Received: 2 April 2021 | Revised: 15 September 2021 | Accepted: 13 December 2021

DOI: 10.1002/acp.3908

RESEARCH ARTICLE

WILEY

Remember to stay positive: Affect and prospective memory in everyday life

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Abstract

The present study aimed to investigate the affect-cognition interplay in young and older adults by studying prospective memory (PM), the realisation of delayed intentions. While most previous studies on the topic were conducted in the laboratory, we examined the influence of naturally occurring affect on PM tasks carried out in participants' everyday lives. For seven consecutive days, participants were asked to rate their affective state nine times per day and send text messages either at specific times (time-based PM) or when a particular event occurred (event-based PM). Results showed that within-participants changes in valence from more positive to more negative affect were associated with decreased PM performance. This was similarly true for young and older adults. The design used allowed linkage of within-participants fluctuations of affect and cognitive functions, constituting a methodological advancement. Results suggest that positive affect has the potential to improve cognitive functioning in everyday life.

KEYWORDS

affect, ageing, everyday life, prospective memory

1 | INTRODUCTION

Natural fluctuations of affect are a common daily experience. Affect, defined as a consciously accessible feeling which varies on the valence (positive vs. negative) and arousal (arousing vs. calm) dimension (Russell, 2003), is considered to fluctuate considerably even within a short amount of time (Brandstätter, 1983). In order to study the impact of affective states on cognition, researchers have typically manipulated affective states in the laboratory and then asked participants to work on cognitive tasks.

Beneficial effects of positive affect on certain cognitive abilities such as fluency and creativity have been reported (see, e.g., Mitchell & Phillips, 2007). However, there is considerable evidence that positive and negative affect can reduce cognitive performance on tasks such as working memory (e.g., Spies et al., 1996), inhibitory control (e.g., Dayan & Huys, 2008), planning (e.g., Phillips et al., 2002), and memory recall (e.g., Ellis et al., 1997). The detrimental effects of positive and negative affect on cognitive abilities have been explained by capacity accounts like the resource allocation model (Ellis & Ashbrooks, 1988). According to this model, affective states are detrimental to cognition because they lead to increased amounts of task-unrelated thoughts (e.g., Seibert & Ellis, 1991), which may withdraw resources from the task at hand.

Studying affect-cognition interactions is especially interesting in later adulthood, as cognitive and emotional ageing seem to follow two different developmental trajectories. In fact, age has a detrimental effect on many cognitive abilities, like retrospective memory (Rönnlund, Vestergren, Mäntylä, & Nilsson, 2011), processing speed (Salthouse, 2012), and executive functioning (Braver & West, 2008). On the contrary, it has been shown that age has a beneficial effect on emotional functioning, as older adults report fewer negative feelings and higher levels of wellbeing compared to their younger counterparts (Carstensen et al., 2011; Charles et al., 2001). These affective changes have been linked to age-related improvements in emotion regulation. In fact, older adults are more effective at suppressing emotions (Wirth & Kunzmann, 2018) and down-regulating negative affect (Scheibe & Blanchard-Fields, 2009).

Studies investigating age differences in affective influences on cognition have sometimes indicated support for a decreased resource model. For example, Phillips et al. (2002) found more detrimental effects of positive and negative mood on planning performance in older compared to young adults. However, other studies support the idea that older adults are more skilled in dealing with emotions, showing that positive and negative affect may impair prospective memory in young but not older adults (Pupillo, Phillips, & Schnitzspahn, 2021; Schnitzspahn et al., 2014). Other studies indicate no age differences in the effects of induced mood states on working memory (Scheibe & Blanchard-Fields, 2009) and episodic recall (Emery, Hale, & Myerson, 2008).

The studies outlined above have experimentally induced affect in the laboratory and then assessed cognitive performance. Although laboratory studies allow control of potential confounds, the applied affect induction procedures have limited ecological validity (Brose & Ebner-Priemer, 2015). Naturally occurring affect may be more variable in intensity and is usually experienced as not linked to any particular object or situation, while induced affect is directly linked to the affect induction procedure (Brose et al., 2014; Ekman, 1994). In addition, affect induced in the laboratory is typically short lasting (Kliegel et al., 2005). For these reasons, researchers have recently started investigating the relationship between naturally occurring fluctuations of affect and cognitive functions (Brose et al., 2012; Riediger et al., 2014). They typically used ambulatory assessments, also known as experience sampling methods (Csikszentmihalyi & Larson, 2014), to collect information about people's thoughts, feelings, and behaviours in their everyday lives (Trull & Ebner-Priemer, 2013). These methodologies not only have the advantage of capturing a behaviour as it occurs spontaneously within a natural setting, increasing ecological validity and reducing recall bias, but they also allow the study of within-person variations in relation to people's own baseline (Bolger et al., 2003).

Studies investigating the effects of daily fluctuations of affect on cognitive performance indicate poorer working memory on days with more negative affect (Brose et al., 2012; Riediger et al., 2011) and improved working memory on days with above-average positive affect (Brose & Ebner-Priemer, 2015). This contrasts with experimental evidence of impaired working memory following induced positive mood (Spies et al., 1996). Positive affect induced in the laboratory might be perceived as a distraction and be regulated, while the more subtle everyday positive affect might also be coupled with motivational states which improve task engagement (Harmon-Jones et al., 2012). The only ageing study investigating the effects of affective state on cognitive functions in everyday life (Riediger et al., 2014) focused on the arousal dimension and reported that tense arousal (feeling nervous) was associated with impaired working memory performance in older but not in young adults. Surprisingly, no previous study considered the valence dimension when investigating the effects of natural fluctuations in affective state on cognition in ageing. While arousal refers to the state of physiological and psychological activation of affective states (Montagrin & Sander, 2016), the valence dimension assigns values to objects or situations and thereby regulates individuals' behaviour (Baddeley, 2013). The main goal of the present study was to investigate the valence dimension of daily affective states and explore their relationships with cognitive performance in naturalistic tasks that had to be performed in young and older adults' everyday lives.

An important cognitive function that is crucial for maintaining independence in later life is prospective memory (PM), the ability to realise delayed intentions (J. Ellis & Kvavilashvili, 2000). Everyday examples of PM are remembering to take medication on time or remembering to call a friend for his/her birthday. PM has been typically tested in the laboratory using a paradigm developed by Einstein and McDaniel (1990). Specifically, participants work on an *ongoing task* (e.g., lexical decision task) while at the same time they are asked to remember to perform an additional PM task (e.g., pressing a key) either at a precise time (e.g., every minute; time-based PM, TBPM), or when a specific event occurs (e.g., the word shown in the course of the ongoing task is a verb; event-based PM, EBPM).

In order to achieve ecological validity, several studies used naturalistic PM tasks that participants were asked to complete in their daily lives (Phillips et al., 2008). Most studies used TBPM tasks, such as asking participants to send text messages at specified target times (Schnitzspahn et al., 2011). Some researchers have also looked at EBPM tasks in daily life, for instance by asking participants to remember to phone the experimenter after receiving a certain text message (Kvavilashvili & Fisher, 2007).

Given the importance of PM for autonomy and social relationships (Woods et al., 2012), researchers are interested to understand how this cognitive ability is influenced by ageing. Several meta-analyses confirmed a general age-related decline in laboratory PM tasks (Henry et al., 2004; Kliegel et al., 2008). However, a different pattern emerges when naturalistic PM tasks are used. In this case, older adults outperform young adults (Henry et al., 2004). This age benefit has been attributed to several possible factors, such as older adults' decreased busyness and more efficient strategy usage (Phillips et al., 2008), increased attributions of task importance (Ihle et al., 2012) and higher general motivation, improved metacognitive awareness, and reduced stress (Schnitzspahn et al., 2011).

Initial lab-based studies on ageing, PM, and affective states showed that young adults' performance was impaired by negative and positive mood, whereas older adults' performance was not influenced by affective states (Pupillo et al., 2021; Schnitzspahn et al., 2014). However, it is still an open question if naturally occurring affective states in everyday life have similar effects on PM in young and older adults than the ones observed in the laboratory. Given the different nature of naturally occurring affective states compared to affective states that have been induced in the laboratory as explained above, it is plausible to assume that they also affect cognition differently.

Only one study examined the influence of affective states on PM in a naturalistic setting (Lagner et al., 2015). Specifically, young male handball players performed parallel versions of a cognitive test battery including a PM task after training or after winning a match. Affect was measured several times throughout the testing sessions.

These measures confirmed more positive affect after winning a match than after training. While this positive affect was associated with impaired short term and working memory performance, there was no effect on PM. However, while the described study was performed in the field, it focused on a specific sample and the effects of an event that is usually experienced as highly emotional instead of examining the effects of natural affect fluctuations on cognition over a longer period of time.

The present study addressed this research gap by exploring how natural fluctuations of affect in everyday life influence PM in young and older adults. It allowed the examination of within-person associations between affect and PM performance at the intraindividual level (Molenaar, 2004), to explore whether fluctuations towards a negative affect or towards a positive affect influenced PM performance. Young and older participants rated their affective state nine times a day for seven consecutive days. We also assigned participants event-based and time-based naturalistic PM tasks each day. In addition, all participants also performed PM tasks in the laboratory to verify that their performance in the two different settings followed the usual pattern of age impairments in the laboratory and age benefits in the field (Henry et al., 2004). Finally, factors that have been shown to influence PM performance in naturalistic tasks as outlined above (i.e., task importance, motivation, everyday stress, busyness, strategy use and metacognitive awareness) were measured to control for their influence on naturalistic PM in addition to potential effects of affect and age.

Different predictions concerning the effects of naturally occurring affect on PM in everyday life of young and older adults can be suggested. Based on the assumptions of the resource allocation model of affect (Ellis et al., 1997; Ellis & Ashbrooks, 1988; Seibert & Ellis, 1991), it can be predicted that positive and negative affect will be detrimental to PM performance, particularly for older adults who have more limited cognitive resources. On the contrary, if natural fluctuations of affective state involve stronger approach-withdrawal motivational aspects (Brose et al., 2012; Brose et al., 2014), better performance under positive and decreased performance under negative affective states would be predicted. In accordance with evidence of improved emotion regulation in older adults (Scheibe & Blanchard-Fields, 2009) and lab-based evidence that negative and positive affective states impaired PM in young but not in older adults (Schnitzspahn et al., 2014), smaller effects of affective states on PM can be predicted in older adults compared to young.

Finally, we predict the typical pattern of PM age impairments in the laboratory and PM age benefits in the field (Henry et al., 2004). The latter should be especially pronounced in naturalistic TBPM tasks (Schnitzspahn et al., 2020).

2 | METHOD

2.1 | Participants

The sample included 74 participants, 37 young ($M_{\text{age}} = 21.61$, age range = 18–29, 14 male, 23 female) and 37 older adults ($M_{\text{age}} = 67.22$, age range = 60–70, 12 male, 25 female). The statistical power to reveal an interaction between affect, PM, and age group, based on the effect sizes published by previous research (Pupillo et al., 2021), was $1 - \beta = 0.82$. All young adults were students at the University of Aberdeen who volunteered in exchange for course credits, while all older adults were volunteers recruited using the participant panel of the School of Psychology. All older participants received £10 as reimbursement for their time. Exclusion criteria were current mental health problems. The study was conducted in accordance with the Declaration of Helsinki and has been approved by the University of Aberdeen School of Psychology Ethics Committee, which adheres to the British Psychological Society ethical guidelines. All participants gave written informed consent before participation.

All participants possessed a smartphone capable of receiving and sending text messages (short message service, SMS) which had also access to the internet. Descriptive data for the two age groups are shown in Table 1. Young and older adults did not differ in levels of education, $t(63.09) = 1.23$, $p = .223$, $d = 0.28$, and reported levels of general health, $t(71) = 0.98$, $p = .330$, $d = 0.23$. The two age groups differed in the initial affect at the beginning of the testing session in the laboratory, as measured by the Positive and Negative Mood Scale (PANAS, Watson et al., 1988). Compared to older adults, young adults reported significantly higher negative affect, $t(41.58) = 2.90$, $p = .006$, $d = 0.69$, and significantly lower positive affect, $t(71) = 40.40$, $p < .001$, $d = 1.03$.

In terms of general cognitive abilities, analyses of processing speed and crystallised intelligence revealed that the two age groups differed in the expected directions. In order to assess crystallised intelligence, we used the Mill-Hill Vocabulary Scale (Raven et al., 1989). Older adults showed significantly higher scores than young adults, $t(69.05) = 6.85$, $p < .001$, $d = 1.59$. Processing speed was assessed via the Digit Symbol Substitution Test (Wechsler, 2008), with young adults obtaining significantly higher scores than older adults, $t(32.02) = 7.36$, $p < .001$, $d = 1.75$.

2.2 | Materials and procedure

All participants were invited to an initial laboratory session, where they completed the socio-demographic questionnaire and the general cognitive abilities measures. After that, participants were instructed to work on the laboratory PM tasks.

2.2.1 | Laboratory PM tasks

We assessed TBPM and EBPM using two separate tasks in the laboratory. Both the EBPM and TBPM tasks were embedded in a lexical decision task, which served as the ongoing task. In this task, participants had to press a 'yes' button every time a series of letters appearing on the screen made up a word, and the 'no' button if that was not the case. We selected 249 neutral words from the Affective Norms of English Words database (ANEW, Bradley & Lang, 1999). All the words were nouns and adjectives, between five and nine letters

TABLE 1 Descriptive data for the study sample as a function of age group

Variable	Young adults, $n = 37$ M (SD)	Older adults, $n = 37$ M (SD)
Age	21.61 (2.24)	67.22 (4.47)
Education (years)	16.35 (2.02)	15.62 (2.99)
Health[a]	3.84 (0.90)	3.81 (0.86)
PANAS		
PA	25.28 (5.64)	31.19 (5.83)
NA	13.28 (4.44)	11.03 (1.38)
Crystallised intelligence[b]	17.24 (2.99)	22.59 (3.69)
Processing speed[c]	69.37 (7.95)	51.72 (11.66)
Importance[d]	3.00 (0.76)	4.06 (0.82)
Motivation[d]	3.27 (0.95)	4.23 (0.65)
Stress[d]	3.20 (1.18)	2.37 (1.10)
Busyness[d]	4.34 (0.80)	3.94 (0.84)
Strategy[e]	0.36 (0.44)	0.61 (0.37)
Metacognitive awareness[f]	1.30 (26.70)	−7.67 (23.50)

[a]Health was self-assessed using a 5-point Likert scale, ranging from 1 (very bad) to 5 (very good).
[b]Crystallised Intelligence was measured with the Mill Hill Vocabulary scale.
[c]Processing speed was measured with the Digit Symbol Substitution Test.
[d]Importance, Motivation, Stress, and Busyness were self-assessed. Participants were asked to rate the extent which they were stressed, busy, motivated, and found the task important, using a 5-point Likert scale, ranging from 1 (Totally agree) to 5 (Strongly disagree).
[e]Strategy represents the average strategy use between EBPM and TBPM, where '1' means that participants used strategies for both EBPM and TBPM; '0.5' means that participants used strategies either for TBPM or for EBPM, and '0' means that participants used no strategy for both EBPM and TBPM.
[f]Metacognitive awareness represents the differences between participants' predictions and their actual performances.

long. In addition, 249 nonwords were obtained by changing one phoneme in the words, keeping them pronounceable. Of the overall 498 stimuli, 46 (23 words and 23 non-words) were used for the practice task, while 452 (226 words and 226 nonwords) were used for the time-based and the event-based PM tasks. The words were presented for 500 ms and were separated by a fixation cross of 725 ms duration.

All participants worked on both the EBPM task and the TBPM task. The order of the tasks was counterbalanced, so that half of the sample started with the EBPM task and the other half started with the TBPM task. For the TBPM task, participants were invited to press the 'Y' button every time a minute had passed. Participants could check the elapsed time by pressing the space bar. This made a small digital clock appear on the bottom of the screen for 2 s. Pressing the 'Y' key within a 5 s time window around the target time was considered a correct response (Kliegel et al., 2001). For the event-based task, participants were instructed to remember to press the 'Y' button every time the word they saw during the lexical decision task was also a verb. Six verbs ('deliver', 'assume', 'expand', 'describe', 'nourish', 'inspire') were used as cues for the EBPM task. Pressing the 'Y' key while a PM target cue was presented, or during the fixation cross that immediately followed it, was considered as a correct response. We ensured that no verbs were presented in the lexical decision task of the TBPM.

For each PM task (EBPM and TBPM task), a delay was created between PM task instruction and task completion by inviting participants to work on the Digit Span Backwards task (Wechsler, 2008) before completing the first PM task. This procedure was repeated for the second PM task, using a different version of the Digit Span Backwards task (Wechsler, 1997). After finishing the second PM task, participants were asked to fill in a post-test questionnaire that was designed to check whether or not they remembered the instructions. After that, participants were given instructions for the field part of the study.

2.2.2 | Naturalistic study phase

Affect assessment

In order to assess everyday affect, we used a computerised version of the valence subscale of the Self-Assessment Mannequin Scale (SAM, Bradley & Lang, 1994). The valence subscale of the SAM is composed by figures depicting emotions linked to 9-point Likert scales which ranged from 'Happy' (1) to 'Unhappy' (9). As we decided to focus on the valence component of affect, for the rest of the article we will refer to valence when talking about affect. Participants were informed that they were going to receive nine SMS a day for seven days to their smartphones. Each SMS included a link to a computerised version of the SAM. Participants had to click on the link, which redirected them to the SAM. They were asked to fill the SAM for every message. After this explanation, participants received a first example message to their smartphone inviting them to rate their first SAM and the experimenter guided them to the completion of this task.

Sampling of affect followed an intensive, time-based, quasi-random, longitudinal design (Csikszentmihalyi & Larson, 2014). Participants received nine SMS per day with a link to the computerised version of the SAM. They were informed that the SMS would always be sent within a 10-h time window, and were invited to select their preferred starting time (e.g., SMS could be sent between 9 a.m. and 7 p.m., between 10 a.m. and 8 p.m., etc.). The SMS were sent through a script which randomised the time of the SMS and communicated with a web-based SMS provider to send them to participants' mobile phones. The algorithm designed to send the SMS was programmed to divide each participant 10-h time-range into three equal time-windows. The algorithm randomly selected three times within that window to send the SMS, with the constraint that the difference between two consecutive SMS was never less than 10 min. These random times changed every day (see Figure 1). Participants were instructed to click on the link and fill in the questionnaire as soon as they realised that they had received an SMS. If they were not able to access the phone right after receiving the SMS, they were still asked to fill in the questionnaire as soon as possible. If participants did not access the phone for prolonged periods of time, the SMS could cumulate. Participants were instructed to open all the SMS received, in order to complete all the questionnaires. After receiving the instructions for the SAM, participants were then given instructions for the naturalistic EBPM and TBPM tasks, respectively.

Naturalistic PM tasks

Two different naturalistic PM tasks were designed to assess EBPM and TBPM. For the EBPM task, participants were instructed to reply to the SMS with 'ok' every time they noticed a word written in uppercase in the instructions of the SAM. The word written in uppercase changed every day for each participant and served as cue for the event-based task. The script randomly selected one of the three SAMs within each time-window to be the one containing the cue. Therefore, participants received three SAMs containing a PM cue every day. The script ensured that the difference between two consecutive cues was never less than 2 h. Receiving an SMS with 'ok' within 5 min after participants answered the SAM questionnaires was considered an accomplished EBPM task.

For the TBPM task, participants were instructed to send an SMS with 'ok time' three times a day at predefined times. These times were randomised for each participant using a script which divided the 10 h time-range chosen by participants into three equal time-windows and then picked a random time within each time-window, with the only rule that the difference between two consecutive target times could not be less than 2 h. At the initial laboratory session, participants were then verbally instructed to send the SMS at the same three times every day, for 7 days. Participants were invited either to note down the three times, or to have them printed out. They were instructed to act naturally and allowed to set reminders if they usually would use them to perform similar kind of tasks in their everyday life. Previous studies varied greatly in the choice of the time window used to define a correct PM response, from 10 min before and after the target time (e.g., Azzopardi et al., 2015) to 20 min after the target time (Niedźwieńska & Barzykowski, 2012). In the present study, we considered it a correct response if participants sent the SMS within 30 min of the target time (15 min before and 15 min after). It was stressed that they should try to send the messages as close to the target times as possible. However, they were further instructed to still send delayed SMS in case they realised that they had missed the target time. Similarly, they were encouraged to send the SMS slightly early if they knew in advance that they will not be able to send it on time because of other commitments.

After giving the instruction of the naturalistic PM tasks, we asked participants to predict their successful future performance in the naturalistic PM tasks, in order to explore *metacognitive awareness*. Participants rated their predicted future performance on a scale ranging from 0% to 100%. Predictions were given separately for event- and time-based naturalistic tasks. The differences between participants' predictions and their actual performances were used as indices of metacognitive awareness of one's own PM ability (Schnitzspahn et al., 2011).

Participants were then thanked and dismissed. When the everyday life part of the experiment was finished, participants received an online post-test questionnaire via e-mail.

Post-test questionnaire

We designed a post-test questionnaire to explore participants' experience with the naturalistic tasks. In particular, we asked participants to rate separately on 5-point Likert scales if each of the three main tasks (i.e., the daily assessments of mood, the naturalistic EBPM and TBPM tasks) was *important* to them (1 = 'Totally agree'; 5 = 'Strongly disagree'). In addition, for each task we asked if participants were *motivated* to perform it using the same 5-point Likert scales (1 = 'Totally agree'; 5 = 'Strongly disagree'). For the EBPM and TBPM tasks, we also asked if they used any *strategies* to help them perform well and to describe these strategies if they used any. *Everyday stress* was measured by asking participants to rate on a 5-point Likert scale if their last week was stressful in general (1 = 'Totally agree'; 5 = 'Strongly disagree'). *Busyness* was measured by asking participants to rate on a 5-point Likert scale if they have been generally busy during the last week (1 = 'Totally agree'; 5 = 'Strongly disagree'). Finally, we invited participants to report any problems they might have had with the tasks.

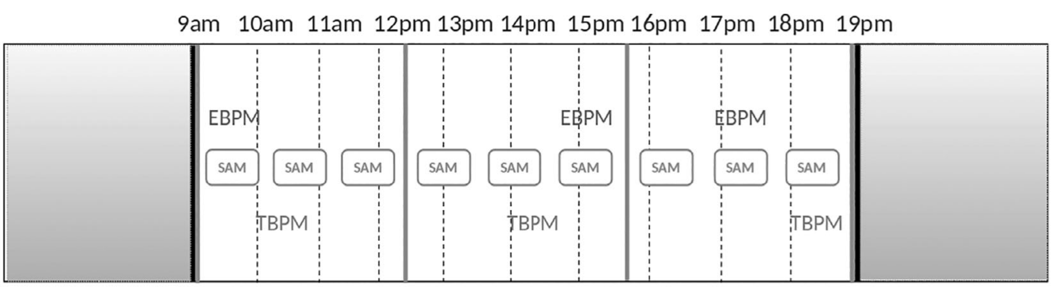

FIGURE 1 Example of a distribution of the SAMs, EBPM trials and TBPM trials. The 10-h time-range was divided into three time-windows. Three SAMs were sent at random times within each of the three time-windows. Among the three SAMs sent within each of the three time-windows, one was randomly selected to contain the word written entirely in uppercase (EBPM task cue). The target times for the TBPM task were also randomised to fall within each one of the three time-windows

TABLE 2 Predicting PM from age group, task type and affect: Model showing Beta coefficients, standard errors, confidence intervals, and odds ratio for fixed effects, and variances, standard errors, and confidence intervals for random effects

				95% Confidence interval		
	b (*SE*)	*t*	*p*	Lower	Upper	OR
Fixed effects						
Intercept	−0.886(0.62)	−1.428	.159	−2.129	0.357	0.412
Time window[a] = 1	−0.252(0.13)	−1.865	.062	−0.518	0.013	0.777
Time window[a] = 0	−0.052(0.14)	−0.381	.703	−0.332	0.217	0.949
Metacognitive awareness	−0.018(0.01)	−2.43	.018	−0.034	−0.003	0.982
Motivation	0.606(0.18)	3.319	.002	0.240	0.973	0.545
Strategy[b] = 1	0.131(0.35)	0.379	.706	−0.564	0.826	1.140
Strategy[b] = 0.5	0.326(0.37)	0.877	.384	−0.420	1.072	1.385
Age group[c]	1.092(0.29)	3.675	.001	0.495	1.689	2.980
Task type[d]	−2.159(0.14)	−15.00	<.001	−2.442	−1.876	0.115
Within affect[e]	−0.123 (0.05)	−2.465	.019	−0.224	−0.021	0.884
Between affect[f]	−0.129(0.10)	−1.316	.194	−0.290	0.073	0.879

	b (*SE*)	*z*	*p*
Level-2 (between-person)			
Random effects			
Intercept	0.813(0.20)	4.115	<.001
Within-person affect	0.006(0.02)	0.226	.821
Level-1 (within-person)			
Residual	0.957(0.03)	30.026	<.001
Autocorrelation	−0.125(0.03)	−4.603	<.001

[a]The variable 'Time window' was categorical and centred at '0', with '−1' representing the first time-window, '0' the second one, and '1' the third one. The baseline is represented by the first time-window (−1).
[b]Strategy represents the average strategy use between EBPM and TBPM, where '1' means that participants used strategies for both EBPM and TBPM; '0.5' means that participants used strategies either for TBPM or for EBPM, and '0' means that participants used no strategy for both EBPM and TBPM. Reference level is 0.
[c]Reference level for age group was young adults.
[d]Reference level for task type was event-based.
[e]Within affect represents affect scores centred at the person-mean (i.e., score minus person-mean score) such that zero represented the person's average. Higher scores reflect greater negative affect.
[f]Between affect represents affect scores centred at the grand mean (i.e., person-mean score minus grand-mean score) such that zero represented the sample average. Higher scores reflect greater negative affect.

2.3 | Statistical analysis

To analyse naturalistic PM performance, generalised linear mixed models (GLMM) were used to account for the clustering of data within individuals, and to model dichotomous, non-normal data. PM performance was modelled using the binomial distribution and logit function. Data were organised in a two-level dataset with assessments nested within participants (for further information, see Supporting Information).

Before testing the effects of affect and age group, we created a covariate baseline model including theoretically-important predictors of PM (task importance, motivation, everyday stress, busyness, strategy use, metacognitive awareness), to control for their effects and reduce the unexplained variance in PM performance (Singer & Willett, 2003). In order to identify the predictors, a backward elimination regression approach was used in which a model including all six predictors (full model) was compared with models in which variables were in turn excluded. This procedure allowed to keep the predictors that best explained the data in the model (Neter et al., 1996). Details of this procedure can be found in the Supporting Information (Table S1).

To distinguish within- and between-person effects, a score centring procedure was required (Bolger & Laurenceau, 2013). For the within-person predictor, affect scores were centred at the person-mean (i.e., score minus person-mean score) such that zero represented the person's average. For the between-person predictor of affect, person-mean scores were centred at the grand mean (i.e., person-mean score minus grand-mean score) such that zero represented the sample average. In addition, the within-person predictor of affect was entered as fixed and random effect, to model the typical within-person effect (fixed) of affect on PM but also allow that effect to vary from person to person (random). The between-person effect was entered as a fixed effect. The approach towards missing data was to include every participant, regardless of the amount of missing data points. All models estimated random effects with a diagonal covariance matrix, residuals with a first-order autoregressive covariance matrix, and used robust standard error estimation.

Where any within-person effects of affect were found, we further investigated if they were driven by variation in positive or negative affect by performing two regression spline analyses (Friedman, 1991). Instead of fitting one regression to the data, these analyses investigated the separate effects of negative and positive affect by fitting two linear regressions with different slopes, determined by a knot point. In the present study, the knot point for affect within-participants is zero, representing the participants' average affect. Therefore, if negative (positive) affect influenced performance, the negative (positive) spline should reach significance. The criterion for statistical significance was set at $\alpha = .05$. Odds ratios (OR), the exponential of the log odds coefficients (β), were calculated as effect sizes.

In order to analyse PM performance as a function of setting, age group, and task type, we analysed proportions of correct PM performance, running a 2 x 2 x 2 mixed ANOVA, with age (young vs. older) as between participant variable, and setting (laboratory vs. naturalistic) and task type (event- vs. time-based) as within participants variables. Follow-up analyses were considered, in case of significant interactions. Effect sizes were computed as Cohen's *d*, with 95% confidence intervals also reported.

Raw data and script of the analysis are available on the Open Science Framework (https://osf.io/3u4jt/).

3 | RESULTS

All participants attempted both the laboratory and the naturalistic PM tasks. However, three participants who consistently failed to follow the instructions of the naturalistic task (e.g., by sending 'OK' to every message received, or not sending messages at all) were identified and excluded from further analyses. Participants excluded were all in the older adults' group. Therefore, the analyses reported in the following sections were conducted on 37 young adults and 34 older adults.

3.1 | Effect of everyday affect, age, and task type on naturalistic PM

Of the overall 1512 possible affect assessments, 223 were not answered and considered as missing, (14.7%). Before performing the main analyses, we explored the amount of variance in affect and PM performance that was within participants and between participants to ensure that there was sufficient variance in both dependent and independent variables within both age groups. Results of this variability analysis in affect and PM are shown in the Supporting Information (Figure S1). Metacognitive awareness, motivation, and strategy use were identified as significant predictors of PM performance in everyday life and included in the final model (see Supporting Information for further information). Higher metacognitive awareness, enhanced motivation, and use of strategies were associated with better PM performance, whereas task importance, everyday stress, and busyness were not associated with performance.

Results of the analysis on the effect of Everyday Affect, Age, and Task Type on Naturalistic PM are presented in Table 2 and Figure 2. There was a main effect of age, with young adults performing significantly worse compared to older adults, and a main effect of task type, with participants overall performing better in the event-based task than in the time-based task. There was also a main effect of affect measured within-participants. More precisely, when participants' affect was more negative than usual, compared to when it was more positive, they were less likely to accomplish a PM task. The OR tells us that when participants' affect became one point more negative on the SAM valence rating scale, participants were 1.13 times less likely to accomplish a PM task. The lack of a significant random effect for affect within-participants indicates that individuals did not differ significantly in their relationship between affect and PM.

In order to investigate whether the effects were mainly driven by changes towards a positive or negative affect, two separate regression

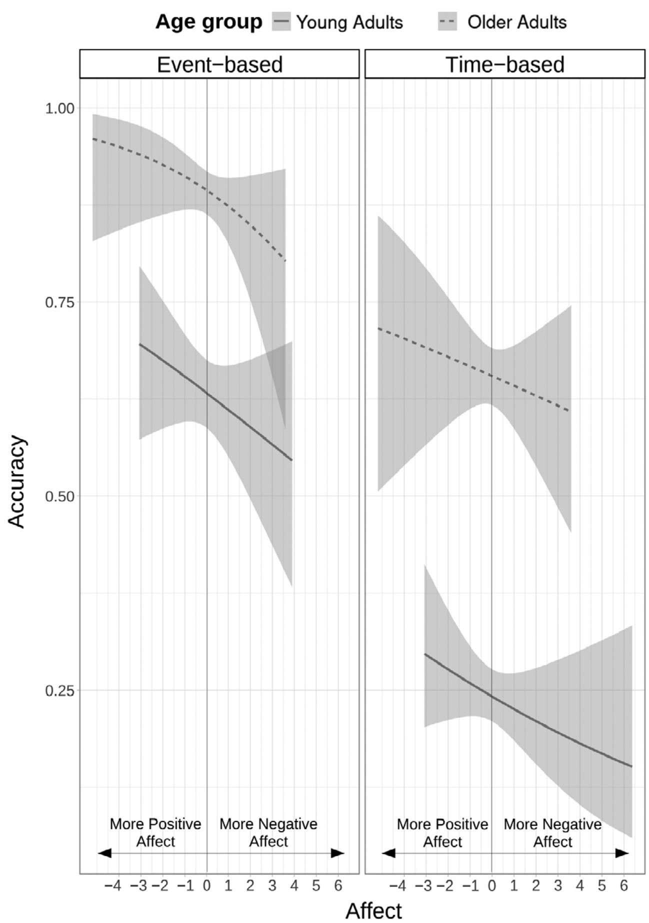

FIGURE 2 Prospective memory performance as a function of age group, task type, and affect. Changes in affect refer to changes compared to participants' neutral point. Values greater than zero refer to a more negative affect, while values smaller than zero refer to a more positive affect. The shaded areas represent 95% confidence intervals

spline analyses were run, considering positive and negative affect, respectively. Results showed that the effect of negative affect was not statistically significant, $b = -0.159$, $SE = 0.08$, $p = .064$, OR = 0.853, while the effect of positive affect was statistically significant, $b = -0.201$, $SE = 0.09$, $p = .024$, OR = 0.818. This indicates better PM performance associated with more positive affect.

Finally, there was no between participants influence of affect on PM, meaning participants with generally higher levels of affect did not have better PM performance than those with generally lower levels.

3.2 | Effect of task setting (laboratory vs. naturalistic), task type (event- vs. time-based), and age group

To compare PM performance in naturalistic and laboratory settings, aggregated performance was analysed as a function of setting, task type, and age group. Results are shown in Figure 3. There was a main effect of the setting, $F(1, 62) = 4.63$, $p = .035$, $\eta_p^2 = .07$, with participants performing better in the naturalistic setting, compared to the lab setting. The effect of task type was also significant, $F(1, 62) = 11.61$, $p = .001$, $\eta_p^2 = .61$, as participants performed better in the EBPM tasks compared to the TBPMs. By contrast, there was no main effect of age group, $F(1, 62) = 1.86$, $p < .177$, $\eta_p^2 = .03$. The setting by age group interaction, $F(1, 62) = 55.16$, $p < .001$, $\eta_p^2 = .47$, the task type by setting interaction, $F(1, 62) = 28.32$, $p < .001$, $\eta_p^2 = .31$, and the task type, by setting, by age group interaction, $F(1, 62) = 8.71$, $p = .004$, $\eta_p^2 = .12$, all reached statistical significance.

Follow-up analyses showed that while there were no age differences in the laboratory EBPM task, $t(70) = 0.914$, $p = .364$, $d = 0.20$, 95% CI for d: [0.122, 0.284], in the laboratory TBPM task young adults significantly outperformed older adults, $t(67) = 3.91$, $p < .001$, $d = 0.95$, 95% CI for d: [0.876, 1.029]. By contrast, in both naturalistic EBPM and naturalistic TBPM tasks older adults performed significantly better than young adults (EBPM: $t(58.68) = 3.80$, $p < .001$, $d = 0.93$, 95% CI for d: [0.859, 10.992]; TBPM: $t(67) = 6.99$, $p < .001$, $d = 1.71$, 95% CI for d: [1.655, 1.769]).).

To explore whether naturalistic and laboratory performance were related, we conducted an additional analysis with age group, laboratory PM performance, type of intention as predictors, and naturalistic PM as outcome measure. Results showed that there was a trend for laboratory PM performance to predict naturalistic performance, χ^2 (1) = 3.80, $p = .088$, while all the interactions did not reach significance, $ps > .537$.

4 | DISCUSSION

The present study was the first to explore the relationship between naturally occurring affect and performance in naturalistic PM tasks. Results showed that changes in affect were associated with PM performance. Specifically, as participants' affective state changed from more negative to more positive than their average, the likelihood of accomplishing a PM task increased. In addition, this effect was not modulated by age group. Further analyses showed that this effect was driven by positive affect that was associated with improved performance. There was a trend for negative affect to be associated with impaired performance.

The covariation of naturally occurring affect with PM is in line with findings from previous studies investigating affective influences on other cognitive abilities in everyday life (Brose et al., 2012; Brose et al., 2014). For negative affect, Brose et al. (2012) showed that participants' working memory was impaired on days characterised by

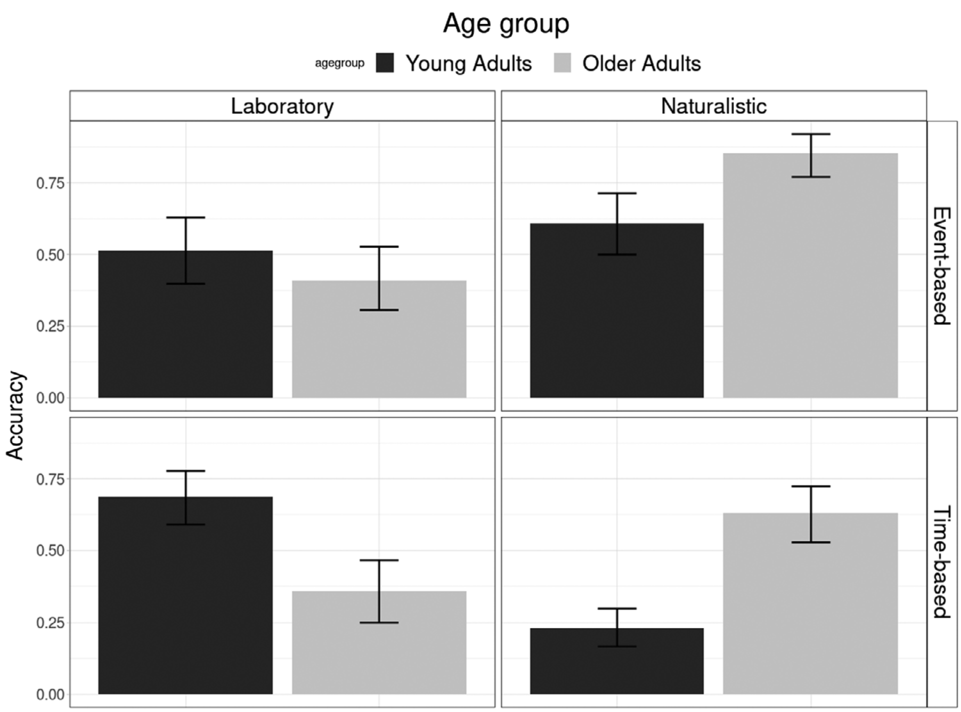

FIGURE 3 PM performance as a function of task type, age group, and setting. Error bars represent 95% confidence intervals

above average negative affect. Moreover, Riediger et al. (2011) showed that participants who on average showed an increased tendency to seek or to maintain a negative affect, a disposition called 'contra-hedonic orientation', performed worse on a working memory task. For positive affect, Brose et al. (2014) found that participants' working memory was improved for days characterised by more positive affect. The present study expanded these findings to PM performance and ageing. In addition, while previous studies considered the effects of day-to-day variation in affect on a single daily cognitive assessment, the present study used a higher temporal resolution by measuring both affect and PM several times throughout the day. Results support the conclusion that the affect participants were experiencing at the moment of the retrieval of the intention was associated with performance.

Using experience sampling methods (Csikszentmihalyi & Larson, 2014), it was possible to capture the experience of affect in real time. Moreover, it allowed consideration of the within-person variation in affective state in relation to participants' own baseline. The importance of individuals' affective neutral point has been emphasised by different authors (Baddeley, 2013; Kahneman, 1999), who considered affect not in absolute terms, but rather in relation to individuals' neutral point. According to this view, the cognitive system is thought to detect changes in affective valence in relation to individuals' baselines in order to regulate the behaviour accordingly (Kahneman, 1999). In line with these theoretical views, the present results suggest that within-person variations in affect but not between-person differences in affect predict cognitive performance.

Results from the present study are in line with lab-based studies on affect-cognition interactions, which have found a general impairment in performance due to negative affective states (Ellis et al., 1997; Figueira et al., 2017; Li et al., 2012). The finding that negative affect tends to be associated with impaired cognitive performance partially supports the resource allocation model (Ellis & Ashbrooks, 1988), according to which negative affect might lead to the production of task unrelated thoughts. This claim has been supported by studies finding an increase in task-unrelated thoughts during negative affect (Figueira et al., 2017; Smallwood et al., 2009). This increased production of task-unrelated thoughts is considered to withdraw resources from the main task leading to reduced cognitive performance. However, the resource allocation model also predicts that participants' performance should be worse during positive affect compared to neutral. The present result of improved PM under positive affect therefore does not support this account.

The finding that positive affect is associated with improved PM is in contrast with findings from laboratory studies (Rummel et al., 2012; Schnitzspahn et al., 2014). This discrepancy between previous lab-based and the present applied work supports the view that affective states induced in the laboratory might be different from naturally occurring states and accordingly have a different effect on cognitive performance (Brose et al., 2014; Ekman, 1994). One suggested difference is that affect induced in the lab can be perceived as a distraction from the task that participants are asked to do, and thus they may be implicitly prompted to regulate their affect in order to focus on the task (Brose et al., 2014). Participants in lab-based studies on cognition are usually instructed to perform the cognitive tasks as accurately and as quickly as possible. Such instructions may stress the importance of the task which may cause participants to focus on it and try to regulate their affect to increase their cognitive performance. However, emotion regulation has been shown to require cognitive control resources (Richards & Gross, 2000). Accordingly, affective states in the laboratory can represent an additional cognitive load, resulting in impaired performance in the cognitive assessment. On the contrary, naturally occurring affect is considered to be more subtle and is not normally perceived as clearly linked to a source or to a particular situation (Russell, 2003). More studies are clearly needed to test this hypothesis, perhaps using different ways to induce affective states, from more classic laboratory mood-induction procedures to more naturalistic and more subtle ones (Brooks et al., 2012; Zemack-Rugar et al., 2007).

It is also possible that the discrepancies between findings from field and laboratory studies are due to differences in participants' motivation to execute the PM tasks. In fact, it has been argued that laboratory mood-induction procedures are unlikely to create motivational states that are high in approach, like desire and enthusiasm, which are associated with goal pursuit (Harmon-Jones et al., 2012). On the contrary, positive affect experienced in everyday life might be coupled with a high motivation state, which might foster task engagement and result in improved performance (see, e.g., Brose et al., 2014; Gendolla & Richter, 2010). These assumptions are supported by studies which have induced positive affect using rewards or gifts (e.g., Isen et al., 1978, study 1 and 2; Padmala & Pessoa, 2011), finding improved memory performance under positive affect, and by theoretical approaches linking these improvements to increased release of dopamine in the prefrontal cortex (Ashby et al., 1999). Further studies specifying the effects of motivational states and positive affect on PM are needed to directly test these assumptions. In previous studies on affect-PM relationships, happy film clips were used to induce positive affective states (Rummel et al., 2012; Schnitzspahn et al., 2014). Future studies could try to induce affective states considered as highly motivating such as desire and enthusiasm.

In contrast to our predictions, we did not find any age difference in the influence of affect on PM. Evidence from a previous study (Schnitzspahn et al., 2014) suggested that older adults' PM may be resistant to the detrimental effects of positive and negative affect. Several reasons might explain the differences between previous findings and findings from the present study. One possibility is that Schnitzspahn et al. (2014) used a typical lab-based PM task that is considerably more challenging for older adults, compared to young adults. In fact, older adults are typically impaired in lab-based PM tasks, while they outperform young adults in naturalistic PM tasks carried out in everyday life (Henry et al., 2004). The high difficulty of lab-based PM tasks for older adults might prompt them to put more effort into task processing, distracting them from the influence of affect. This explanation is supported by evidence suggesting that high task demands lessen the effects of affective states on cognitive performance (Van Dillen & Koole, 2007).

In relation to overall age differences in PM, the present study replicated the consolidated pattern of age-related deficits in the laboratory and age-related benefits in the field (Henry et al., 2004). The present study also found evidence to support the suggested interaction between PM task type, setting and age group (Schnitzspahn et al., 2020), with more pronounced age-related deficits in the laboratory, and more pronounced age-related benefits in the field for TBPM compared to EBPM tasks. In addition, in line with previous studies (Ihle et al., 2012; Schnitzspahn et al., 2013) several variables were found to be predictive of naturalistic PM performance. More precisely, better metacognitive awareness, stronger motivation, and strategy use were positively associated with PM performance. On the contrary, other variables like everyday stress and busyness were not associated with PM performance.

It is important to note that in the present study everyday stress and busyness were not measured on a daily basis, but at the end of the testing week. As these variables vary on a daily basis, it is possible that their daily fluctuations may have influenced affect and/or PM in the present study although their retrospective assessment was not associated with performance. In addition, in the present study we did not limit participants in their use of strategies, as we were interested in their natural, spontaneous behaviour. Participants reported a variety of memory strategies as a result (see Tables S3 and S4), which did not allow us further investigation into the effects of specific strategies on PM, as the numbers per strategy differed and were generally low leading to low power for analyses on subsamples (see Supporting Information for exploratory analyses). Future studies could manipulate the kind of strategy participants are encouraged to use, to clarify the role of certain strategies (e.g., setting external reminders) for PM in young and older adults under differing levels of affect.

It is important to note that results presented in this study are correlational, and thus do not allow any causal inference. In fact, even though positive affect may be coupled with improved PM performance, and negative affect might be associated with impaired PM performance, a reverse causal effect cannot be excluded. Accomplishing a PM task in the present study could have enhanced affect, while forgetting could have led to a more negative affect. Moreover, a third variable that we did not measure in the present study might underlie the observed associations. For instance, receiving a reward might have boosted both PM and affect.

Another possible limitation of the present findings may be limited statistical power. Since no similar naturalistic studies on affect and PM were conducted before, the power calculation was based on effects derived by a previous laboratory study investigating age by affect interactions on PM (Pupillo et al., 2021). However, lab-induced affect might be more intense compared to naturally occurring fluctuations of affect leading to an underestimation of the number of participants required to detect effects of affect and age on PM in a naturalistic setting. For this reason, similar future studies should consider increasing participant numbers.

Despite assessing affect and PM in participants' everyday lives using their own smartphones, the methods used in the present study are still somewhat artificial. In fact, the assigned tasks, namely sending SMS at predefined times or events, were imposed by the experimenter and not part of participants' routines. In order to achieve the highest level of ecological validity (Phillips et al., 2008), future studies should assess the effects of daily affect on participants' self-generated intended actions and their fulfilment (e.g., Schnitzspahn et al., 2016).

To sum up, the present study made an important contribution to the understanding of how natural fluctuations of affect are coupled with cognitive performance. Specifically, it showed that fluctuations towards a more negative affect tended to be associated with increased likelihood of not accomplishing PM tasks, while fluctuations towards a more positive affect were associated with increased capability of remembering to execute intentions. This is similarly true for young and older adults.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

Data and script have been made publicly available at the Open Science Framework and can be accessed at https://osf.io/3u4jt/.

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How to cite this article: Pupillo, F., Powell, D., Phillips, L. H., & Schnitzspahn, K. (2022). Remember to stay positive: Affect and prospective memory in everyday life. *Applied Cognitive Psychology*, *36*(1), 179–190. https://doi.org/10.1002/acp.3908