Hey buddy, why don't we take it outside: An experience sampling study of prospective memory

Francis T. Anderson¹ · Mark A. McDaniel¹

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Abstract

Relatively little research has focused on how prospective memory (PM) operates outside of the laboratory, partially due to the methodological problems presented by naturalistic memory research in general and by the unique challenges of PM in particular. Experience sampling methods (ESM) offer a fruitful avenue for this type of research, as recent work from Gardner and Ascoli (*Psychology and Aging*, 30, 209–219, 2015) has shown. They found that people thought about PM around 15% of the time, and that future thinking was more common than past thinking. In two studies, we replicated our own findings and those reported by Gardner and Ascoli. To summarize, people think about the future more often than the past (30% compared to 13%), and PM occupies our thoughts approximately 13–15% of the time, supporting claims made by some researchers that our episodic memory systems are forward-looking (Klein in *Journal of Applied Research in Memory and Cognition*, 2, 222–234, 2013). Of those PM thoughts, participants reported that 61% were internally cued, rather than externally triggered. Through the use of multi-level modeling, we additionally found that PM thoughts were more likely when the respondent was alone than with people, and earlier in the day. Finally, we found that participants higher in neuroticism were more likely to report thinking of PM, and that this was driven entirely by the anxiety facet. Most generally, we hope to have demonstrated the value of ESM to help researchers investigate and understand naturalistic PM.

Keywords Prospective memory · Experience sampling · ESM · Momentary thoughts · Future thoughts

Introduction

Prospective memory (PM) is the ability to remember to perform an intended action at a specific time or event in the future (Einstein & McDaniel, 1990). In recent years, much basic research has been devoted to understanding the cognitive processes that underlie successful PM retrieval and performance (see Anderson, McDaniel, & Einstein, 2017, for a current review). Much less research, however, has focused on how PM operates outside of the laboratory, partially due to the methodological problems presented by naturalistic memory research in general and by the unique challenges of PM in particular. Notably, key features of PM – such as its “one-off” nature (i.e., usually there is only one opportunity to

successfully perform the intention), the fact that PM must be self-initiated (rather than experimenter-cued or reminded), and the potential for introducing demand characteristics regarding the nature of the study – create barriers to investigating PM outside the laboratory.

Assessing the importance of PM in daily life

Intuitively, it stands to reason that PM is an important aspect of functional living when one considers the numerous PM challenges people face every day. In addition to the dozens of habitual PM tasks most healthy people successfully perform (e.g., remembering to brush one's teeth, take medication, or pack gym clothes before work), people must remember to perform a host of less frequent actions such as remembering to get groceries, take an umbrella on a rainy day, or buy a loved one a birthday present. Yet, establishing the importance of PM in daily life has required some creative methodological approaches. Crovitz and Daniel (1984), for example, asked participants to keep a forgetting diary, in which they were asked to record the nature of anything they became aware of forgetting. They found that

✉ Francis T. Anderson
anderson.f@wustl.edu

¹ Department of Psychological and Brain Sciences, Washington University, 1 Brookings Dr, Campus Box 1125, St. Louis, MO 63130, USA

around 50% of reported episodes of forgetting were prospective in nature. Similarly, anecdotal reports from both Einstein and McDaniel (1996) and Kliegel and Martin (2003) note that when their students were asked to introspect and determine their most recent experience of forgetting, over half were PM failures. Taking a different approach, both Marsh, Hicks, and Landau (1998) and Ellis and Nimmo-Smith (1993) asked participants to list their upcoming PM intentions, to go about their lives, and then return to the laboratory to assess the success or failure of those intentions. Marsh et al. found that participants reported an average of 15.5 intentions per week they needed to complete, with a completion rate of approximately 70–75%, and Ellis and Nimmo-Smith found that participants reported an average of 23.5 intentions with an 88% completion rate.

More recently, ecological momentary assessment (EMA) or experience sampling methods (ESM) have gained traction in understanding the nature of people's cognitive experiences in everyday life. ESM can be employed in a number of ways, ranging from self-initiated diary studies like those previously mentioned, to externally prompted surveys triggered by beepers or cell phone notifications. Further, ESM can be used in a variety of settings, with participants receiving prompts or probes while performing a laboratory task or while going about their normal lives (Scollon, Prieto, & Diener, 2009). For example, Sellen, Louie, Harris, and Wilkins (1997) measured PM in the workplace using "active badges." Participants were given PM tasks to complete during their normal working lives, and were to click their badges when they remembered to perform the PM task and when they were thinking about the PM task. Participants thought about the task 4.4 times per day, with a success rate of approximately 42%. Thoughts about the task decreased over the course of the week, and participants were more likely to think of the PM task in transitional settings (e.g., stairwells or hallways) than in settled locations (e.g., at one's desk).

Although ESM offers a promising approach to studying PM in everyday life, it has not been until recently that technological solutions to programming, statistics, and other methodological challenges have become available to facilitate the use of ESM. Accordingly, there are only a few ESM studies relating to PM. A handful of these ESM studies offer insight into people's ability to plan for the future but do not directly focus on PM. In the following sections, we synthesize the ESM research that has sampled momentary conscious experience as it relates to future-oriented thought and secondarily to PM. Then, we review the first study to use ESM to directly assess the natural frequency of PM in daily life (Gardner & Ascoli, 2015). Building on that novel study, we present two studies that were conducted to more clearly distinguish PM-related thoughts from general future-oriented thoughts, and to demonstrate the potential of ESM for the study of everyday PM.

Momentary sampling of conscious thoughts

Humans have the ability to engage in mental time travel, reconstructing events from the past and constructing possible events in the future (Szpunar, 2010). Some researchers have gone so far as to claim that the primary reason for our episodic memory systems is to anticipate future events and prepare ourselves for action (De Brigard, 2014; Irish & Piguet, 2013; Klein, 2013; Szpunar, Spreng, & Schacter, 2014; Tulving, 2005). From an evolutionary perspective, our evolved brain structures and the corresponding behaviors they enable must serve as functional mechanisms for enhancing survival and fitness. As such, Klein (2013) argues that our memory systems directly serve envisioning and planning for the future. Beyond logic and introspection, however, there has been little research validating this claim. The potential for ESM to directly tap into people's momentary conscious experiences allows us to examine this proposition more closely: If memory serves the future, there should be a healthy bias in prospective thinking, as people plan for and anticipate challenges.

Much of the research using ESM to sample momentary thoughts is tangential but related to PM (often focused on mindwandering) in that researchers have been more broadly interested in whether or not people are focused on the task at hand, and if not, what the quality of those thoughts are. Specifically, when people mindwander, are they apt to think about the future, and if so, are these future-oriented thoughts related to planning and remembering to perform intentions? Several studies using random thought probes in the laboratory during a cognitive task, for example, have taken note of a "prospective bias" in mindwandering, in that off-task thoughts were more frequently categorized as being about the future (Baird, Smallwood, & Schooler, 2011; Smallwood, Nind, & O'Connor, 2009; Smallwood et al., 2011; Stawarczyk, Cassol, & D'Argembeau, 2013; Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011, however, see Plimpton, Patel, & Kvavilashvili, 2015).

Sampling momentary thoughts in people's daily lives has generated less research, but is especially interesting because it helps avoid many of the demand characteristics of the laboratory, and samples a large range of experiences, resulting in considerable variability in thoughts between and within people. In a variety of studies, Cameron (1972) simply asked people (unexpectedly, mostly using area sampling by going door-to-door) what they were thinking about in the previous instant. The study found that the majority of thoughts were present-oriented (67%), followed by future-oriented (25%), and finally past-oriented (8%). Klinger and Cox (1987) randomly prompted participants to report their thoughts when a beeper rang during a normal day, and found that people were thinking of the present 67% of the time, either the past or future 12% of the time, and had no particular time orientation 11% of

the time. Partitioning thoughts only into mindwandering episodes, Song and Wang (2012) found a strong prospective bias to mindwandering, with 40% of thoughts devoted to thinking about the future (present 16% and past 22%). Looking at future thoughts only, D'Argembeau, Renaud, and Van der Linden (2011) had participants record all of their future-oriented thoughts when going about their daily lives and 52.5% of those reported were devoted to planning actions.

When considering these findings in concert, there are some commonalities. In nearly all studies, whether sampled in or outside of the laboratory, people largely tended to be on-task and focused on the present. However, when people were not focused on the present (perhaps mindwandering), there appears to be a prospective bias in the laboratory, but results are inconclusive when sampling outside the laboratory. Finally, many of people's future-oriented thoughts may be directly relevant to PM, in that they are often devoted to planning for the future.

Measuring the natural frequency of PM

Gardner and Ascoli (2015) more directly assessed the frequency with which people think about their prospective intentions. They probed younger and older adult participants through their mobile phones, and asked them to categorize their current thought as a PM (thinking of a task or event that is to occur in one's personal future), an autobiographical memory (AM; the recall of a personally experienced episode in one's past), or the absence of a memory (e.g., focused on the task at hand). Each participant received approximately 220 prompts across an average of 19 days. Of these, 10% were categorized as AM by both younger and older adults. Whereas younger adults categorized another 10% as PM, older adults were twice as likely to be thinking about PM, at 20%.

Of note, the researchers used a somewhat different definition of PM than is typically used in the literature. They define PM to participants as:

“The recollection of a task or event that is to occur in the personal future, for example, bringing to mind an intention to stop at the grocery store on your way home from work. More generally, PM could include first person perspective thinking of future actions or events, for example, imagining the route you are going to take to arrive at the store (Gardner & Ascoli, 2015, p. 210).”

PM researchers, instead, have defined PM more narrowly as remembering to perform an intended action in the future. Specifically, PM involves first encoding an intention (e.g., I need to remember to buy dog food on my way home) that must be delayed until the appropriate time or event, and at that appropriate moment one must suspend ongoing activity (i.e., driving home) to perform the intended action. In the context of the present study, we suggest that the estimates of

PM reported by Gardner and Ascoli (2015) possibly encompassed both PM and more general future-oriented episodic thought (see Schacter, Addis, & Buckner, 2008). That is, someone could be thinking generally about the future, such as imagining the movie they are going to go see later on, and incorrectly classify this as PM (under the Gardner & Ascoli, 2015, procedure). If, however, someone was thinking about needing to remember to bring cash to the movie theater because it does not accept cards, then this would be a correct PM classification. The latter case is PM because the person generated a specific intention that must be delayed until later. Further, Gardner and Ascoli limited the potential variability in momentary thoughts to the narrow categories of AM, PM, or other, which could bias the observed relative rates (i.e., in moments of indecision, participants may have been more inclined to respond PM or AM rather than other).

Study 1

The present study was conducted to more directly isolate PM-specific thoughts, and to provide a more comprehensive range of options in which to categorize people's current thoughts. Toward that end, we defined PM to our participants as: “I was thinking about something specific I need to remember to do in the future (e.g., do laundry, get groceries, turn in assignment).” In addition, we provided people with another future-oriented response category, two past-oriented categories, and two present-oriented categories.

We followed Gardner and Ascoli (2015) by collecting subjective estimates of thoughts, to determine whether participants are cognizant of their daily conscious experiences. There has been some research showing that people lack meta-awareness or meta-consciousness in that they are unaware of their own tendency to mindwander (especially under cognitive load; Baird, Smallwood, Fishman, Mrazek, & Schooler, 2013; Smallwood & Schooler, 2006). Research more broadly focused on metacognition has also found that students are poor at predicting future test performance (Callender, Franco-Watkins, & Roberts, 2016; Nelson & Dunlosky, 1991) or the correctness of their responses on a test (Rawson & Dunlosky, 2007) without experimenter intervention. However, Callender et al. (2016) were able to boost metacognitive accuracy with feedback and practice. Gardner and Ascoli found that participants were accurate in estimating the relative proportions of PM and AM, but it is possible that these broad categories did not require making more difficult, fine-grained distinctions, resulting in good metacognition. Therefore, we were interested in whether meta-consciousness of momentary thoughts is fallible, and if so, whether it can be improved by participants spending a week classifying their thoughts (i.e., practice).

Most generally, we were interested in informing the theoretical idea developed by Klein (2013) and others (De Brigard,

2014; Irish & Piguet, 2013; Szpunar et al., 2014; Tulving, 2005), that there should be prospective bias to momentary conscious experience, and to test the hypothesis that prospective thinking is focused on planning for future events and contingencies. This idea is based on the argument that memory was designed by natural selection to anticipate and plan for the future, and thus that people are generally oriented to respond to the “now and the next.” By splitting future-oriented thought into both PM and more general episodic future thought, we can estimate what proportion of our future thoughts are directly related to planning for and executing future intentions.

Our final objective was to explore what factors are associated with the nature of people’s momentary conscious experience. Following Sellen et al. (1997), we included as predictors of participants’ self-rated categories of thoughts whether or not people were alone, time (both time of day and across the duration of the study), and location (at work/school, home, or other). We additionally coded responses as occurring on a weekend or a weekday, following Gardner and Ascoli (2015). In both of these studies, there are limitations in directly assessing the influence of these variables on PM. We have noted that PM is hard to tease apart from general future-oriented thought in the Gardner and Ascoli study, but we should also mention that the Sellen et al. study of PM was restricted to experimenter-imposed intentions in a work context. By incorporating the predictors of both studies, we can extend their findings to concretely measure these predictors’ influence on individuals’ natural thinking of PM in an everyday context.

Method

Procedure Participants were 61 Washington University in St. Louis undergraduates who received course credit or monetary compensation. There were no experimental conditions; all participants knew they would participate in an experience sampling study attempting to estimate the relative rates of future, past, and present thoughts (with no explicit mention of PM). Surveys were created and administered using Qualtrics, and text message signals were sent to participants’ phones (containing a link to the survey) using Survey Signal software. The experimenter explained all procedures and survey questions, answering any questions people had and providing numerous examples about how to categorize their thoughts.

After enrolling their phone to receive text message alerts, participants left the laboratory and did not come back for the duration of the study. They began receiving surveys the next day. Both at the beginning and the end of the study, participants were emailed a questionnaire asking them to assess, on a scale of 1–10, how often they estimate thinking about each of these seven response options in their daily lives. In doing so, we can determine the accuracy of people’s meta-consciousness, and if this changes as a result of spending a week categorizing their thoughts.

Experience sampling Five text message alerts were sent each day, over the course of 6 days, bringing the total number of possible surveys to 30 per participant. Signals occurred randomly between 9 a.m. and 10 p.m., with no less than an hour separating signals. We intentionally kept the number of surveys low enough to not be considered a burden, and more importantly, so participants would not be thinking about the study all of the time. This must be balanced with giving the participants enough opportunities to successfully model their data (we wanted at least 20 responses per participant on average). Enrollment in the study always took place during a weekday, ensuring that both weekend days and weekdays were sampled for each participant. Further, the window of time a participant had to answer an individual survey was 1 h, after which the survey was inaccessible. They were encouraged to respond immediately upon seeing the signal; however, if they were in the middle of something important, such as driving, they were told to still complete the survey at a later point. In this eventuality, participants were asked to report the thought they had, for example, while driving, rather than the thought they had upon actually filling out the survey (e.g., once they had finished driving). Using these procedures, we sought to minimize the number of incomplete surveys, without asking participants to rely too heavily on their long-term memory. Participants were informed of all of the preceding information.

For each survey, questions remained in the same order. The first and primary question was, “What were you thinking about directly prior to receiving this prompt?” Seven responses were available, as seen in Table 1, and the placement of each option was randomized for each individual survey. Though we were primarily interested in the frequency of thoughts related to PM, special care was taken not to bias participants, and each of the seven options were given equal consideration, emphasis, and

Table 1 Response options for the primary survey question: “What were you thinking about directly prior to receiving this prompt?” and their codings

Coding	Response option
PM	I was thinking about something specific I need to remember to do in the future (e.g., do laundry, get groceries, turn in assignment)
Future	I was thinking about the future, generally (e.g., upcoming events, life goals, etc.)
AM	I was thinking about past life events (e.g., what I had for breakfast, if I took my medicine today, summer vacation)
SM	I was trying to remember specific information that I know (e.g., definition of a word, someone’s name, class content)
On Task	I was completely focused on the task at hand (e.g., studying, socializing, watching TV)
Nothing	I wasn’t thinking about anything in particular, nor was I focused on a current task (e.g., meditating or napping)
Other	Other

explanation. The second question asked participants if they were at home, work/school, or other. The third question asked if they were with people or alone. The fourth and final question asked if they saw the notification because their phone buzzed/rang, or because they were on their phone for other reasons (e.g., checking the time). The final question was included in order to determine if the quality of thoughts differ when one is already on the phone as opposed to going about daily life.

Statistical methods Experience sampling data have a naturally hierarchical structure, requiring the use of hierarchical linear modeling (HLM). In this case, the outcome variable of survey responses (Level 1) is nested within participants (Level 2). Therefore, one would expect the responses of each individual participant to be more similar than responses across participants (i.e., the intra-class correlation; ICC). Further, HLM is necessary to account for variability in responding between participants (i.e., some participants will answer more surveys and thereby contribute more data, increasing their reliability). In this study, our primary dependent variable is multinomial, as there are seven options to the survey. Therefore, we recoded responses to be compatible with a standard logistic regression model, such that participants either reported thinking about PM or not (0, 1), for example, and applied a logistic HLM using the *glmer* function in the *R* package *lme4* (Bates, Maechler, Bolker, & Walker, 2015).

Continuous predictors (e.g., time of day in hours) were group-mean centered (i.e., within participants), and dichotomous predictors (e.g., weekend, weekday) were coded with 0s and 1s. In the case of each individual model, we first allowed both slopes and intercepts to vary between participants, and

then tested whether a simpler model only allowing intercepts to vary was significantly different. If not, then the simpler model was favored. The best interpretation of logistic regression is by using Odds Ratios (OR; Hosmer, Lemeshow, & Sturdivant, 2013). The OR is the odds that an outcome will occur (in this case, thinking about PM), compared to the odds of the outcome not occurring for a one-unit increase of a certain predictor. For example, if we code a dichotomous predictor 0 and 1, then an OR of 1.5 would indicate that the odds of thinking about PM are 1.5 times greater at coding 1 than they are at coding 0. (For a detailed explanation of the statistical methodology required for experience sampling and other longitudinal data, see Bolger & Laurenceau, 2013.)

Results

Descriptives and ANOVA results Sixty-one participants responded to an average of 83.7% ($SE = .014$) of the surveys, resulting in 1,531 responses. After a survey was opened, it took participants 56 s on average to complete the survey. As seen in Fig. 1, of these responses, 17% ($SE = .014$) were thoughts about PM, 13% ($SE = .012$) were thoughts about the general future, 6% ($SE = .008$) were thoughts about one's personal past, 6% ($SE = .010$) were spent recalling information, 45% ($SE = .022$) were on-task thoughts, 10% ($SE = .013$) were about nothing in particular, and 3% ($SE = .007$) were labeled as "other." To determine whether or not the frequencies of thinking about these categories differed from each other, we employed a within-subjects one-way analysis of variance (ANOVA) with seven levels: one for each of our thought classifications. The number of responses in each category were

Fig. 1 Mean proportion of thoughts by category for Study 1. *PM* prospective memory, *Future* general future thoughts, *AM* autobiographical memory (past life events), *SM* semantic memory

(recalling information), *On task* focused on task, *Nothing* nothing in particular, *Other* none of the previous classifications. Error bars represent standard errors

summed within participants, and were all significantly different from each other ($p < .05$) except that future thoughts were not different from thoughts about nothing, and thoughts about one's personal past were not different from thoughts spent recalling information, $F(6, 360) = 98.55$, $MSE = 8.016$, $p < .001$. Collapsing across future, past, and present categories, we found that they were all different from each other, $F(2, 120) = 79.53$, $MSE = 22.25$, $p < .001$, with present thoughts ($M = .55$, $SE = .024$) being the most prevalent, followed by future ($M = .30$, $SE = .020$) and then past ($M = .12$, $SE = .013$) thoughts.

Regarding our predictor variables (see Table 2), we found that participants were most likely to be at home, followed by at work/school, and least likely to be somewhere else. The average time of day was 2:40 p.m. Participants were with other people around half of the time, and were already on their phones around half of the time. Lastly, nearly three-quarters of the surveys occurred on a weekday. In the next set of analyses we examined whether these factors were associated with the frequency of reported PM thoughts.

Predicting PM thoughts When estimating the full model, examining the effects of our predictors on PM and allowing both slopes and intercepts to vary, the model failed to converge because we had too many predictors and not enough observations. Therefore, in our PM model (see Table 3), we instead allowed only intercepts to vary randomly but included all predictors. We then created individual models for each of the significant predictors, allowing both slopes and intercepts to vary. In no case did the variance of slopes reach significance, so we elected to only let intercepts vary. Before testing the model, we first checked whether thinking about PM changed over the course of the study (i.e., did participants naturally begin to think about PM more as the week went on?). This was not significant, implying that the act of filling out the surveys themselves did not influence PM. Next, looking at the PM model, we found that participants were 1.87 times more likely to think about PM when they were alone than

Table 2 Mean estimated proportions of the predictors and their standard errors for Study 1

	Work	Home	Other	Time	With others	Weekday	On phone
Mean	.31	.48	.21	14.66	.53	.70	.46
SE	.020	.020	.020	.044	.020	.030	.009

Note. *Work, Home, and Other* were part of the same question asking participants where they were at the time of the survey. *Time* refers to time of day in hours (e.g., 14.66 is equivalent to 2:40 p.m.). *With Others* is the proportion of surveys they completed around other people. *Weekday* refers to the number of surveys on a weekday. *On Phone* refers to the proportion of surveys received when already on their phone, rather than interrupted in daily life

Table 3 PM Model in Study 1 allowing only intercepts to vary randomly

	PM		
	Odds ratio	CI	p
Fixed parts			
(Intercept)	0.13	0.08 – 0.20	<.001
With People (0) Alone (1)	1.87	1.37 – 2.56	<.001
Time of Day (Hr)	0.96	0.93 – 1.00	.064
Not at Work (0) At Work (1)	0.96	0.62 – 1.48	.858
Not at Home (0) At Home (1)	1.00	0.67 – 1.50	.995
Weekday (0) Weekend (1)	1.09	0.80 – 1.49	.568
Interrupted (0) On Phone (1)	0.99	0.74 – 1.32	.922
Random parts			
τ_{00} , Subject		0.356	
N_{Subject}		61	
ICC_{Subject}		0.098	
Observations		1531	
Deviance		1271.015	

Note. *ICC* intraclass correlation coefficient: a measure of the within-subjects correlation in responses, τ_{00} the variance between subjects' intercepts, *Odds ratio* the odds that an outcome will occur compared to the odds of the outcome not occurring (odds of thinking about PM compared to not, for a one unit increase in the predictor variable)

when they were with people ($OR = 1.87$, $p < .001$). Participants were also marginally more likely to think about PM earlier in the day, such that with each additional hour of the day, the odds of thinking about PM decreased by a factor of .96 ($OR = .96$, $p = .06$). None of the other predictors was significantly associated with PM thoughts.

Predicting non-PM thoughts Using the same procedures, we followed in estimating the PM model, we examined the effects of our predictors on the other thought classifications. Thoughts about the general future were marginally less likely when participants were at home ($OR = .69$, $p = .08$). Thoughts about one's personal past were marginally less likely when participants were at work/school ($OR = .56$, $p = .07$). Thoughts spent recalling information were significantly more likely when participants were at work/school ($OR = 2.43$, $p = .009$). Participants were significantly more likely to label their thoughts as being focused on the task at hand when they were with people ($OR = .54$, $p < .001$), as the day got later ($OR = 1.04$, $p = .02$), and when they were interrupted/not already on their phones ($OR = .74$, $p = .01$). Participants reported thinking about nothing in particular marginally more often when they were alone ($OR = 1.46$, $p = .08$). They were also significantly more likely to think about nothing earlier in the day ($OR = .93$, $p = .003$), when they were at home ($OR = 2.11$, $p = .009$), when it was the weekend ($OR = 1.58$, $p = .02$), and when they were already on their phones ($OR = 1.87$, $p = .001$). The thoughts labeled "other" were not

modeled because there were not enough observations (3%) and the model failed to converge. We again checked whether thinking about any of the other options changed over the course of the study. We found that thinking about nothing was significantly more likely later in the week ($OR = 1.02, p < .001$), and that this effect was entirely driven by the increased likelihood to think about nothing over the weekend. That is, when the weekend predictor was added to the model, the effect of time was no longer significant, whereas the weekend effect was. No other effects were significant.

Meta-consciousness In order to determine whether or not people had awareness of the frequency of their conscious experiences in terms of past, present, and future orientations, we asked participants to judge on a scale of 1–10 how often they estimate thinking about each of the seven response options in daily life. We then calculated a relative proportion for each thought type within participants by dividing each individual rating by their total rating sum. As an unrealistic example, if a participant responded 10 out of 10 for every option, then we would divide the 10 they reported for PM by 70 to determine that they think about PM approximately 14% of the time. We correlated participants' actual proportion of thoughts for each category with their predicted proportion, both before and after participating in the study. In general, participants were far more accurate after completing the study (average r across response options = .41) than they were before the study (average $r = .25$). Individual correlations are shown in Table 4, and the mean predicted and postdicted proportion of thoughts for each category are shown in Table 5.

Before discussing these results, we report a second study that confirms the stability of the patterns, as well as extends our investigation to several new issues.

Study 2

In Study 2, one key goal was to replicate the results from Study 1. Due to the relatively few reports thus far that have used ESM to investigate PM, we wanted to ensure that participants' responses were reliable estimates of the nature of

people's momentary conscious thoughts. To provide additional confidence in the patterns, in this study we doubled our sample size ($N = 122$).

Another important goal was to apply the ESM approach to studying three components of PM that have received little attention in the literature. First, our participants completed a Big-Five personality battery, enabling us to determine if individual differences in personality predict the likelihood of thinking about PM. An early informal observation about PM was that in everyday life, people appear to attribute others' PM failures to poor conscientiousness, an attribution that seems to be rarely associated with people's retrospective memory failures (Winograd, 1988). Extending this informal observation, some have speculated that people higher in conscientiousness should exhibit better PM (Arana, Meilan, & Perez, 2008; Cuttler & Graf, 2007; Pearman & Storandt, 2005; Smith, Persyn, & Butler, 2015). The reasoning is that those higher in conscientiousness may be more likely to enlist cognitive resources to monitor (e.g., keep the PM intention in mind) and they may develop more organized plans for fulfilling intentions (see Cuttler & Graf, 2007). A few studies have attempted to correlate conscientiousness and PM, with mixed results. Cuttler and Graf (2007) found that conscientiousness predicted PM performance (for two of three PM tasks), Arana et al. (2008) found that "rule-consciousness" predicted PM, and Pearman and Storandt (2005) also found a significant correlation with conscientiousness. By contrast, Salthouse, Berish, and Siedlecki (2004), Smith et al. (2015), and Uttl, White, Wong Gonzalez, McDouall, and Leonard (2013) found no relationship between conscientiousness and PM. However, all of these findings are directed at PM accuracy (rather than PM thoughts), do not include self-generated naturalistic intentions, and are largely underpowered.

Another potential personality factor affecting PM is neuroticism. For example, more neurotic individuals may perform worse because their working memory resources are being borrowed to facilitate rumination and worry (e.g., forgetting a PM intention because you are preoccupied; cf. Rude, Hertel, Jarrold, Covich, & Hedlund, 1999, for a similar view for why depressive tendencies are associated with reduced PM performance). While most of the aforementioned studies found

Table 4 Correlations between actual and estimated proportions of thoughts both pre- and post-study

	PM	Future	AM	SM	On task	Nothing	Other
Pre	.07 (-.18, .32)	.42* (.19, .61)	.20 (-.06, .43)	.24 (-.02, .46)	.45* (.22, .63)	.23 (-.02, .46)	.11 (-.14, .35)
Post	.59* (.39, .74)	.46* (.23, .65)	.25 (-.01, .48)	.32* (.06, .54)	.42* (.17, .61)	.41* (.17, .61)	.44* (.20, .63)

Note. PM prospective memory, *Future* general future thoughts, *AM* autobiographical memory (past life events), *SM* semantic memory (recalling information), *On task* focused on task, *Nothing* nothing in particular, *Other* none of the previous classifications

Pre-study $N = 61$. Post-study $N = 56$

Ninety-five percent confidence intervals are noted in parentheses

*Correlation is significant at the 0.05 level

Table 5 Mean estimated proportions of thoughts and their standard errors both pre- and post-study

	PM	Future	AM	SM	On task	Nothing	Other
Pre	.21 (.007)	.19 (.009)	.12 (.006)	.14 (.007)	.19 (.010)	.09 (.007)	.06 (.007)
Post	.19 (.010)	.16 (.012)	.10 (.008)	.12 (.009)	.28 (.016)	.11 (.011)	.06 (.008)

Note. *PM* prospective memory, *Future* general future thoughts, *AM* autobiographical memory (past life events), *SM* semantic memory (recalling information), *On task* focused on task, *Nothing* nothing in particular, *Other* none of the previous classifications

Pre-study $N = 61$. Post-study $N = 56$

Standard errors are noted in parentheses

no effect of neuroticism on PM, Cuttler and Graf (2007) and Pearman and Storandt (2005) both found correlations with neuroticism in the *opposite* direction: Individuals with higher neuroticism had better PM. Although unexpected, Cuttler and Graf offer the possible explanation that people higher in neuroticism were more likely to worry about performing the PM task, rather than worry about other concerns which would presumably distract them from the PM task.

We also included follow-up questions more specifically targeting the nature of the participants' reported thoughts. Regarding PM follow-up questions, we asked whether or not participants reported a PM because they were forming the intention, completing the intention, or simply thinking about the intention. Additionally, participants were asked whether or not the thought was internally or externally cued/triggered. These questions were designed to help better understand the nature of thoughts related to everyday PM (i.e., outside of the laboratory), exploring aspects of PM that laboratory paradigms have thus far not considered. For example, in the laboratory, nearly all of the PM tasks are assigned by the experimenter to the participant, so we know very little about processes associated with self-initiated intention formation. The inclusion of the follow-up question concerning internal versus external cuing was intended to provide insights about the degree to which these processes, identified in laboratory PM research (e.g., Scullin, McDaniel, & Shelton, 2013; Smith, Hunt, & Murray, 2017), are present in everyday PM.

Method

Participants were again Washington University in St. Louis undergraduates who received course credit or monetary compensation; the sample size was 122 undergraduate students. The method was nearly identical to that of Study 1. We replaced the pre- and post-study meta-consciousness survey with the second edition of the Big Five Inventory (BFI-2; Soto & John, 2017). Participants completed this before beginning the ESM portion of the study. The other change was to include follow-up questions for each of our seven response options. After selecting the PM category, participants were first asked: "Were you forming the intention you were

thinking about, completing the intention, or simply thinking about an intention you had already created and have yet to complete?" They were then asked: "Was the thought triggered by an external cue (e.g., something in your environment made you think about it), or did you self-initiate the thought (e.g., you weren't reminded by anything; instead you intentionally thought about it)?" Follow-up questions for the other six options were included to reduce the likelihood of participants guessing the nature of the study. Two questions each followed PM and AM, and one question followed each of the other options. Follow-up questions are presented in Table 6.

Results and discussion

The analysis methods and the structure for presenting the results are identical to Study 1.

Table 6 Follow-up questions received after selecting one of the seven response options

Option	Follow-up questions
PM	Were you forming the intention you were thinking about, completing the intention, or simply thinking about an intention you had already created and have yet to complete? Was the thought triggered by an external cue (e.g., something in your environment made you think about it), or did you self-initiate the thought (e.g., you weren't reminded by anything; instead you intentionally thought about it)?
Future	Were you thinking about the immediate future, or long term?
AM	Were you thinking about the recent past, or distant? Was the thought triggered by an external cue (e.g., something in your environment made you think about it), or did you self-initiate the thought (e.g., you weren't reminded by anything; instead you intentionally thought about it)?
SM	Were you trying to recall general information, or was it specific to work/class?
On Task	How long have you been focused on the task?
Nothing	Can you simply not remember clearly what you were thinking about, or were you genuinely not thinking about anything?
Other	Briefly, what was the thought? (If it is personal, feel free to put N/A)

Descriptives and ANOVA results One hundred and twenty-two participants responded to an average of 84.7% ($SE = .002$) of the surveys, resulting in 3,099 responses. After a survey was opened, it took participants 53 s on average to complete the survey. As seen in Fig. 2, 12% ($SE = .006$) were thoughts about PM, 18% ($SE = .007$) were thoughts about the general future, 9% ($SE = .005$) were thoughts about one's personal past, 5% ($SE = .004$) were spent recalling information, 46% ($SE = .009$) were on-task thoughts, 9% ($SE = .005$) were about nothing in particular, and 2% ($SE = .002$) were labeled as “other.” To determine whether or not the frequencies of thinking about these categories reliably differed from each other, we again employed a within-subjects ANOVA with seven levels; one for each of our thought classifications. The number of responses in each category were summed within participants, and were all significantly different from each other ($p < .05$) except that thoughts about one's personal past were not different from thoughts about nothing, $F(6, 726) = 258.79$, $MSE = 6.63$, $p < .001$. Collapsing across future, past, and present categories, we found that they were all different from each other, $F(2, 242) = 193.95$, $MSE = 16.80$, $p < .001$, with present thoughts being the most prevalent ($M = .55$, $SE = .015$), followed by future ($M = .30$, $SE = .012$) and then past thoughts ($M = .14$, $SE = .009$). In sum, we closely replicated the findings from Study 1, with the only notable difference being an increase in general future thoughts and a decrease in PM thoughts.

For the follow-up questions, 46% of the time participants selected PM, they were forming an intention ($SE = .026$), 25% of the time they were completing an intention ($SE = .022$), and 29% of the time they were just thinking about the intention ($SE = .023$). A one-way, within-subjects ANOVA of the summed frequencies found that forming PM intentions were

significantly more likely than either completing or just thinking about a PM task, which were not different, $F(2, 242) = 11.89$, $MSE = 1.22$, $p < .001$. PM thoughts were reported to be internally-cued 61% of the time and externally-cued 39% of the time ($SE = .025$). Using a paired-samples t -test of the summed frequencies within participants, this difference was significant, $t(121) = 3.90$, $p < .001$. Finally, there was no significant interaction between these two factors, $F(2, 242) = .04$, $MSE = .585$, $p = .957$, suggesting that PM thoughts were more likely to be internally cued regardless of whether they were forming (77% internal, 23% external), completing (88% internal, 13% external), or just thinking (89% internal, 11% external) about the intention. We also asked whether AM memories were externally or internally cued, and found that AM were more likely to be externally cued, $t(121) = 3.91$, $p < .001$.

Regarding our predictor variables (see Table 7), we again found that participants were most likely to be at home, followed by at work/school, and least likely to be somewhere else. The average time of day was 2:50 p.m. Once again, participants were with other people for around half of the time, and already on their phones around half of the time. Lastly, around two-thirds of the surveys were answered on a weekday. For personality, participants had a mean extraversion of 3.40 ($SE = .013$), agreeableness of 3.87 ($SE = .011$), conscientiousness of 3.66 ($SE = .013$), neuroticism of 2.84 ($SE = .018$), and openness of 3.82 ($SE = .013$). In the next set of analyses we examined whether these factors were associated with the frequency of reported PM thoughts.

Predicting PM thoughts As seen in Table 8, we found that participants were 1.41 times more likely to think about PM when they were alone than when they were with people ($OR =$

Fig. 2 Mean proportion of thoughts by category for Study 2. *PM* prospective memory, *Future* general future thoughts, *AM* autobiographical memory (past life events), *SM* semantic memory

(recalling information), *On task* focused on task, *Nothing* nothing in particular, *Other* none of the previous classifications. Error bars represent standard errors

Table 7 Mean estimated proportions of our predictors and their standard errors for Study 2

	Work	Home	Other	Time	With others	Weekday	On phone
Mean	.34	.48	.18	14.83	.45	.67	.47
SE	.009	.009	.007	.043	.009	.008	.009

Note. *Work, Home, and Other* were part of the same question asking participants where they were at the time of the survey. *Time* refers to time of day in hours (e.g., 14.83 is equivalent to 2:50 p.m.). *With others* is the proportion of surveys they completed around other people. *Weekday* refers to the number of surveys on a weekday. *On phone* refers to the proportion of surveys received when already on their phone, rather than interrupted in daily life

1.41, $p < .001$). Participants were also marginally more likely to think about PM earlier in the day, such that with each additional hour of the day, the odds of thinking about PM decreased by a factor of .97 ($OR = .97$, $p = .06$). These findings directly replicate the results from Study 1.

Examining personality next, only neuroticism (z-scored) was significant ($OR = 1.20$, $p = .02$), and this effect appeared to be entirely driven by the anxiety facet ($OR = 1.32$, $p = .02$), rather than depression ($OR = .90$, $p = .38$) or emotional volatility ($OR = 1.02$, $p = .90$). The few studies examining the relationship between PM and personality have yielded inconsistent results, yet we found evidence supporting a

Table 8 PM Model in Study 2 allowing only intercepts to vary randomly

	PM		
	Odds ratio	CI	p
Fixed Parts			
(Intercept)	0.09	0.07 – 0.13	<.001
With People (0) Alone (1)	1.41	1.11 – 1.81	.006
Time of Day (Hr)	0.97	0.94 – 1.00	.059
Not at Work (0) At Work (1)	1.16	0.82 – 1.63	.396
Not at Home (0) At Home (1)	1.12	0.78 – 1.60	.542
Weekday (0) Weekend (1)	0.86	0.68 – 1.11	.246
Interrupted (0) On Phone (1)	1.12	0.89 – 1.40	.348
Random Parts			
τ_{00} , Subject		0.265	
N_{Subject}		122	
ICC_{Subject}		0.075	
Observations		3099	
Deviance		2155.836	

Note. *ICC* intraclass correlation coefficient: a measure of the within-subjects correlation in responses, τ_{00} the variance between subjects' intercepts, *Odds ratio* the odds that an outcome will occur compared to the odds of the outcome not occurring (odds of thinking about PM compared to not, for a one unit increase in the predictor variable)

positive relationship between neuroticism and PM, as did Cuttler and Graf (2007) and Pearman and Storandt (2005). In contrast, speculations that conscientiousness might be related to PM were not supported ($OR = .97$, $p = .70$). We were initially concerned that limited variability in conscientiousness could impair our ability to detect a significant correlation, but the variability of conscientiousness in our sample ($SD = .71$) was similar to that of Soto and John's (2017) internet sample ($N = 1000$; $SD = .77$) and larger than their student sample ($N = 459$; $SD = .64$).

Predicting non-PM thoughts Because non-PM thoughts are not the focus of this investigation, we do not report the results from our models on non-PM thoughts in the text. For purposes of completeness, however, we combined Studies 1 and 2 together to maximize power, and report the results in tables presented in the Appendix. The Appendix also reports the combined results for PM thoughts.

General discussion

The present study had three main objectives: (1) to estimate the contents of people's momentary thoughts in their everyday environments, specifically with regard to establishing the prevalence of PM thoughts and their triggers (environmental cues or self-initiated) and distinguishing between PM-oriented thoughts and more general future-oriented thoughts; (2) to gather information regarding the relative frequency of thoughts tied to retrospective remembering, on-task concerns, or the future – we hoped to relate these patterns to the hypothesis that people's episodic memory systems are tuned or relied upon to anticipate the future and plan for it, perhaps more so than for retrieving the past per se (Klein, 2013); and (3) to investigate whether predictors of PM thoughts identified in a constrained environment (cf. Sellen et al., 1997) generalize to everyday contexts and personal (rather than experimenter-provided) PM intentions, and to investigate other possible naturalistic predictors (such as personality factors) of PM. In addition to these objectives, we also sought to assess the accuracy of one's meta-consciousness and if this increases after a week of having to classify the nature of one's thoughts.

Regarding our first objective, Gardner and Ascoli (2015) found that on average (collapsed across age groups) participants reported thinking about autobiographical memory (AM) 10% of the time and PM 13%. In our studies, we obtained relatively overlapping estimates of 6% and 17%, respectively, in Study 1 and 9% and 12%, respectively in Study 2. These estimates across three independent studies and with different populations and age ranges are strikingly convergent, providing strong evidence for a stable rate of PM thoughts at about 13–15% (see Fig. 3 for a histogram depicting the variability of this rate). The only potential difference between the studies

Fig. 3 Histogram depicting the number of participants (from Studies 1 and 2) in each bin for the proportion of PM thoughts out of total thoughts

was that our young adult participants reported more PM thoughts than those in the Gardner and Ascoli study; the reason our overall PM rates are so convergent is because in their study older adults were more likely to think about PM than young adults. More research is needed to determine whether young adults in our study reported more PM thoughts than the typical young adult, or whether those in Gardner and Ascoli's study reported fewer than is typical. Indeed, if young adults generally experience PM thoughts at the same rate as we found in our study, it is still an open question as to whether there are differences between younger and older adults. However, if indeed there are no differences between younger and older adults, our findings converge well with those reported by Gardner and Ascoli.

Note that the convergence was obtained despite using some different instructions for classifying thoughts. We asked participants to differentiate between PM and more general future thoughts, whereas Gardner and Ascoli gave participants instructions to also include, "... first person perspective thinking of future actions or events" (Gardner & Ascoli, 2015, p. 210). We initially conjectured that these latter instructions may have encouraged participants to classify general future thoughts as PM. However, the current set of results suggests that Gardner and Ascoli's participants did *not* tend to lump general future thoughts and PM thoughts together. If that had been the case, we would have expected their PM rates to be closer to our combined future thoughts categories (30% of the time in both Study 1 and Study 2).

Extending Gardner and Ascoli (2015) and our Study 1, in Study 2 (in response to the follow-up question posed after a PM-thought classification) participants reported that most of their PM thoughts involved forming intentions for future action. This is especially interesting because in the laboratory most PM intentions are experimenter-given. Therefore, one of the most prominent components to everyday PM thoughts – the spontaneous formation of intentions – is not reflected in the extant PM literature.

An issue that has received much attention in the laboratory PM research, however, is the nature of what triggers retrieval of thoughts about formed intentions (e.g., McDaniel, Guynn, Einstein, & Breneiser, 2004; Scullin et al., 2013; Smith et al., 2017). Kvavilashvili and Fisher (2007), using a naturalistic PM task, demonstrated that with experimenter-given intentions, most PM thoughts were triggered by the environment. In direct contrast, we found that participants reported that 61% of their PM thoughts were self-initiated. The discrepancy in these findings may hinge on Kvavilashvili and Fisher requiring participants to report on the one experimenter-provided PM task over the course of a week before the task was to be executed. It would seem inefficient or ineffective for a participant to self-initiate thinking about the PM intention days before the target time for completion. Rather, one might likely self-initiate thinking about the PM intention upon coming closer to the target event (as has been found in the laboratory; e.g., Marsh, Hicks, & Cook, 2006; Smith et al., 2017). In our study, by contrast, participants had many PM intentions, presumably with shorter delays than 1 week (e.g., perhaps even later that very day), and people are more likely to self-initiate PM thoughts for tasks they expect to execute in the near future (i.e., people do not appear to maintain the PM intention until they are in the appropriate context to perform it). Alternatively, the discrepancy between our results and Kvavilashvili and Fisher's might be explained by variation in the importance of the PM tasks across studies. It is possible, for example, that experimenter-given intentions like those used by Kvavilashvili and Fisher are not considered as important as self-created PM intentions. Because prior research has shown that people are more likely to devote attentional capacity to more important PM tasks (Kliegel, Martin, McDaniel, & Einstein, 2004) – presumably to support internal cuing of the intention – the relative importance of one's PM task could influence the preponderance of internally cued PM thoughts. These possibilities would be an important direction for future research.

Our findings also speak to general theoretical debate about the functions for which memory was shaped (e.g., see De

Brigard, 2014; Irish & Piguet, 2013; Klein, 2013; Nairne, 2010; Szpunar et al., 2014; Tulving, 2005). Historically, very little research has focused on future-oriented episodic thought, and has instead been devoted to understanding episodic memory systems and how they allow us to re-experience past events. More recently, however, some theorists have suggested that memory might have been designed, perhaps through evolutionary pressures, to be forward-looking (Klein, 2013; Tulving, 2005) – to serve anticipating the future and planning for it. Our results, by demonstrating a healthy prospective bias, are consistent with this claim. That is, in two studies, participants were substantially more likely to be thinking about the future (30%) than the past (13%), provided that their thoughts were not captured by the present (55%).

Although these data do not directly inform the functional design of people's episodic memory systems, they imply that our memory systems are used relatively more to envision the future than to remember the past, a finding that would align with Klein's (2013) thesis about the purpose of memory. In addition, laboratory ESM studies have frequently found a prospective bias in thoughts, though this research has not specifically distinguished between prospective memory and mind wandering about the future (Baird et al., 2011; Smallwood et al., 2009; Smallwood et al., 2011; Stawarczyk et al., 2011; cf. Plimpton et al., 2015). The future-oriented thought reflected in our data (and in Gardner & Ascoli, 2015) helps inform Tulving's (2002) proposal that memory allows people to mentally place themselves forward in time, a process he termed *proscopic chronesthesia*. We had previously speculated "that a central and ubiquitous function of productive proscopic chronesthesia is prospective memory" (Einstein et al., 2005, p. 327), a hypothesis that is consistent with the incidence of PM future-oriented thoughts in the present findings. Specifically, in a naturalistic setting we found that between 57% (Study 1) and 40% (Study 2) of future-oriented thoughts were devoted to PM (see also D'Argembeau et al., 2011 for a similar split in future thoughts). Accordingly, much of future thinking is directed towards planning intended actions and preparing to execute those actions (but see Cameron, 1972; Klinger & Cox, 1987; Song & Wang, 2012, for somewhat inconclusive results).

The general view we embrace here is that our episodic memory systems are designed to be "forward looking," and that both autobiographical memory and episodic future thought can be used in similar ways to meet the demands of the future. In terms of autobiographical memory, using our previous example about remembering to bring money to a cash-only movie theater, presumably this intention was formed based on previous experience. Perhaps the last time you went to that particular theater you did not have cash, and your friend had to buy you a ticket. Realizing that you are once again going to the same theater, and remembering the previous time you did not bring cash, allows you to plan ahead

and form the intention to bring cash. Under this line of reasoning, it is even possible that individuals with better autobiographical memory therefore have more opportunity to successfully plan and execute future intentions. A recent finding that is consistent with this possibility is that more detailed autobiographical memory retrieval is associated with greater future thinking (Poerio et al., 2017). In terms of episodic future thought, it appears that the incidence of mindwandering about the future is related to more concrete (i.e., less abstract) future goals (Medea et al., 2016). Perhaps then, episodic future thought is partly serving successful completion of particular concrete goals (PM intentions).

Our final objective was to examine what factors are associated with the nature of people's momentary conscious experience; specifically, we looked at whether PM thoughts were predicted by the presence of other people, time (both time of day and across the duration of the study), location (at work/school, home, or other), whether it was a weekend or week day, and whether they were interrupted or already on their phone. Our predictors were mainly adopted from Sellen et al. (1997) and Gardner and Ascoli (2015). We found that participants were more likely to be thinking of PM when they were alone and when it was earlier in the day, but none of the other predictors were associated with PM. Further, this pattern was obtained in both of the present studies. Though little research has examined the impact of these factors on PM directly, one study found that naturalistic PM performance was better in the morning than at midday or in the evening (Leirer, Tanke, & Morrow, 1994). The authors speculated that as activity level increases during the day (e.g., busying oneself with life's demands) attentional capacity devoted to PM decreases. Tangentially, we also found that the likelihood of being alone decreased as each day progressed, and that on-task thoughts increased. Considering these findings and the fact that PM thoughts decreased throughout the day, our findings support Leirer et al.'s (1994) hypothesis. Thus, a potential description of the dynamics of individuals' daily PM-related thoughts is that people wake up, are alone and unpreoccupied (perhaps engaging in relatively automatic and habitual actions such as getting dressed), and begin to form intentions for their day. As the day progresses, they (presumably) perform many of these intentions, get involved in cognitively demanding tasks, and PM thoughts become less frequent.

In relation to prior research, Sellen et al. (1997) found no effect due to the presence of others, though they were worried that the sight of others wearing their badges in the workplace would actually increase the likelihood of PM thoughts. It is possible, therefore, that being around people *did* increase PM thoughts (in Sellen et al.), but in concert with the greater likelihood of spontaneously thinking about PM when alone (as found in our studies), no significant differences emerged. Sellen et al. also found that PM thoughts decreased over the course of the week, but this was likely due to having the same

experimenter-imposed PM task on each day. The task could have become more habitual, lessening the cognitive demands of that task. In our study, by contrast, PM thoughts remained constant across days, likely because participants had new and changing PM tasks each day. Similarly, Gardner and Ascoli (2015) found no decrease in PM thoughts as the study progressed. In fact, they found that the rates of PM (and AM) were stable across a number of variables. PM thoughts did not change as a function of time of day, weekday versus weekend, across the duration of the study, or as a function of the number of surveys received. Our results only differ from these in that we found significantly fewer PM thoughts as the day progressed. It remains possible that in Gardner and Ascoli's study there was a small effect of time of day, but it was not revealed because they analyzed these data using a less sensitive statistical technique (comparing first half of thoughts per day to second half of thoughts) than used herein (time of day was analyzed continuously).

There has been less published research on the relationship between personality and PM, though some researchers have suggested that both conscientiousness and neuroticism could play a role (e.g., Cuttler & Graf, 2007). More conscientious individuals were predicted to have higher PM based on the assumption that they should be more careful and mindful when planning and executing intended actions. Neuroticism was predicted to hurt PM, because ruminative thoughts could occupy working memory and distract those individuals (cf. Rude et al., 1999). Cuttler and Graf (2007) reported that higher conscientiousness was associated with better PM, but contrary to expectations they also found that more neurotic individuals performed better. In light of this surprising finding, they suggested the possibility that highly neurotic people ruminate more about the need to perform upcoming tasks (see also, Pearman & Storandt, 2005; Perkins, Arnone, Smallwood, & Mobbs, 2015). Our results directly support that hypothesis, showing that people higher in neuroticism, and more specifically anxiety, are significantly more likely to be thinking about PM. We did not, however, find that conscientiousness was associated with more PM thoughts.

One possible explanation for this divergence from our expectation is that conscientious people may be more successful at performing PM, but do not need to think about PM more. Perhaps they are simply better and more careful planners, able to offload intentions to their environment (e.g., calendars and smart-phone notifications), and thus avoid thinking too much about their intentions. We attempted to address this possibility with our own data, predicting the locus of PM retrieval (internal, external) by conscientiousness when participants reported they were completing a PM intention. The rationale being that if individuals who are more conscientious offload their intentions, they may be more likely to retrieve their intentions via external cues. The relationship was not significant and was in the opposite

direction than predicted ($OR = 1.5, p = .11$), so it is unclear why conscientiousness was not related to PM.

We were also interested in whether participants displayed accurate meta-consciousness. That is, were participants able to closely estimate how often they think about each of the seven classifications in reality? Gardner and Ascoli (2015) asked an independent sample of young adults to estimate the proportion of thoughts devoted to PM and AM, and found that their estimates were not significantly different from actually obtained proportions. Taking a slightly different approach, we asked our participants make an estimate both before and after participating in the ESM study. In this way, we were able to correlate an individual's estimations with his or her actual thought proportions. Before completing the study, participants were only somewhat accurate, with significant correlations between participant's estimates and their actual thoughts for general future thoughts and on-task thoughts only. After spending a week classifying their thoughts, participants were far more accurate, with estimates that significantly correlated with all thought categories except AM (which was marginally significant). Although participants had some knowledge at the outset regarding their momentary conscious experiences (especially for general future thoughts and on task thoughts), a week of daily intermittent reflection substantially improved people's awareness of the nature of thoughts with which they are occupied. To the extent that this kind of meta-consciousness is desirable, these findings suggest a possible way to improve its accuracy.

In sum, based on high convergence among our studies and that of Gardner and Ascoli (2015), we suggest that researchers can be fairly confident that people think about the future more often than the past, and that PM occupies our thoughts approximately 13–15% of the time. Also, the present studies broadened the scope of thought classifications, allowing a more fine-grained categorization of momentary thoughts. Based on these findings, we observed a sizeable prospective bias in thoughts, offering support for the hypothesis that our memory-system is highly engaged in future-thinking (Klein, 2013; Tulving, 2005). Perhaps most importantly for present purposes, our data suggest that future thinking prominently involves prospective memory: planning intentions to complete in the future, and self-initiating thoughts toward completing those intentions. Most generally, we hope to have demonstrated the value of a method (ESM) to help researchers investigate and understand PM outside of the laboratory, in natural circumstances as people live their lives.

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Appendix

Models of Thoughts Using Data Combined Across Both Study 1 and 2

Table 9 PM Model combining the results of Studies 1 and 2, allowing only intercepts to vary randomly

	PM		
	Odds ratio	CI	p
Fixed Parts			
(Intercept)	0.11	0.08 – 0.14	<.001
With People (0) Alone (1)	1.58	1.31 – 1.92	<.001
Time of Day (Hr)	0.97	0.95 – 0.99	.007
Not at Work (0) At Work (1)	1.09	0.84 – 1.41	.526
Not at Home (0) At Home (1)	1.05	0.80 – 1.38	.740
Weekday (0) Weekend (1)	0.94	0.78 – 1.14	.540
Interrupted (0) On Phone (1)	1.05	0.88 – 1.26	.565
Random Parts			
τ_{00} , Subject		0.344	
N_{Subject}		183	
ICC_{Subject}		0.095	
Observations		4630	
Deviance		3420.502	

Note. PM prospective memory, ICC intraclass correlation coefficient: a measure of the within-subjects correlation in responses, τ_{00} the variance between subjects' intercepts, *Odds ratio* the odds that an outcome will occur compared to the odds of the outcome not occurring (odds of thinking about PM compared to not, for a one unit increase in the predictor variable).

Table 10 General Future Model combining the results of Studies 1 and 2, allowing only intercepts to vary randomly

	Future		
	Odds ratio	CI	p
Fixed Parts			
(Intercept)	0.18	0.14 – 0.23	<.001
With People (0) Alone (1)	1.08	0.90 – 1.30	.419
Time of Day (Hr)	0.99	0.97 – 1.02	.516
Not at Work (0) At Work (1)	0.88	0.69 – 1.11	.282
Not at Home (0) At Home (1)	0.99	0.77 – 1.28	.960
Weekday (0) Weekend (1)	0.84	0.70 – 1.01	.058
Interrupted (0) On Phone (1)	1.03	0.87 – 1.23	.701
Random Parts			
τ_{00} , Subject		0.429	
N_{Subject}		183	
ICC_{Subject}		0.115	
Observations		4630	
Deviance		3716.855	

Note. ICC intraclass correlation coefficient: a measure of the within-subjects correlation in responses, τ_{00} the variance between subjects' intercepts, *Odds ratio* the odds that an outcome will occur compared to the odds of the outcome not occurring (odds of thinking about PM compared to not, for a one unit increase in the predictor variable)

Table 11 AM Model combining the results of Studies 1 and 2, allowing only intercepts to vary randomly

	AM		
	Odds ratio	CI	p
Fixed Parts			
(Intercept)	0.08	0.06 – 0.11	<.001
With People (0) Alone (1)	0.96	0.75 – 1.22	.715
Time of Day (Hr)	0.98	0.95 – 1.01	.127
Not at Work (0) At Work (1)	0.91	0.67 – 1.23	.542
Not at Home (0) At Home (1)	0.75	0.54 – 1.05	.092
Weekday (0) Weekend (1)	1.19	0.95 – 1.51	.137
Interrupted (0) On Phone (1)	1.05	0.84 – 1.32	.669
Random Parts			
τ_{00} , Subject		0.358	
N_{Subject}		183	
ICC_{Subject}		0.098	
Observations		4630	
Deviance		2393.157	

Note. AM thoughts about one's personal past, ICC intraclass correlation coefficient: a measure of the within-subjects correlation in responses, τ_{00} the variance between subjects' intercepts, *Odds ratio* the odds that an outcome will occur compared to the odds of the outcome not occurring (odds of thinking about PM compared to not, for a one unit increase in the predictor variable)

Table 12 SM Model combining the results of Studies 1 and 2, allowing only intercepts to vary randomly

	SM		
	Odds ratio	CI	p
Fixed Parts			
(Intercept)	0.04	0.02 – 0.06	<.001
With People (0) Alone (1)	0.93	0.69 – 1.26	.650
Time of Day (Hr)	1.01	0.97 – 1.05	.636
Not at Work (0) At Work (1)	1.00	0.65 – 1.53	.984
Not at Home (0) At Home (1)	1.77	1.16 – 2.70	.008
Weekday (0) Weekend (1)	0.95	0.70 – 1.29	.740
Interrupted (0) On Phone (1)	0.84	0.63 – 1.11	.228
Random Parts			
τ_{00} , Subject		0.790	
N_{Subject}		183	
ICC_{Subject}		0.194	
Observations		4630	
Deviance		1666.959	

Note. SM thoughts spent recalling information, ICC intraclass correlation coefficient: a measure of the within-subjects correlation in responses, τ_{00} the variance between subjects' intercepts, *Odds ratio* the odds that an outcome will occur compared to the odds of the outcome not occurring (odds of thinking about PM compared to not, for a one unit increase in the predictor variable)

Table 13 On Task Model combining the results of Studies 1 and 2, allowing only intercepts to vary randomly

	On task		
	Odds ratio	CI	p
Fixed Parts			
(Intercept)	1.06	0.87 – 1.28	.578
With People (0) Alone (1)	0.63	0.55 – 0.73	<.001
Time of Day (Hr)	1.06	1.04 – 1.08	<.001
Not at Work (0) At Work (1)	0.98	0.81 – 1.17	.809
Not at Home (0) At Home (1)	1.22	1.01 – 1.49	.040
Weekday (0) Weekend (1)	1.03	0.90 – 1.18	.636
Interrupted (0) On Phone (1)	0.79	0.69 – 0.90	<.001
Random Parts			
τ_{00} , Subject		0.335	
N_{Subject}		183	
ICC_{Subject}		0.092	
Observations		4630	
Deviance		5810.359	

Note. ICC intraclass correlation coefficient: a measure of the within-subjects correlation in responses, τ_{00} the variance between subjects' intercepts, Odds ratio the odds that an outcome will occur compared to the odds of the outcome not occurring (odds of thinking about PM compared to not, for a one unit increase in the predictor variable)

Table 14 Nothing Model combining the results of Studies 1 and 2, allowing only intercepts to vary randomly

	Nothing		
	Odds ratio	CI	p
Fixed Parts			
(Intercept)	0.04	0.03 – 0.06	<.001
With People (0) Alone (1)	1.64	1.28 – 2.10	<.001
Time of Day (Hr)	0.92	0.89 – 0.95	<.001
Not at Work (0) At Work (1)	1.41	1.02 – 1.95	.037
Not at Home (0) At Home (1)	0.49	0.34 – 0.72	<.001
Weekday (0) Weekend (1)	1.20	0.96 – 1.51	.109
Interrupted (0) On Phone (1)	1.79	1.43 – 2.25	<.001
Random Parts			
τ_{00} , Subject		0.514	
N_{Subject}		183	
ICC_{Subject}		0.135	
Observations		4630	
Deviance		2381.059	

Note. ICC intraclass correlation coefficient: a measure of the within-subjects correlation in responses, τ_{00} the variance between subjects' intercepts, Odds ratio the odds that an outcome will occur compared to the odds of the outcome not occurring (odds of thinking about PM compared to not, for a one unit increase in the predictor variable)

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