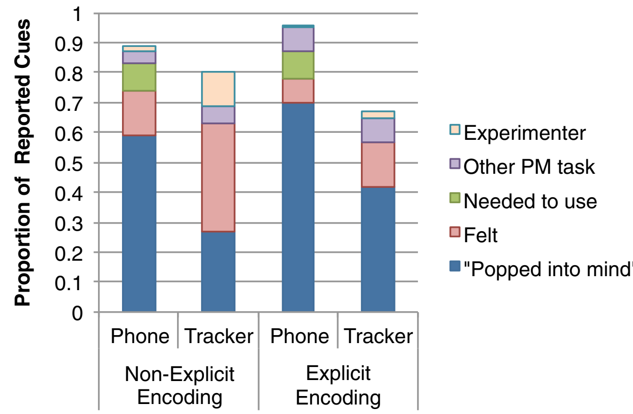
In response to the question, "Did you think about your phone or the tracker during the experiment?" Twenty-eight percent of participants reported thinking about their phone in the non-explicit-encoding condition and 19% did so in the explicit-encoding condition. For the tracker, 73% reported doing so in the non-explicit-encoding condition; 51% did so in the explicit-encoding condition. Chi-square tests revealed that thinking about the need to remember to retrieve one's phone was not associated with memory success for either the non-explicit-encoding, $\chi^2 = 3.32$, $p = .10$, $BF_{01} = 1.24$, or explicit-encoding, $\chi^2 = .73$, $p = 1.0$, $BF_{01} = 7.12$, condition. In contrast, thinking about the tracker was associated with better memory for the non-explicit-encoding condition, $\chi^2 = 7.80$, $p = .009$, $BF_{01} = .12$, but not the explicit-encoding condition, $\chi^2 = 2.33$, $p = .16$, $BF_{01} = 1.07$. Therefore, although most participants reported monitoring about the tracker, and this helped them remember, most did not monitor about their phone, and those who did were just as likely to forget.

Next, we examined what cued participants to remember. Most people (60%–70%) responded that remembering to ask for their cell phone simply "popped into mind" (see Figure 3).

A three-way chi-square test was used to analyze the distribution of cues reported for the phone and the tracker in the non-explicit-encoding versus explicit-encoding conditions. This rate did not differ whether participants were explicitly told to remember or not, $G^2(10) = .50$, $p = 1$. A McNemar's chi-square test did reveal a significant difference between the distribution of responses for the cell versus the tracker, $\chi^2(3) = 25.23$, $p < .001$. Visual examination of the distribution showed that participants reported that the intention to retrieve one's cell phone popped into mind more often than the intention to return the tracker, suggesting that participants relied on spontaneous retrieval more often to remember the personally relevant task than the less-relevant task.

Figure 3

Proportions of the Different Types of Cues That Participants Said Caused Them to Remember to Retrieve Their Cell Phone or Return the Tracker in the Non-Explicit-Encoding and Explicit-Encoding Conditions



Note. PM = prospective memory. See the online article for the color version of this figure.

Differences in Sex

Last, we assessed potential differences in memory success between men and women. Men and women did not differ in how often they forgot their cell phone in either condition (non-explicit-encoding: $\chi^2 = 1.71$, $p = .233$, $BF_{01} = 2.45$; explicit-encoding: $\chi^2 = .65$, $p = .58$, $BF_{01} = 4.82$). The same was true for the tracker (non-explicit-encoding: $\chi^2 = .042$, $p = 1$, $BF_{01} = 3.92$; explicit-encoding: $\chi^2 = 3.79$, $p = .08$, $BF_{01} = .53$).

Discussion

Students forgot to retrieve their cell phone fairly often in this study. Forgetting was greater for the experimenter-relevant task, yet an explicit instruction to remember both tasks did not reduce forgetting. Forgetting the cell phone was as frequent whether or not participants in the non-explicit-encoding condition reported explicitly encoding the intention. Forgetting was as frequent irrespective of the delay between intention formation and performance. Monitoring the need to retrieve their cell phone during the delay also did not reduce forgetting. However, forgetting was reduced for participants who reported processing salient environmental cues (e.g., "feeling" that their phone was missing). Each finding is discussed in turn.

Personally Relevant Versus Abstract PM Tasks

Unsurprisingly, participants forgot their cell phone (personally relevant task), less often than the activity tracker (experimenter-relevant task). What is surprising is that there was only a 10%–13% difference in the forgetting rates. Task importance is known to affect PM forgetting (Peter & Kliegel, 2018; Walter & Meier, 2014). Critically, task importance is determined by the subjective value that the participant assigns to the task based on the perceived gains/losses resulting from task completion/noncompletion. Reduced forgetting for the cell phone compared to the tracker can be attributed to the personal relevance of the task. The habitual nature of remembering one's phone also may have contributed to the differences in forgetting rates (Rose et al., 2010). As it relates to forgetting a baby in a car, a fatal error often occurs when there is a deviation in the caregiver's habitual routine (Diamond, 2019).

Nonexplicitly Encoded Versus Explicitly Encoded Tasks

The lack of a difference between the non-explicit-encoding and explicit-encoding conditions is the most intriguing result. Analyses revealed no statistically significant differences in the distributions of forgetting rates between the conditions for both the tracker and the cell phone. Although many participants in the non-explicit-encoding condition did report making a "mental note" to remember to retrieve their cell phone and retrieve the tracker, doing so had little effect on forgetting rates. We propose that the PM intentions were "autonomically" encoded and retained such that, when participants were leaving the lab, the majority of participants had the intentions spontaneously "pop into mind." This was especially true for the cell phone (60%–70%) compared to the tracker (30%–40%). For habitual PM tasks like remembering to bring one's cell phone, keys, and so forth, habitually checking for them upon leaving likely supports remembering for both explicitly encoded and autonomically encoded tasks.

We use the term, "autonomic encoding," to capture PM tasks that are encoded in the absence of explicit/conscious awareness. We propose the term "autonomic" because we believe that the terms "incidental" and "implicit" fail to capture the type of habitual PM involved in remembering to bring one's baby or cell phone with them. This is because (a) such intended actions are intentionally encoded—one knows that one needs to care for one's child (or bring one's cell phone with them for that matter)—and (b) the situation requires an explicit/declarative/volitional action—the behavior does not occur implicitly or without awareness. The term "autonomic" is used here to describe this unique type of PM and is adopted from the term used to describe the body's regulation of involuntary actions via the autonomic nervous system, although we do not intend to directly connect the two.

We suspect that autonomic PM operates subconsciously, but, just as one can engage conscious control over autonomic functions like breathing (e.g., during mindfulness meditation), conscious control over autonomic PM processes can also be engaged to help support PM. When a caregiver puts a baby in the car seat for a drive, they clearly formed an intention to bring the baby with them somewhere. Nonetheless, our results show that explicit encoding did not significantly reduce PM errors. This highlights an important role for autonomic processes in PM.

These findings are consistent with at least two studies. Kvavilashvili et al. (2013) also examined PM for a task involving a personal belonging (wristwatch) that they suggested was "implicitly formed." The authors concluded that "the conscious formation of an intention may not always be necessary for successful remembering as stipulated in the prospective memory literature" (p. 873). More recently, Scullin et al. (2018) probed the thoughts of 680 participants during the encoding of PM intentions in eight experiments and found that participants frequently reported mind-wandering, "hardly thinking about the PM task," or engaging in idiosyncratic, "perfunctory" processes rather than following the experimenter's explicit instructions. The authors concluded that participants often encode PM intentions with little effort, that variability in encoding effort often has little effect on PM remembering, and that PM intentions are often encoded "in passing."

We propose the term "autonomic" encoding to capture this unique, understudied form of PM intention formation and recommend that the concept be incorporated into PM theories. As it relates to cases of a forgotten baby, we suspect that autonomic encoding is the default method by which caregivers form the intention to bring their baby with them, and this form of PM encoding is typically sufficient. However, errors can occur when there is a constellation of other contextual factors, for example, divergence from habitual routine, sleep deprivation, stress, distraction, and so forth (Diamond, 2019). The implications for this form of autonomic intention formation in terms of the culpability and legal consequences when errors do occur are briefly discussed below.

Retention Interval

One finding of the present study that may be surprising, which has important implications for understanding PM in the real-world and cases of forgotten babies, is that forgetting rates were unaffected by increasing delays. Although this may be counterintuitive, PM researchers have shown that forgetting to perform intentions can occur very rapidly (Einstein et al., 2000) and be unaffected by delays between intention formation and performance (Hicks et al., 2000). For example, PM forgetting was as frequent when the interval between intention formation and retrieval was 10 weeks, 2 days, or even 10 min (Nigro & Cicogna, 2000). As it relates to cases of a forgotten baby, it may seem reasonable to assume that caregivers would be more likely to forget a child in their car after a long drive versus a short drive, but our data and other empirical evidence contradict this line of thinking. Therefore, judges, lawyers, and jurors considering cases of forgotten babies should disregard the amount of time between intention formation and failed retrieval as a potential cause.

Implications for PM Theory

PM research typically involves explicitly instructing participants to perform abstract intentions with little-to-no personal relevance during unnatural scenarios (Phillips et al., 2008). A novel aspect of the present study is that we introduce hypotheses and data regarding *autonomic PM*. The standard PM paradigm has been considerably beneficial for theory development by imposing experimental control to isolate hypothesized cognitive processes of interest. However, no model to date has incorporated a role of non-explicitly encoded intentions (Kvavilashvili, 2021; Kvavilashvili & Rummel, 2020). Because most daily PM tasks likely fall under this category, this is an important area to address in future research and PM theories.

Implications for Cases of Forgotten Babies

According to legal opinion, if a caregiver who forgot their child did not possess "mens rea"—that is, knowledge or intent of wrongdoing at the time of their inaction—a crime has not occurred, and the caregiver should not be prosecuted for criminal culpability or negligence (Breitfeld, 2020). As described in Weingarten's (2009) Pulitzer Prize-winning article on cases of forgotten babies, "if you're capable of forgetting your cell phone, you are capable of forgetting your child … [these are] failures of memory, not of love."

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Supplemental Material

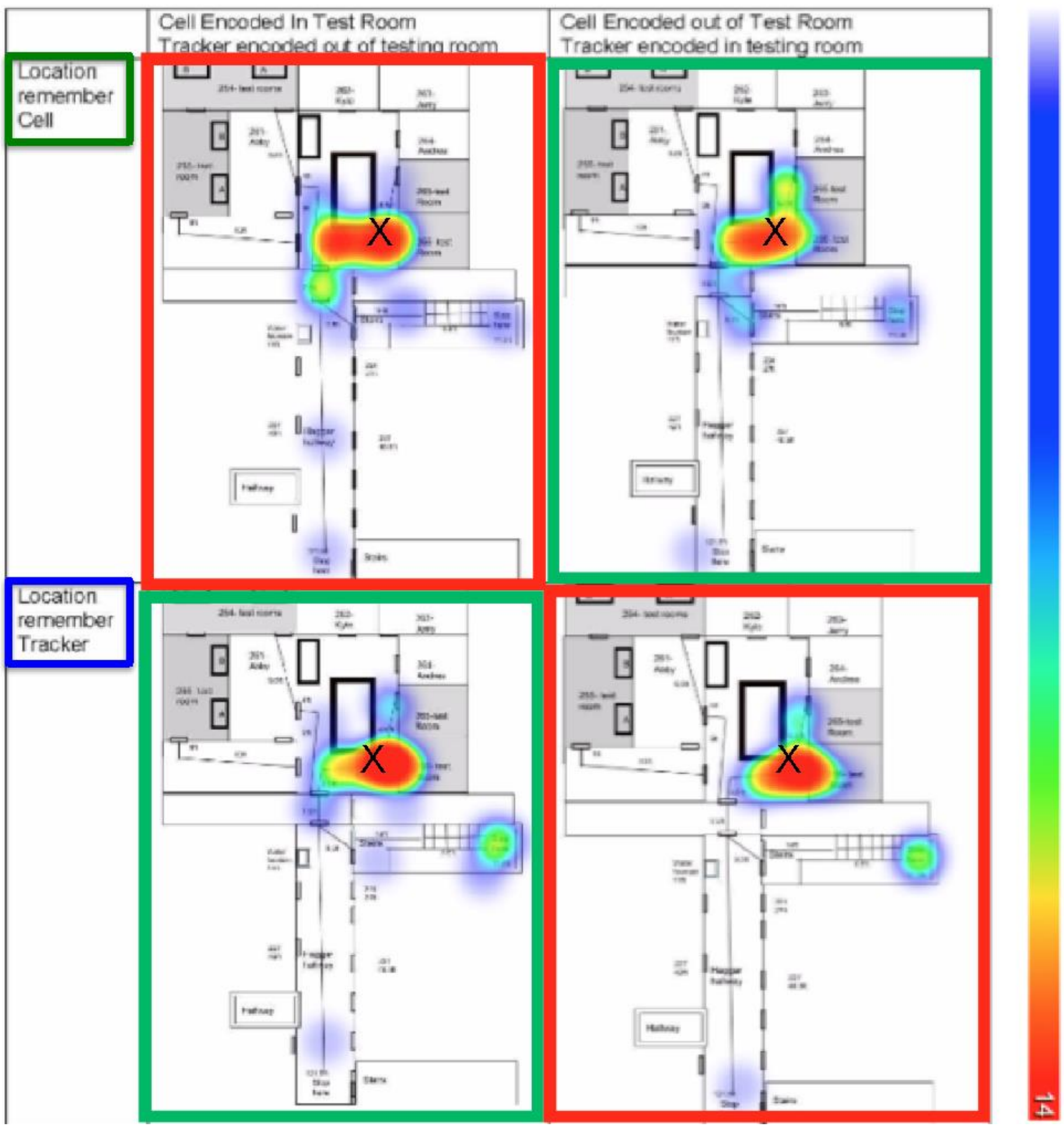
As described in the main text, two additional hypotheses were tested to examine the extent to which 1) forgetting rates could be reduced when there was a match between the locations where the items were encoded and where they were to be retrieved, and 2) remembering would occur when students passed through doorways. Due to issues with the psychometric properties of the measurement of these effects, details about the motivation, predictions, results, and discussion regarding these hypotheses are reported below for the interested reader and for the sake of transparency:

1. Based on prior research from the PM literature, we suspected that forgetting would be worse when there was a mismatch between the location where intentions were initially formed and where they were to be retrieved (Hannon & Daneman, 2007), so we manipulated the locations where the cell-phone was taken from the participant (inside or outside of the testing room); the tracker was given to the participant in the opposite location; the locations were counterbalanced across participants.
2. Does walking through a doorway trigger retrieval of the intentions? Based on prior research from the event-segmentation literature, we hypothesized that the location where participants would stop to remember to ask for their cell-phone back or return the tracker would cluster around doorways (Radvansky & Copeland, 2006). In one field experiment, Sellen et al. (1997) gave Xerox workers badges and measured their naturalistic PM, as well as their thoughts about the intentions and where they occurred, which was usually in the stairwell and around doors.

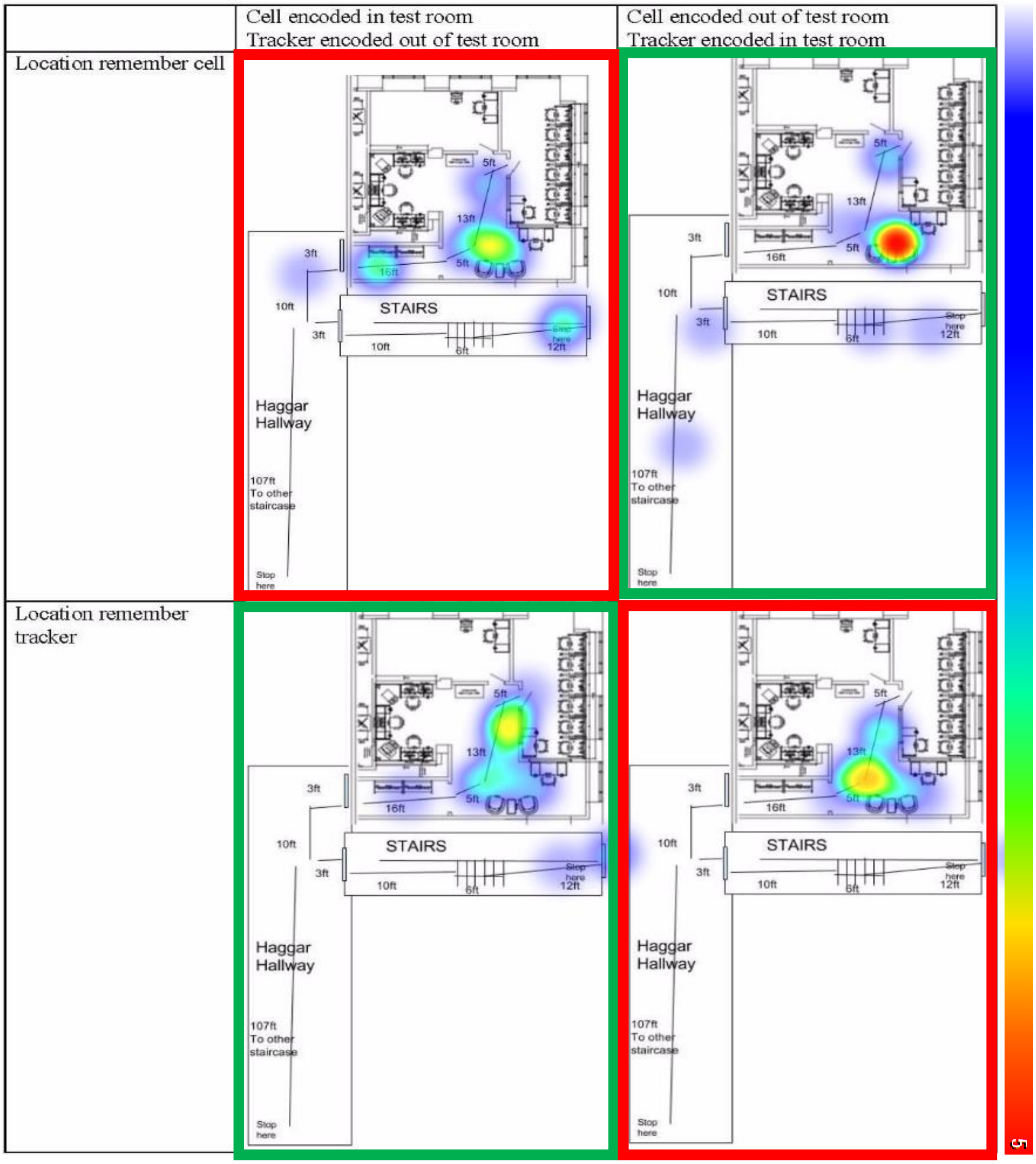
Methods and Analyses

In order to test these hypotheses and also to analyze the data using a less stringent/categorical definition of memory success that may be more sensitive to differences between conditions, we computed the distance from the location in the lab where the tasks were to be remembered and the location where the participant actually did stop to ask for their phone or return the tracker. How far the person traveled before they remembered is a proxy to capture the degree of forgetting using a continuous measure. When the participant truly forgot and had to be stopped before leaving the building, the maximum distance from the target location was recorded. This distance-traveled measure also allowed a more fine-grained assessment of a potential difference in memory performance when there was either a match or mismatch between the locations where the intentions were formed and to be retrieved. However, this measure was not normally distributed and square-root transformation failed to correct for non-normality. Therefore, we refrained from analyzing these data and exercised caution with interpreting them.

We manipulated where the items were encoded, so that we could measure forgetting when there was either a match or mismatch between where they encoded the intention and where it was to be retrieved and performed. The heat maps and lab layout/floorplans in Figure 3 show where participants stopped to ask for their phone back or return the tracker in each of the four conditions, with warmer colors reflecting higher numbers of participants. Although some research has shown that PM forgetting was worse when there was a mismatch between the location where intentions were initially formed and where they were to be retrieved (Hannon & Daneman, 2007; Henry et al., 2020; McDaniel, Robinson-Riegler, & Einstein, 1998; Nowinski & Dismukes, 2005), there was not a clear difference in the clustering of where most people retrieved the intention when there was a match or mismatch between where the intention was formed and where it was to be enacted. There also was not a clear clustering around any of the doorways that people walked through. There was clustering around the exit of the building because this is where we stopped the participants who forgot before they left the building. To quantify performance for analysis, we computed the distance from where participants were to perform their intentions and where they actually stopped and remembered—or where we stopped them before they left the lab. This confirmed what the heat maps show, that there was no difference in whether there was a match or mismatch between encoding or retrieval. However, as discussed below, due to issues with the psychometric properties of the distance traveled measures, as well as variability between the physical locations, distances, and the number and types of doorways that participants had to travel between intention formation and retrieval between the two testing labs, we caution forming solid conclusions and inferences based on these results. Future research is needed to establish more reliable and valid measures to assess the effects of an encoding/retrieval match vs. mismatch and passing through doorways on spontaneous retrieval of non-explicitly encoded PM intentions.



Supplemental Figure 1. Overview of the lab layout and the locations where participants remembered to retrieve their cell-phone or return the experimenter's activity-tracker in the four conditions where there was a match (green border) or mismatch (red border) between the locations where the intentions were encoded and where they were to be retrieved and performed (X marks the spot). (Heatmap for lab 2 is presented in the Supplemental Figure 2.)



Supplemental Figure 2. Floorplan and Heatmap distribution of distances traveled before remembering cell-phone and tracker for Lab 2. Highlighted in green is when there was an encoding-retrieval match, and in red is an encoding-retrieval mismatch.

Supplemental Table 1. Proportions (and Ns) of participants who forgot to retrieve their cell or return the tracker either before leaving the building or before leaving the lab in the Non-Explicit (n=108) and Explicit (n=84) encoding conditions; the remaining participants correctly remembered inside the lab.

Object Encoding Condition	Forgot	Left the lab, remembered later
Cell		
Non-Explicit	0.074 (8)	0.194 (21)
Explicit	0.048 (4)	0.048 (4)
Tracker		
Non-Explicit	0.176 (19)	0.037 (4)
Explicit	0.179 (15)	0.012 (1)

Supplemental Table 2. Numbers of participants who forgot both the cell and tracker, forgot one but remembered the other item, or remembered both items in the Non-Explicit and Explicit encoding conditions.

Encoding Condition		Forgot Tracker	Remember Tracker
Non-Explicit Encoding	Forgot Cell	1	7
	Remember Cell	18	82
Explicit Encoding	Forgot Cell	2	2
	Remember Cell	13	67

When participants remembered both the cell-phone and tracker, we asked them if remembering one item cued them to remember the other item. Those numbers and percentages are reported below in Supplemental Table 3.

Supplemental Table 3. The numbers and percentages of participants who reported that remembering one item cued them to remember the other item split by the conditions.

Encoding Condition	Reported that tracker cued cell memory	Reported that cell cued tracker memory
Non-Explicit Encoding	11/75= 14.6%	4/7= 57.1%
Explicit Encoding	19/55= 34.5%	11/12= 92%

When people remembered their cell first and remembered both items, the cell was more likely to be a memory trigger to remember the tracker compared to when people remembered the tracker first. Likewise, one item was more likely to trigger memory for the other in the explicit encoding condition than the non-explicit encoding condition.

Supplemental Discussion:

As shown above, there was no difference in forgetting rates when there was a match vs. mismatch between the location where the intentions were formed and where they were to be retrieved. Previous research has shown that PM performance is enhanced when there is a match between the type of cognitive processing at encoding and retrieval (e.g., McDaniel et al., 1998). We suspected that this phenomenon, which reflects the broader principles of 'encoding specificity' and 'transfer-appropriate-processing', would also be true when there was a match vs. mismatch in the physical locations where the intentions were encoded and where they were to be retrieved. A match in the environmental contexts between encoding and retrieval, such as between a classroom where learning and testing occurs, has long been known to facilitate retrospective memory (Smith, 1979). With regards to PM, both researchers and laypersons report anecdotal evidence for this phenomenon, such as when an intention to get something from the kitchen is formed while sitting on the couch in the living room, but cannot be retrieved while inside the kitchen, yet does come back to mind upon returning to the living room. While such anecdotes may be common and reflect a fundamental principle of memory, we did not find evidence for an effect of a match/mismatch of the encoding and retrieval context on PM performance in this study. This may be because the context shift from encoding the intention in the lab vs. inside the testing room and retrieving it before leaving the lab was rather minimal. Also, the distance traveled metric did not have sufficient psychometric properties to be able to validly test this hypothesis.

Future research with more valid measures and stronger context shifts are needed to adequately test this hypothesis.

Based on event segmentation theory and evidence that walking through a doorway affects memory updating and consolidation (Radvansky et al., 2011; Radvansky, & Zacks, 2017), we hypothesized that the context shift of walking through the doorway of the lab may have been a potent cue that affected PM retrieval. The rationale is that events are cognitively segmented by changes in physical boundaries, and such event segmentation plays a fundamental role in memory encoding, consolidation, and retrieval. We thought that, because the intentions were formed inside the lab, physically crossing the boundary (the doorway) would result in memory updating processes that may have cued the need to consolidate memory of the events that occurred inside the lab and begin the encoding and consolidation of a new, temporally and spatially segregated memory of the new event (traveling from the lab to accomplish one's next goal, e.g., going to the cafeteria for lunch). When participants forgot to retrieve their phone or return the tracker inside the lab, we thought that "spontaneous" retrieval would occur when they passed through the doorway. That is, when PM intentions are non-explicitly encoded and retained at a latent, "autonomic" level, we hypothesized that participants would be signaled that they were leaving an object of value in (or taking one from) the location inside the previous event boundary. We expected to see that the locations where participants stopped and turned to ask the experimenter for their phone back or return the tracker would cluster around the doorway of the lab, especially in the non-explicit encoding condition. However, as seen in the heat maps of the lab and building floor plans, we found no evidence of such spontaneous retrievals clustering around the doorway. Again, we suspect that this may be because the strength of the context shift of moving from inside the testing room in the lab to the hallway to exit the building was insufficient to systematically elicit spontaneous retrieval at that precise location across participants. Also, the variability in the number and type of doorways that were passed through between the two labs, and variability in the distances between the numerous doorways and the locations where the intentions were formed may have undermined our sensitivity to detect such effects. Future research in more consistent and constrained environments, perhaps with stronger context shifts, is needed to more rigorously test this hypothesis.

Anecdotally, the phenomenon of forgetting an intended action (e.g., turning off an appliance), but then retrieving the intention shortly after leaving one's home is a commonly reported PM error. What signals such spontaneous retrieval at that particular time and location? Intuitively, it seems like there is a clear role of event boundaries and the act of entering vs. exiting physical locations in triggering

PM retrieval, especially for PM target locations that should cue retrieval and initiation of PM intentions associated with the beginning or end of a target event. Although we did not find evidence to support these hypotheses in the current study, we think this is an important area to be addressed by future PM research and we propose the current and related designs as potentially fruitful methods to address such questions.

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