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Psychophysiology of prospective memory

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Prospective memory involves the self-initiated retrieval of an intention upon an appropriate retrieval cue. Cue identification can be considered as an orienting reaction and may thus trigger a psychophysiological response. Here we present two experiments in which skin conductance responses (SCRs) elicited by prospective memory cues were compared to SCRs elicited by aversive stimuli to test whether *a single* prospective memory cue triggers a similar SCR as an aversive stimulus. In Experiment 2 we also assessed whether cue specificity had a differential influence on prospective memory performance and on SCRs. We found that detecting a single prospective memory cue is as likely to elicit a SCR as an aversive stimulus. Missed prospective memory cues also elicited SCRs. On a behavioural level, specific intentions led to better prospective memory performance. However, on a psychophysiological level specificity had no influence. More generally, the results indicate reliable SCRs for prospective memory cues and point to psychophysiological measures as valuable approach, which offers a new way to study one-off prospective memory tasks. Moreover, the findings are consistent with a theory that posits multiple prospective memory retrieval stages.

Keywords: Prospective memory; Arousal; Psychophysiology; Electrodermal activity.

Prospective memory is the ability to remember a planned action at the appropriate occasion in the future. In contrast to retrospective remembering, prospective remembering is typically *self-initiated* and not stimulated by an explicit request to remember. In addition, for event-based prospective memory tasks, prospective memory cues are usually embedded in an ongoing activity that has to be interrupted in order to perform the prospective memory task. Thus, a critical feature of a prospective memory cue is that it occurs as an integral part of the ongoing activity and does not require special treatment (i.e., it can be missed without a participant realising it). Due to the necessity of self-initiated retrieval, detecting a prospective memory cue requires an orienting reaction. It is well known that orienting reactions influence psychophysiological measures such as the skin conductance response (SCR) similar to the arousal induced by aversive stimuli (Boucsein, 1992). However, the psychophysiological reactions which underlie encountering a prospective memory cue are largely unknown. The goal of the present study is to further our understanding of the processes underlying prospective memory retrieval and to compare the psychophysiological

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signature of encountering a prospective memory cue and an aversive picture.

In the past, psychophysiological measures have been successfully employed to inform theories of memory (e.g., Bechara et al., 1995). However, there is only one study which assessed SCRs in a prospective memory task (Kliegel, Guynn, & Zimmer, 2007). Based on the noticing plus search model (Einstein & McDaniel, 1996) and the general assumption that noticing a significant stimulus elicits a SCR, Kliegel et al. (2007) hypothesised that if prospective memory forgetting is primarily caused by a failure to notice a cue, then SCRs for prospective hits should be higher and SCRs for prospective misses should be similar to correctly rejected neutral ongoing task trials. Alternatively, if prospective memory forgetting is primarily caused by a failure of a directed memory search after noticing a cue, then misses and correct rejections of ongoing task lures should provoke substantial SCRs. Kliegel et al. conducted two experiments to evaluate the potential explanations. In the first experiment an auditory word rating task was used as the ongoing activity. Participants had to rate randomly selected words on four possible dimensions (pleasantness, concreteness, desirability, childishness) by pressing one of two distinct keys. For the prospective memory task participants had to press a third predefined key whenever one of three cue words appeared. The task consisted of 92 trials with six embedded prospective memory cues which appeared every 13th to 15th trial. SCRs were measured for each trial. The results showed that SCRs for prospective hits were significantly higher than correctly rejected neutral trials. Prospective hits also elicited significantly higher SCRs than prospective misses. Moreover, prospective misses showed significantly higher SCRs than correctly rejected neutral trials. In a second experiment in which 12 ongoing stimuli were replaced with lures (half of which were semantically and phonologically similar to the prospective memory cues each) these results were replicated. Furthermore, SCRs for correct rejections of both types of lures were higher than for correct rejections of neutral ongoing task trials. These results are consistent with the noticing plus search model of prospective memory. Furthermore, as only six prospective memory cues were employed in these two experiments, the findings suggest that reliable psychophysiological results may be obtained even for *one single* prospective memory cue.

In everyday life prospective memory tasks are usually one-off tasks that do not involve repeated cues which may act as reminders to fulfil the task (cf. Meier, von Wartburg, Matter, Rothen, & Reber, 2011). Hence it was our main goal to test whether the orienting reaction of encountering *a single* prospective memory cue is equally reliable in eliciting an SCR as the arousal reaction of encountering an aversive stimulus (i.e., photograph of a road traffic accident). Aversive stimuli were used because SCRs to aversive stimuli are well characterised. In healthy individuals, SCRs for unpleasant stimuli are usually stronger and more reliable than for pleasant stimuli (MacDowell & Mandler, 1989). Conceptually, SCRs to aversive stimuli reflect emotional reactions whereas SCRs to prospective memory cues are hypothesised to reflect orienting reactions. However, there is no direct link between SCRs to aversive stimuli and SCRs to prospective memory cues as similar SCRs can reflect different underlying processes. Accordingly, different brain regions seem to be associated with different functional roles in electrodermal activity (e.g., Boucsein, 1992). That is, the amygdala is likely to be associated with affective processes and the prefrontal cortex with processes related to orientation and attention. Similarly, verbal and visual stimuli produce very similar SCRs although they are based on activities in different brain areas.

In this study we also investigated whether encountering an aversive stimulus would affect the psychophysiological and behavioural reaction to a subsequent prospective memory cue. We reasoned that an unexpected aversive stimulus might cause a short "attentional blink" during which a prospective stimulus is not sufficiently processed for successful retrieval, or that an aversive stimulus may cause an aroused state which diminishes an appropriate transfer from planning to self-initiated retrieval of the prospective memory task (Meier & Graf, 2000).

These questions were addressed in two separate experiments. In Experiment 1 we tested whether detecting a prospective memory cue elicits a similar SCR as an aversive stimulus. We used a complex short-term memory (STM) task as an ongoing task which involved the simultaneous processing of easy-to-name objects and unrelated nouns (Meier et al., 2011; see also Meier, Zimmermann, & Perrig, 2006). The ongoing task required participants to read each word aloud while memorising the object for later recall. The prospective memory task was to perform an action when a word from the category of musical instruments was displayed. During the ongoing STM task, half of the participants were presented with the aversive stimulus. The purpose of Experiment 2 was to generalise the findings from Experiment 1 with a different ongoing task (i.e., a simple picture comparison task; cf. Zimmermann & Meier, 2006). In addition we tested the effect of cue specificity. Previous behavioural studies have shown that specific intentions lead to better prospective memory performance than categorical intentions (Brandimonte & Passolunghi, 1994; Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; Ellis & Milne, 1996; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Meier et al., 2011). No psychophysiological study has tested categorical intentions. However, this is important because it might inform us about the processes underlying the performance advantage for specific cues found on the behavioural level. Thus half of the participants were instructed to press a particular key when a picture of an eagle was presented (i.e., specific instruction) and the other half were instructed to press a particular key when a picture of a bird was presented (i.e., categorical instruction). All participants were shown the same picture of an eagle as the prospective memory cue.

We expected to find significant SCRs for the aversive stimulus as well as for the prospective memory cue in both experiments. For prospective memory misses, we expected the SCRs to be substantially reduced in comparison to SCRs for prospective memory hits. Nevertheless, SCRs to prospective memory misses were expected to be significantly higher than SCRs for their respective neutral baseline stimuli. Moreover, we hypothesised that encountering a prospective memory cue immediately after an aversive stimulus would result in a lower SCR to the prospective cue and in lower prospective memory performance. For Experiment 2 we additionally expected that, on a behavioural level prospective memory performance would be higher for specific than for categorical intentions. Accordingly, as outlined in detail in the Discussion section of Experiment 1, on a psychophysiological level we were assuming we would find greater SCRs for specific than categorical intentions.

EXPERIMENT 1

Method

Participants. A total of 86 volunteers participated in this study. Due to a technical error during the acquisition of the skin conductance, data of 13 participants were lost. Moreover, three participants were identified as "non-responders" who showed no variation in their skin conductance and they were omitted from analyses. Thus the data analysis was conducted with 35 participants remaining in the "neutral" Picture Valence condition and 35 in the "aversive" Picture Valence condition (39 women and 31 men, M = 26 years, SD = 5.53). The study was approved by the local ethics committee of the University of Bern. All participants were fully informed about the purpose of the study and advised that they could withdraw at any time during the experiment. All participants gave verbal consent.

Apparatus. Presentation of stimuli was computerised using E-Prime 1.1 software (Psychology Software Tools, Pittsburgh, PA, USA). Experimental materials were presented against a white background in the centre of a 17-inch VGA monitor. SCRs were measured with two shielded Ag/AgCl-electrodes (FMS Falk Minow Services, Herrsching, Germany), 8 mm in diameter, filled with TD-246 (PAR Medizintechnik GmbH, Berlin, Germany), a neutral medium with 0.5% NaCl. SCR data were acquired with a skin conductance level meter (UFI, model 2701, Morro Bay, CA, USA). To digitise SCR data, an analogue to digital converter (MacLab / 4s ML740, AD Instruments Ltd, Castle Hill, NSW, Australia) was used. SCR data were recorded using a Macintosh G4 computer (Apple Computer Inc., Cupertino, CA, USA) with Chart v4.2 software (AD Instruments Ltd, Castle Hill, NSW, Australia).

Materials. A total of 72 words and 72 photographs were used for the complex STM task. Four- to eight-letter German nouns with medium frequency and medium to high concreteness were selected from two different sources (Hager & Hasselhorn, 1994; Ruoff, 1981). Photographs of easy-to-name objects were taken from the internet. They corresponded to a standardised set of 260 line drawings (Snodgrass & Vanderwart, 1980). These stimuli were grouped into four sets of lists. Each set consisted of four lists of word–object pairs. Within each set, the lists contained three, four, five, and six items (i.e., word–object pairs). Two sets were used for baseline and experimental trials each. In the fourth set of lists the final six-item list included the aversive stimulus in the second position in the experimental condition. The aversive stimulus was a photograph of a road traffic accident. In the control condition the same stimulus was used but with the traffic accident deleted and the photograph neatly retouched, thus transforming it into a neutral stimulus. In both experimental conditions the same six-item list included the prospective stimulus in the fifth position. Four different names of musical instruments were used as prospective memory cues (i.e., "piano", "guitar", "violin", and "trumpet").

Procedure. Skin conductance was continuously measured by a constant voltage (0.5 V) and sampled at 20 Hz with two electrodes, attached to the thenar and hypothenar eminences of the non-dominant hand. Participants were tested individually. They were seated in a comfortable chair, 60 cm in front of a computer screen, and informed that the experiment consisted of a variety of tasks.

First participants were instructed for the STM task. They were told that they would be presented with a series of words and photographs, which would appear simultaneously on the screen. They were instructed to read each word aloud and memorise the photograph on each trial. They were also told that after a few pairs of words and photographs, an instruction to recall the photographs would appear on the screen. They were instructed to recall all of the photographs—or as many as possible—in any order. The procedure was the same for all trials of the STM task. For each list of word–object pairs the experimenter started the presentation by pressing the space bar. Each word–object pair was centred vertically and horizontally within a 7 cm by 7 cm square; the word was horizontally centred and was printed in 18-point font. Each word–object pair was presented for 1500 ms. After each list the instruction to recall the photographs appeared on the screen. An example of a six-item list is shown in Figure 1.

To ensure that participants had understood the instructions correctly, they were asked to repeat them in their own words. Then they were instructed to relax, not to move, to remain silent, and to respond only to the stimuli that would appear on the screen. Then the baseline measure of the STM task consisting of eight trials (i.e., two sets with four lists each) was administered. The experimenter wrote down the responses on a separate answer sheet. Next the instructions for the prospective memory task were given. Participants were instructed to inform the experimenter *whenever you see a word that is the name of a musical instrument* and to give *a brief description of what it looks like*. They were given an example of what kind of description was considered appropriate. Specifically they were told that if the prospective memory cue was, for example, "saxophone", an appropriate description would be "an instrument that is typically made of metal and has a silvery or golden colour". To exclude the possibility that the STM task might interfere with remembering the prospective memory task in the critical list, participants were informed that they were not required to recall a list that contained a prospective memory cue. To ensure that participants understood the instructions, they again had to repeat them in their own words.

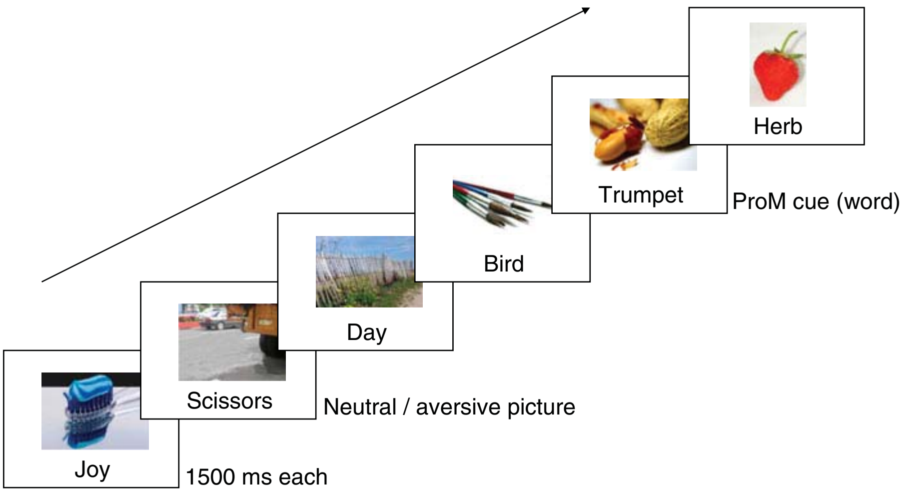

Figure 1. STM list with embedded prospective memory task ("neutral" Picture Valence condition). In the "aversive" Picture Valence condition, in the second picture a casualty lies behind the wheel of the truck. The materials were originally presented in German (to view this figure in colour, please see the online version).

Next two unrelated distractor tasks were administered for a total retention interval of approximately 5 minutes (Meier et al., 2011).

Then the ongoing task consisting of the other eight word lists of the STM test was administered. The procedure was identical to the baseline task with two exceptions: (a) depending on the experimental condition, the aversive stimulus or its respective neutral control stimulus (i.e., between-subject manipulation) was embedded in the second position of the last list; (b) the prospective memory cue was embedded in the fifth position of the same list as the aversive stimulus. Prospective memory performance was scored as correct when a participant recognised the prospective memory cue any time from the occurrence of the word (i.e., fifth position of the last six word–object pair list) until the end of the recall phase of that list (i.e., when the participant stated that he/she did not remember any further object).

At the end of the experiment, participants who failed to perform the prospective memory task were asked whether they remembered that they were instructed to perform an additional task under specific conditions and what they had to do. As all participants remembered both components, these data are not described or discussed any further.

SCR analysis. Skin conductance data were analysed with Ledalab (version 3.4.4) by the means of a Continuous Decomposition Analysis which decomposes skin conductance into continuous tonic and phasic activity (Benedek & Kaernbach, 2010). The method is based on standard deconvolution. It is important to note that the method allows reliable estimates of SCRs even with short inter-trial intervals (i.e., 2 seconds). The method prevents the refractory period of the SCR associated with the aversive stimulus from reducing the measured SCR associated with the subsequent prospective memory cue and it is generally artefact resistant (Benedek & Kaernbach, 2010). For the analysis of SCRs a response window of 3 seconds was defined, ranging from 1 to 4 seconds after stimulus onset. The selection of the response window reflects the fact of SCR onset latencies of 1 second or more (Dawson, Schell, & Filion, 2000). SCRs were defined as the average phasic driver in the response window with higher values indicating higher autonomic arousal. It is important to mention that this score represents phasic activity most accurately (Benedek & Kaernbach, 2010). Neutral photographs in the second and fifth position of the eight-word list of the baseline STM were used as a psychophysiological baseline according to the aversive stimulus and the prospective stimulus respectively. Furthermore, for the measurement of SCR peak latencies a minimum amplitude criterion of .05 μS was adopted. Baseline stimuli were not considered for the analysis of SCR peak latencies because neutral stimuli are not expected to elicit SCRs. That is, SCRs to baseline stimuli will not exceed the minimum amplitude criterion for a large portion of participants.

Results

An alpha level of 0.05 was used for all statistical tests. Prospective memory performance was measured as the proportion of correct responses. Because only one prospective memory cue was administered, the proportion of correct responses was equal to the proportion of successful participants.

Prospective memory performance. First we tested whether an aversive picture immediately before a prospective memory cue affected prospective memory performance. The proportion of successful prospective memory retrieval (i.e., prospective hits) was .49 for the "aversive" Picture Valence condition and .49 for the "neutral" Picture Valence condition, respectively. Obviously, these proportions were not statistically different, $\chi^2(1) = .00$, $p = 1.00$.[1]

Ongoing task performance. The total number of remembered objects in the practice block of the STM task was 21.89 ($SD = 3.22$) for the "aversive" Picture Valence condition and 21.86 ($SD = 3.13$) for the "neutral" Picture Valence condition, respectively. In the test block of the STM task the total number was 19.54 ($SD = 3.33$) for the "aversive" Picture Valence condition and 19.49 ($SD = 3.41$) for the "neutral" Picture Valence condition, respectively.

A mixed two-factorial analysis of variance (ANOVA) with Picture Valence (aversive, neutral) as a between-subjects factor and Block (practice, test) as a within-subjects factor revealed a significant main effect of Block, $F(1, 68) = 49.34$, $p < .001$, $\eta_p^2 = .42$, indicating that overall the

[1]We also conducted the analysis with the full dataset. That is, with the behavioural data of all 86 participants. Notably, the pattern of significance remained the same as for the 70 participants whose SCR data were available.

proportion of remembered objects was higher in the practice block compared to the test block. No other effect was significant (see Footnote 1).

SCR to aversive picture vs SCR to prospective memory hit. To contrast SCRs for arousal reactions and prospective remembering, we first calculated the difference between the aversive picture and its respective neutral baseline picture and the difference between the prospective memory cue and its respective neutral baseline picture for those participants with successful prospective memory retrieval only. As depicted in Figure 2, SCRs for successful prospective memory retrieval were higher than SCRs for arousal reactions. A mixed two-factorial ANOVA, with Picture Valence (aversive, neutral) as a between-subjects factor and Stimulus Type (picture, prospective hit) as a within-subjects factor, revealed a significant main effect of Stimulus Type, $F(1, 32) = 17.22$, $p < .001$, $\eta_p^2 = .35$, and a significant interaction, $F(1, 32) = 5.22$, $p < .05$, $\eta_p^2 = .14$. No other effect was significant.

Subsequent *t*-tests showed that SCR differences for the Stimulus Type "picture" were greater in the aversive picture condition than the neutral picture condition, $t(32) = 2.97$, $p < .01$. However, prospective hits did not differ with respect to the factor Picture Valence, $t(32) = .56$, $p = .580$. Moreover, in the "neutral" Picture Valence condition SCR differences for the Stimulus Type "prospective hits" were significantly greater than SCR differences for the Stimulus Type "picture", $t(16) = 4.38$, $p < .001$, but this was not the case in the "aversive" Picture Valence condition, $t(16) = 1.38$, $p = .188$.

SCR to aversive picture. Next we tested whether the aversive stimulus did indeed elicit an arousal reaction (Table 1a, left side). Analysing all participants, SCRs to the aversive picture were higher than SCRs to the neutral picture. A mixed two-

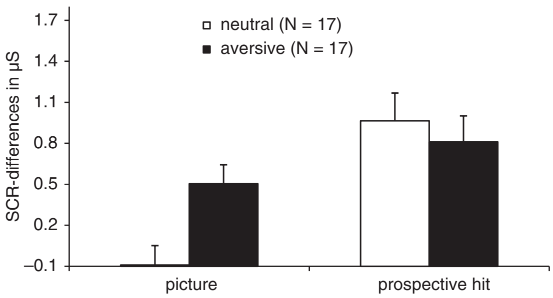

Figure 2. SCRs in µS for the difference between the picture / prospective hits and their respective baselines according to the neutral and aversive Picture Valence condition. Error bars represent standard errors.

factorial analysis of variance (ANOVA), with Picture Valence (aversive, neutral) as a between-subjects factor and Picture Trial (baseline, test) as a within-subjects factor, revealed a significant interaction, $F(1, 68) = 15.29$, $p < .001$, $\eta_p^2 = .18$. No other effect was significant. Subsequent *t*-tests showed that SCRs between the two Picture Valence conditions differed for the test picture, $t(68) = 2.58$, $p < .05$, but not for the baseline picture, $t(68) = 1.56$, $p = .123$.

SCR to prospective memory retrieval after aversive picture. SCRs for prospective hits were numerically smaller after an aversive picture than after a neutral picture (see Table 1b, left side). A mixed two-factorial ANOVA, with Picture Valence (aversive, neutral) as a between-subjects factor and Memory Trial (ongoing, prospective) as a within-subjects factor, revealed a significant main effect of Memory Trial, $F(1, 32) = 40.63$, $p < .001$, $\eta_p^2 = .56$. The interaction, however, was not significant, $F(1, 32) = .31$, $p = .580$, $\eta_p^2 = .01$. No other effect was significant.

Next we analysed peak latencies of SCRs for prospective hits to determine if the aversive picture delayed the SCR response to the prospective memory cue. Mean peak latency in the aversive picture condition was 2.07 seconds ($SE = .21$) and in the neutral picture condition it was 2.03 seconds ($SE = .23$). We were not able to confirm our hypothesis, $t(24) = .13$, $p = .894$.

SCR to prospective memory cue. SCRs for the prospective memory cue increased more for participants with successful prospective memory retrieval than for participants with prospective memory misses (see Table 1c, left side). A mixed two-factorial ANOVA, with Retrieval Success (hit, miss) as a between-subjects factor and Memory Trial (ongoing, prospective) as a within-subjects factor, revealed a significant main effect of Retrieval Success, $F(1, 68) = 108.78$, $p < .001$, $\eta_p^2 = .62$, and of Memory Trial, $F(1, 68) = 35.31$, $p < .001$, $\eta_p^2 = .34$, and a significant interaction, $F(1, 68) = 4.84$, $p < .001$, $\eta_p^2 = .21$.

Subsequent *t*-tests comparing the two Retrieval Success conditions showed that SCRs differed for "prospective" Memory Trials, $t(68) = 4.47$, $p < .001$, but not for "ongoing" Memory Trials, $t(68) = .98$, $p = .332$. Moreover, a *t*-test revealed that SCRs for prospective memory misses also approached significance in comparison to their respective ongoing trials, $t(37) = 1.45$, $p = .095$, one-tailed.

TABLE 1
Mean SCRs (in μS) for Experiments 1 and 2

	Experiment 1					*Experiment 2*				
Between subjects Variable	*SCR [in μS]*				N	*SCR [in μS]*				N
(a) Picture Valence	baseline		test			baseline		test		
neutral	.52	(.12)	.36	(.08)	35	.18	(.03)	.21	(.05)	40
aversive	.32	(.05)	.70	(.11)	35	.20	(.03)	.76	(.14)	39
(b) Picture Valence	ongoing		prospective (hits)			ongoing		prospective (hits)		
neutral	.50	(.13)	1.47	(.22)	17	.19	(.04)	1.73	(.16)	35
aversive	.38	(.08)	1.19	(.18)	17	.19	(.03)	1.67	(.16)	29
(c) Retrieval Success	ongoing		prospective			ongoing		prospective		
hit	.44	(.08)	1.33	(.14)	34	.19	(.03)	1.70	(.11)	64
miss	.34	(.07)	0.48	(.12)	36	.16	(.03)	.62	(.22)	15

(a) For the baseline and the neutral and aversive test picture, respectively; (b) For the ongoing task trials and prospective memory hits after the neutral and aversive picture, respectively; (c) For the ongoing task trials and prospective memory hits and misses, respectively. Standard errors in parentheses. Note that the pattern of results is remarkable similar between the two experiments.

For the sake of comparability with Experiment 1, we collapsed the SCRs for the (non-significant) Cue specificity factor for Experiment 2.

Discussion

The results indicate that successful detection of *a single* prospective memory cue reliably elicited SCRs comparable to those generated by an arousal state through the means of an aversive stimulus. In contrast, prospective misses showed substantially lower SCRs, but nevertheless in trend they were somewhat higher than their respective baseline. Hence this is the first study to provide a relatively pure psychophysiological measure (i.e., SCR) for one-off event-related prospective memory—“ProM proper” (Graf & Uttl, 2001). Moreover, we hypothesised that an unexpected and unpleasant experience immediately before a prospective memory cue would reduce prospective memory performance and the SCR associated with prospective memory retrieval. However, this was not the case.

Verbal responses may influence respiration and irregular respiration affects psychophysiological measures such as SCRs (Schmidt & Walach, 2000). Therefore we might have found more pronounced effects with motor responses, especially for SCRs to prospective memory misses which were in trend different from their baseline. Hence we designed an experiment with motor response requirements to test for replication and extension of the current results.

Previous studies have shown that specific intentions lead to more prospective memory hits than categorical intentions on a behavioural level (Brandimonte & Passolunghi, 1994; Einstein et al., 1995; Ellis & Milne, 1996; Marsh et al., 2003; Meier et al., 2011). Therefore we were interested in whether we would also find a difference on a psychophysiological level. According the discrepancy attribution model of prospective memory, people constantly evaluate the fluency of their own information processing (McDaniel, Einstein, Guynn, & Breneiser, 2004). Hence an event is recognised as singular (in the sense of being novel or different) if its actual fluency is experienced differently from its expected fluency (Graf, 2005). By its constitution, a prospective memory cue is pre-processed in terms of specifying an intention in a previous planning phase. Thus prospective memory cues which were specified to a greater degree during the planning phase should elicit more discrepancy between expected and experienced fluency than cues that were specified to a lesser degree. It follows that the discrepancy attribution model would predict higher SCRs for specific instructions in comparison to categorical instructions (cf., Mandler, 1980, 1991, 1994; McDaniel et al., 2004; Whittlesea & Williams, 1998, 2001a, 2001b).

EXPERIMENT 2

Method

Participants. A total of 80 undergraduate students from the University of Bern participated in this study for course credit. One participant who showed no variability in skin conductance was excluded as non-responder. The data analysis was conducted with the remaining 79 participants (67 women and 12 men, M = 22.24 years, SD = 4.26). The study was approved by the local ethics committee of the University of Bern. Participants took part voluntarily and were fully informed about the purpose of the study. They were advised that they could withdraw at any time during the experiment. All participants gave verbal consent.

Apparatus. Apparatus was the same as in Experiment 1.

Materials. For the picture comparison task a total of 160 pictures were required; 80 pictures for practice and 78 pictures for the ongoing task in which the prospective memory cue occurred. One additional picture was used as aversive stimulus or as its corresponding control picture, respectively, and another additional picture was used as the prospective memory cue. Pictures of easy-to-name common objects were taken from the study by Zimmermann and Meier (2006). They were standardised in size and resolution and then duplicated such that each picture occurred twice, side by side on a computer screen. Half of the copies were slightly modified such that they differed from the original in one prominent feature. The prospective memory cue was a photograph of a flying eagle. The aversive stimulus, as well as the respective control stimulus, was the same photograph of a road traffic accident as in Experiment 1.

Procedure. Skin conductance was continuously measured by a constant voltage (0.5 V) and sampled at 20 Hz with two electrodes, attached to the thenar and hypothenar eminences of the non-dominant hand. Participants were tested individually. They were seated in a comfortable chair, 60 cm in front of a computer screen and informed that the experiment consisted of a variety of tasks.

First, participants were instructed for the picture comparison task. They were told that they would see a pair of pictures and that some picture pairs were identical but some were slightly different. They were instructed to indicate for each pair whether the pictures were identical or not by pressing the “b” key or the “n” key with the index and middle finger of the dominant hand. The instructions were explained until participants understood and were able to repeat them. Thereafter, participants were asked to relax, to remain silent, and to respond to the stimuli that would appear on the screen. Next, 80 trials of the picture comparison task were presented in pseudo-random order. On each trial a centred fixation cross was presented for 1000 ms, followed by a pair of pictures side by side horizontally in the centre of the screen, which was presented until a response was made. If no response was made within 1500 ms the picture disappeared and “Please respond!” was presented in an 18-point font in the centre of the screen.

Then instructions for the prospective memory task were given. Participants were informed that we were interested in how well they could remember to carry out an activity in the future. The activity was to press a particular key on the keyboard. Specifically, they were instructed to immediately press the “H” key on the keyboard with the right index finger every time they saw a specific picture and the picture of the eagle was shown in the condition with the specific instruction (cf., Brandimonte & Passolunghi, 1994; Einstein et al., 1995; Ellis & Milne, 1996; Marsh et al., 2003; Meier et al., 2011). In the categorical condition participants were instructed to press the “H” key on the keyboard with the right index finger every time they saw a picture of a bird. Cue specificity was manipulated between participants.

Next participants were presented with two unrelated distractor tasks which lasted about 20 minutes. Then the ongoing task with the embedded prospective memory task was started without mentioning the prospective memory task again. A total of 80 new picture pairs were presented. At the 66th position half of the participants were presented with the aversive stimulus and the other half with the corresponding neutral variant of the aversive stimulus (i.e., between-subjects manipulation). All participants were presented with the prospective memory cue at the 70th position. A schematic example of a trial including the prospective memory cue is presented in Figure 3.

Whenever a prospective memory cue was presented participants had to press the “H” key with their right index finger. At the end of the experiment participants who failed to perform the prospective memory task were asked whether they remembered that they were instructed to perform an additional task under specific conditions and what they had to do. As all participants remembered both components, these data are not further discussed.

SCR analysis. Skin conductance data were analysed with Ledalab (version 3.4.4) by the means of a Continuous Decomposition Analysis which decomposes skin conductance into continuous tonic and phasic activity (Benedek &

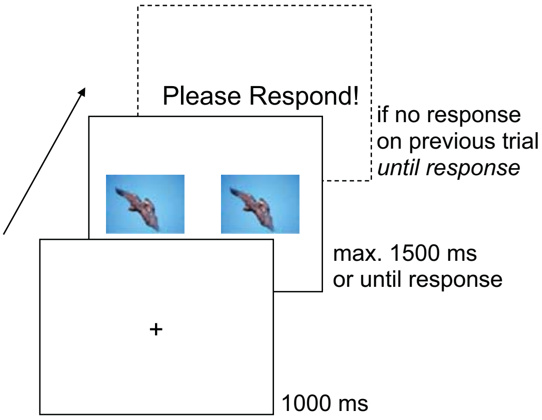

Figure 3. A trial of the ongoing task including the prospective memory cue. "Please respond!" was only shown if the participant did not respond within 1500 ms on the precedent frame and was presented until a response key was pressed (to view this figure in colour, please see the online version).

Kaernbach, 2010). For the analysis of SCRs a response window of 5 seconds was defined, ranging from 1 to 6 seconds after stimulus onset. SCRs were defined as the average phasic driver in the response window, with higher values indicating higher autonomic arousal. Neutral photographs at the 46th and 50th position of the ongoing task in the test phase were used as psychophysiological baseline according to the aversive stimulus at the 66th and the prospective stimulus at 70th position, respectively. As in Experiment 1, for the measurement of SCR peak latencies a minimum amplitude criterion of .05 μS was adopted and again baseline stimuli were not considered for the analysis of SCR peak latencies.

Results

Prospective memory performance. The proportion of successful participants (i.e., prospective hits)

TABLE 2
Ongoing task performance of Experiment 2

	Condition	*Instruction*	*Practice*	*Test*
(a)	control	specific	0.73 (.01)	0.71 (.01)
		categorical	0.74 (.01)	0.71 (.01)
	experimental	specific	0.74 (.01)	0.70 (.01)
		categorical	0.73 (.02)	0.69 (.02)
(b)	control	specific	1196 (81)	1214 (68)
		categorical	1237 (77)	1276 (80)
	experimental	specific	1175 (55)	1157 (56)
		categorical	1134 (65)	1146 (42)

(a) Proportion of correct responses and (b) Mean reaction times in ms. Standard errors in parentheses.

was .93 for the specific instruction condition and .69 for categorical instruction condition. Prospective memory performance in the specific condition was significantly higher, $\chi^2(1) = 6.95$, $p < .05$. For the "aversive" Picture Valence condition the proportion of the participants who remembered to perform the prospective memory task was .74, and for the "neutral" Picture Valence condition the proportion of successful participants was .88. However, we were again unable to confirm that encountering an aversive stimulus lowers subsequent prospective memory performance, $\chi^2(1) = 2.22$, $p = .161$.

Ongoing task performance. The proportion of correct responses and reaction times for the ongoing task are presented in Table 2. A mixed three-factorial ANOVA with Picture Valence (aversive, neutral) and Cue specificity (specific, categorical) as between-subjects factors and Block (practice, test) as a within-subjects factor revealed a significant main effect of Block for response accuracy, $F(1, 75) = 29.62$, $p < .001$, $\eta^2_p = .28$, with a higher proportion of correct responses in the practice block compared to the test block. No other effect was significant. The same type of analysis for the reaction times revealed no significant effect at all.

SCR to aversive picture vs SCR to prospective memory hit. As in Experiment 1, to compare SCRs for arousal reactions and prospective memory cues the SCR differences between the aversive picture and its respective neutral baseline picture were compared with the prospective memory cue and its respective neutral baseline picture for participants with successful prospective memory retrieval only. As depicted in Figure 4, SCRs for successful prospective memory retrieval are higher than

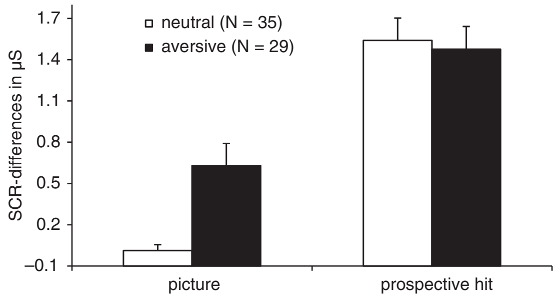

Figure 4. SCRs in μS for the difference between the picture / prospective hits and their respective baselines according to the neutral and aversive Picture Valence condition. Error bars represent standard errors. For the sake of comparability with Experiment 1, we collapsed the SCRs for the (non-significant) Cue specificity factor for Experiment 2.

SCRs for arousal reactions. Cue specificity did not interact with any of the other factors (see Supplementary Materials, Supplementary Figure, and Supplementary Table). A mixed three-factorial ANOVA with Picture Valence (aversive, neutral) and Cue specificity (specific, categorical) as between-subjects factors and Stimulus Type (picture, prospective hit) as a within-subjects factor revealed a significant main effect of Stimulus Type, $F(1, 60) = 92.55$, $p < .001$, $\eta_p^2 = .61$, and Cue specificity, $F(1, 60) = 4.20$, $p < .05$, $\eta_p^2 = .07$, and a significant Stimulus Type × Picture Valence interaction, $F(1, 60) = 7.13$, $p < .01$, $\eta_p^2 = .11$. No other effect was significant.

Subsequent *t*-tests showed that SCRs differed with respect to Picture Valence for the Stimlus Type "picture", $t(62) = 4.03$, $p < .001$, but not for the Stimulus Type "prospective hit", $t(62) = .27$, $p = .787$. For both Picture Valence conditions, there was a significant SCR increase for "prospective hits" when compared to the "picture". That is, for the "aversive" Picture Valence condition, $t(28) = 4.95$, $p < .001$, and for the "neutral" Picture Valence condition, $t(34) = 9.15$, $p < .001$, respectively.

SCR to aversive picture. SCRs for the aversive stimulus increased in the aversive picture condition but not in the neutral picture condition (see Table 1a, right side). However, SCRs were not influenced by cue specificity. A mixed three-factorial ANOVA with Picture Valence (aversive, neutral) and Cue specificity (specific, categorical) as between-subjects factors and Picture Trial (baseline, test) as a within-subjects factor revealed a significant main effect of Picture Trial, $F(1, 75) = 18.37$, $p < .001$, $\eta_p^2 = .20$, and of Picture Valence, $F(1, 75) = 13.13$, $p < .001$, $\eta_p^2 = .15$, and a significant Picture Trial × Picture Valence interaction, $F(1, 75) = 13.98$, $p < .001$, $\eta_p^2 = .16$. No other effect was significant. Subsequent *t*-tests showed that SCRs between the two Picture Valence conditions differed for the test picture, $t(77) = 3.81$, $p < .001$, but not for the baseline picture, $t(77) = .55$, $p = .584$.

SCR to prospective memory retrieval after aversive picture. SCRs for prospective hits were only slightly smaller after an aversive picture than after a neutral picture (see Table 1b, right side). A mixed two-factorial ANOVA with Stimulus Valence (aversive, neutral) as a between-subjects factor and Memory Trial (ongoing, prospective) as a within-subjects factor revealed a significant main effect of Memory Trial, $F(1, 62) = 167.74$, $p < .001$, $\eta_p^2 = .73$. The interaction was not significant, $F(1, 62) = .07$, $p = .787$, $\eta_p^2 = .001$. No other effect was significant.

Next we analysed peak latencies of SCRs for prospective hits to determine if the aversive picture delayed the SCR response to the prospective memory cue. Mean peak latency in the aversive picture condition was 2.70 seconds ($SE = .11$) and in the neutral picture condition it was 2.90 seconds ($SE = .08$). Again, the aversive picture did not the delay the SCR to the prospective memory cue significantly, $t(62) = 1.58$, $p = .120$. The pattern of SCR peak latencies was also reflected by the pattern of RTs to prospective hits. Mean RT in the aversive picture condition was 1393 ms ($SE = 56$) and in the neutral picture condition it was 1488 ms ($SE = 93$), $t(62) = .83$, $p = .411$.

SCR to cue specificity for prospective hits. For prospective hits, SCRs were 1.18 µS ($SE = .16$) for specific instructions and .20 µS ($SE = .04$) for the respective baseline. For prospective hits of the categorical instructions, SCRs were 1.54 µS ($SE = .15$) and .17 µS ($SE = .04$) for the respective baseline. A two-factorial ANOVA with Cue specificity (specific, categorical) as a between-subjects factor and Memory Trial (ongoing, prospective) as a within-subjects factor revealed a significant main effect of Memory Trial, $F(1, 62) = 164.21$, $p < .001$, $\eta_p^2 = .73$. Of specific interest was the interaction Memory Trial × Cue specificity. However, SCRs for prospective hits were not significantly influenced by the instructed cue specificity, $F(1, 62) = 1.04$, $p = .312$, $\eta_p^2 = .02$. No other effects were significant.

Next we analysed peak latencies of SCRs for prospective hits to determine if the categorical instruction delayed the SCR response to the prospective memory cue. Mean peak latency in the categorical instruction condition was 2.90 seconds ($SE = .12$) and in the specific instruction condition it was 2.74 seconds ($SE = .07$). The categorical instruction did not delay the SCR to the prospective memory cue significantly, $t(62) = 1.25$, $p = .217$.

Again, the pattern of SCR peak latencies was also reflected by the pattern of RTs to prospective hits. Mean RT in the categorical picture condition was 1512 ms ($SE = 114$) and in the neutral picture condition it was 1396 ms ($SE = 52$), $t(62) = 1.01$, $p = .318$.

SCR to prospective memory cue. SCRs for the prospective memory cue increased more for participants with successful prospective memory retrieval compared to participants with prospective memory misses (see Table 1c, right side). A mixed two-factorial ANOVA with Retrieval Success (hit, miss) as a between-subjects factor and Memory Trial (ongoing, prospective) as a within-subjects factor revealed a significant main effect of Retrieval Success, $F(1, 77) = 16.58$, $p < .001$, $\eta^2_p = .57$, and of Memory Trial, $F(1, 77) = 56.88$, $p < .001$, $\eta^2_p = .43$, and a significant interaction, $F(1, 77) = 16.12$, $p < .001$, $\eta^2_p = .17$. Subsequent *t*-tests comparing the two Retrieval Success conditions showed that SCRs differed for the "prospective" Memory Trials, $t(77) = 4.14$, $p < .001$, but not for the "ongoing" Memory Trials, $t(77) = .50$, $p = .620$. Moreover, SCRs for prospective memory misses were higher than their respective ongoing trials, $t(14) = 2.05$, $p < .05$, one-tailed.

SCR to prospective memory cue as a function of cue specificity. SCRs to prospective memory cues were not significantly influenced by cue specificity. The corresponding analyses are presented in Supplementary Results. However, these results must be treated with caution because only three participants missed the prospective memory cues in the specific cue condition.

Discussion

The finding of Experiment 1 that successful detection of *a single* prospective memory cue reliably elicits SCRs was replicated in Experiment 2. The advantage of motor response requirements in the current experiment led to the expected effect; the substantially reduced SCRs of prospective misses were significantly higher than their respective baseline. However, one might want to be cautious because the finding is based on a rather small sample. Nevertheless, it is also important to mention that the finding is in line with the trend in Experiment 1 and previous research (Kliegel et al., 2007). Again, this finding confirms our suggestion that encountering a prospective memory cue elicits an orienting reaction.

As in Experiment 1, the occurrence of an unexpected and unpleasant experience immediately before a prospective memory cue did not affect prospective memory performance or the SCR associated with prospective memory retrieval. Thus, despite the different methods used in Experiments 1 and 2, the pattern of results was very similar, demonstrating the robustness of the effects. In relation to the discrepancy attribution model of prospective memory (McDaniel et al., 2004), we were also interested to know whether we could find a psychophysiological marker for cue specificity and replicate previous findings of a performance advantage for more specified cues on a behavioural level. The results confirmed our expectations on a behavioural level. However, on a psychophysiological level, we did not find any difference between specific and categorical prospective memory intentions when the intention was successfully retrieved. Thus singularisation of a prospective memory cue seems to be independent of a particular intention.

GENERAL DISCUSSION

The first goal of this study was to test whether detecting *a single* prospective memory cue in a one-off task elicits a similar SCR as an aversive stimulus. The results showed that this was the case for both experiments. SCRs were at least as high for successful prospective memory retrieval as for the aversive stimulus. Importantly, prospective misses also elicited SCRs higher than their respective baseline, but they were substantially reduced in comparison to prospective hits. The second goal was to test whether encountering an aversive stimulus immediately before the prospective memory cue would lead to a distinct effect on the SCR to the prospective memory cue and whether it would invoke a corresponding behavioural effect. However, this was not the case in either experiment. The third goal was to test the impact of cue specificity. On a behavioural level we replicated the findings of previous studies. Specific intentions led to more prospective memory hits than categorical intentions. However, on a psychophysiological level intention specificity had no influence when the intention was successfully retrieved.

The psychophysiological results of both experiments are consistent with the findings of Kliegel et al. (2007) and suggest that encountering prospective memory cues trigger SCRs. Beyond that, we were able to show that *a single* prospective memory cue is equally alike to elicit a reliable SCR as an aversive stimulus. The importance of this finding towards the understanding of the psychophysiology of prospective memory becomes clear in consideration of the fact that most prospective memory tasks in everyday life are one-off tasks that do not present multiple cues of multiple instances to fulfil the task (Meier et al., 2011). Thus SCRs of the present study reflect a relatively pure measurement of event-based prospective memory—ProM proper (Graf & Uttl, 2001; Meier & Graf, 2000; Uttl, 2006).

The finding that *a single* prospective memory cue reliably elicits SCRs for prospective memory hits and likely for prospective memory misses also has important methodical implications. In essence it means that sensitive results can be obtained in cognitive neuroscience studies without the need to repeat prospective memory cues dozens of times. However, one important aspect to keep in mind when measuring SCRs is that verbal responses in contrast to motor responses may influence respiration, and irregular respiration affects SCRs (Schmidt & Walach, 2000). Therefore experimental effects are likely to be more pronounced with motor response requirements, as was the case in our experiments especially for SCRs to prospective memory misses.

On a psychophysiological basis our results suggest that at least two processes are involved in prospective memory retrieval. First, noticing the cue is reflected in the finding that prospective memory misses were likely to elicit SCRs. Second, SCRs for successful retrieval of prospective memory cues were higher compared to misses indicating subsequent retrieval processes. This is consistent with the notion that prospective memory retrieval reflects an orienting reaction. However, it is open to debate how many retrieval stages are involved in successful prospective memory or, in other words, what the SCRs are indexing when comparing prospective memory hits to misses. With behavioural responses where a key is either pressed or not, we are not able to tell the different retrieval stages apart. Measuring much more variable SCRs to prospective memory cues may offer a way out of this dilemma. One might reasonably assume that an SCR to a prospective memory cue would depend on how many retrieval processes have been completed (e.g., noticing, singularisation, inhibition of the ongoing activity, intention retrieval, initiation of the prospective memory task; see Graf, 2005; Marsh, Hicks, & Watson, 2002). Hypothetically, each stage from encountering a prospective memory cue through to execution of the prospective memory task may contribute to the magnitude of the orienting reaction that is elicited. As a consequence, if more stages are fulfilled, a higher SCR may result and the likelihood of successful prospective memory performance will be increased. Hence a fully developed SCR will not be shown without successful retrieval of the prospective memory task.

It will be a challenge for future research to find out how exactly the magnitude of an SCR reflects the number of different stages achieved towards successful prospective memory retrieval. A reasonable starting point would be to design experiments which provoke different types of prospective memory failures. For instance, the difficulty of the retrospective component could be manipulated so that it is either easy or hard to retrieve. Higher SCRs to misses would be expected in the "hard" as compared to the "easy" condition, because in the former condition the participant may notice and singularise the prospective memory cue and even inhibit the ongoing activity, whereas the latter condition the participant may only notice the prospective memory cue (as was likely to be the case in our experiments). Another experiment along these lines could involve testing the idea that in older adults, despite successful noticing of prospective memory targets, the prospective memory task cannot be completed successfully due to a failure in disengagement from the ongoing task (Zimmermann & Meier, 2006, 2010). Again, it would be expected that a failure in disengagement would lead to higher SCRs than prospective memory misses but lower SCRs than prospective memory hits. Similarly, measuring SCRs may be a valid method to measure whether prospective intentions were efficiently deactivated after the intention was finished (see Scullin, Bugg, McDaniel, & Einstein, 2011).

On a behavioural level we were able to show an intention specificity effect, in that specific intentions led to more successful prospective memory retrieval than categorical intentions. However, on a psychophysiological level we did not find any difference between specific and categorical prospective memory intentions when the intention was successfully retrieved. Related to this, measuring SCRs to prospective memory cues may be less suitable for detecting differences in retrieval processes if in fact they are all completed successfully and as a consequence the prospective memory cue is retrieved. In line with this, no differences would be expected for successfully retrieved prospective memory intentions in an experiment where cue focality has been manipulated (for behavioural cue-focality manipulations, see Hicks, Cook, & Marsh, 2005; Rummel, Kuhlmann, & Touron, 2013; Scullin, McDaniel, Shelton, & Lee, 2010).

Neither on a behavioural nor on a psychophysiological level were we able to show an impact of an aversive stimulus on prospective memory retrieval. Hence it would be an interesting endeavour for future research to test whether presenting a stronger aversive stimulus before a prospective memory cue would significantly reduce prospective memory performance. One such stimulus might be a loud startling noise, as it is used during classical fear conditioning (e.g., Bechara et al., 1995; Meier & Rothen, 2007, 2009; Rothen et al., 2013; Rothen, Nyffeler, von Wartburg, Müri, & Meier, 2010). As such a stimulus would cause an immediate startle reaction, and depending on the interval between this stimulus and the prospective cue, participants might be distracted for long enough to actually miss the prospective memory cue.

To conclude, the present study demonstrates that encountering *a single* prospective memory cue reliably elicits a SCR comparable to that of an arousal reaction. Moreover, our findings suggest that encountering a prospective memory cue resembles an orienting reaction and that the size of the SCR depends on the number of successfully completed retrieval processes. Hence measuring SCRs to prospective memory cues offers new opportunities to measure different retrieval stages of prospective memory. This may be especially informative when the prospective memory cue is noticed but the intention is not successfully retrieved.

SUPPLEMENTARY MATERIAL

Supplementary material for this article is available via the supplemental tab on the article's online page at http://dx.doi.org/10.1080/09658211.2013.847106

REFERENCES

Bechara, A., Tranel, D., Damasio, H., Adolphs, R., Rockland, C., & Damasio, A. R. (1995). Double dissociation of conditioning and declarative knowledge relative to the amygdala and hippocampus in humans. *Science*, *269*(5227), 1115–1118. doi:10.1126/science.7652558

Benedek, M., & Kaernbach, C. (2010). A continuous measure of phasic electrodermal activity. *Journal of Neuroscience Methods*, *190*(1), 80–91. doi:10.1016/j.jneumeth.2010.04.028

Boucsein, W. (1992). *Electrodermal activity*. New York, NY: Plenum University Press.

Brandimonte, M. A., & Passolunghi, M. C. (1994). The effect of cue-familiarity, cue-distinctiveness, and retention interval on prospective remembering. *The Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology*, *47*(3), 565. doi:10.1080/14640749408401128

Dawson, M. E., Schell, A. M., & Filion, D. L. (2000). The electrodermal system. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology* (pp. 200–223). Cambridge: Cambridge University Press.

Einstein, G. O., & McDaniel, M. A. (1996). Retrieval processes in prospective memory: Theoretical approaches and some new empirical findings. In M. A. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 115–142). Mahwah, NJ: Erlbaum.

Einstein, G. O., McDaniel, M. A., Richardson, S. L., Guynn, M. J., & Cunfer, A. R. (1995). Aging and prospective memory: Examining the influences of self-initiated retrieval processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(4), 996–1007. doi:10.1080/713755662

Ellis, J., & Milne, A. (1996). Retrieval cue specificity and the realisation of delayed intentions. *The Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology*, *49*(4), 862. doi:10.1037/0278-7393.21.4.996

Graf, P. (2005). Prospective memory retrieval revisited. In N. Ohta, C. M. MacLeod, & B. Uttl (Eds.), *Dynamic cognitive processes* (pp. 305–332). Tokyo: Springer-Verlag. Retrieved from http://www.springerlink.com/content/h85p897828626554/

Graf, P., & Uttl, B. (2001). Prospective memory: A new focus for research. *Consciousness and Cognition*, *10*(4), 437–450. doi:10.1006/ccog.2001.0504

Hager, W., & Hasselhorn, M. (Eds.). (1994). *Handbuch deutschsprachiger Wortnormen [Handbook of German word norms]*. Göttigen: Hogrefe.

Hicks, J. L., Cook, G. I., & Marsh, R. L. (2005). Detecting event-based prospective memory cues occurring within and outside the focus of attention. *The American Journal of Psychology*, *118*(1), 1–12. doi:10.2307/30039040

Kliegel, M., Guynn, M. J., & Zimmer, H. (2007). The role of noticing in prospective memory forgetting. *International Journal of Psychophysiology*, *64*(3), 226–232. doi:10.1016/j.ijpsycho.2006.09.007

MacDowell, K. A., & Mandler, G. (1989). Constructions of emotion: Discrepancy, arousal, and mood. *Motivation and Emotion*, *13*(2), 105–124. doi:10.1007/BF00992957

Mandler, G. (1980). Recognizing: The judgment of previous occurrence. *Psychological Review*, *87*(3), 252–271. doi:10.1037/0033-295X.87.3.252

Mandler, G. (1991). Your face looks familiar but I can't remember your name: A review of dual process theory. In W. E. Hockley & S. Lewandowsky (Eds.), *Relating theory and data: Essays on human memory in honor of Bennet B. Murdock* (pp. 207–225). Hillsdale, NJ: Erlbaum.

Mandler, G. (1994). Hypermnesia, incubation, and mind popping: On remembering without really trying. In C. Umiltà & M. Moscovitch (Eds.), *Attention and performance 15: Conscious and nonconscious information processing* (pp. 3–33). Cambridge, MA: MIT Press.

Marsh, R. L., Hicks, J. L., Cook, G. I., Hansen, J. S., & Pallos, A. L. (2003). Interference to ongoing activities covaries with the characteristics of an event-based intention. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*(5), 861–870. doi:10.1037/0278-7393.29.5.861

Marsh, R. L., Hicks, J. L., & Watson, V. (2002). The dynamics of intention retrieval and coordination of action in event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*(4), 652–659. doi:10.1037/0278-7393.28.4.652

McDaniel, M. A., Einstein, G. O., Guynn, M. J., & Breneiser, J. (2004). Cue-Focused and Reflexive-Associative Processes in Prospective Memory Retrieval. *Journal of Experimental Psychology. Learning, Memory & Cognition*, *30*(3), 605–614. doi:10.1037/0278-7393.30.3.605

Meier, B., & Graf, P. (2000). Transfer appropriate processing for prospective memory tests. *Applied Cognitive Psychology*, *14*(7), 11–27. doi:10.1002/acp.768

Meier, B., & Rothen, N. (2007). When conditioned responses "fire back": Bidirectional cross-activation creates learning opportunities in synesthesia. *Neuroscience*, *147*(3), 569–572. doi:10.1016/j.neuroscience.2007.04.008

Meier, B., & Rothen, N. (2009). Training grapheme–colour associations produces a synaesthetic Stroop effect, but not a conditioned synaesthetic response. *Neuropsychologia*, *47*(4), 1208–1211. doi:10.1016/j.neuropsychologia.2009.01.009

Meier, B., von Wartburg, P., Matter, S., Rothen, N., & Reber, R. (2011). Performance predictions improve prospective memory and influence retrieval experience. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, *65*(1), 12–18. doi:10.1037/a0022784

Meier, B., Zimmermann, T. D., & Perrig, W. J. (2006). Retrieval experience in prospective memory: Strategic monitoring and spontaneous retrieval. *Memory*, *14*(7), 872. doi:10.1080/09658210600783774

Rothen, N., Nikolić, D., Jürgens, U. M., Mroczko-Wąsowicz, A., Cock, J., & Meier, B. (2013). Psychophysiological evidence for the genuineness of swimming-style colour synaesthesia. *Consciousness and Cognition*, *22*(1), 35–46. doi:10.1016/j.concog.2012.11.005

Rothen, N., Nyffeler, T., von Wartburg, R., Müri, R., & Meier, B. (2010). Parieto-occipital suppression eliminates implicit bidirectionality in grapheme–colour synaesthesia. *Neuropsychologia*, *48*(12), 3482–3487. doi:10.1016/j.neuropsychologia.2010.07.032

Rummel, J., Kuhlmann, B. G., & Touron, D. R. (2013). Performance predictions affect attentional processes of event-based prospective memory. *Consciousness and Cognition*, *22*(3), 729–741. doi:10.1016/j.concog.2013.04.012

Ruoff, A. (1981). *Häufigkeitswörterbuch gesprochener Sprache [Dictionary of word frequencies in spocken language]*. Tübingen: Niemeyer.

Schmidt, S., & Walach, H. (2000). Electrodermal activity (EDA): State-of-the-art measurement and techniques for parapsychological purposes. *Journal of Parapsychology*, *63*(3), 221–221.

Scullin, M. K., Bugg, J. M., McDaniel, M. A., & Einstein, G. O. (2011). Prospective memory and aging: Preserved spontaneous retrieval, but impaired deactivation, in older adults. *Memory & Cognition*, *39*(7), 1232–1240. doi:10.3758/s13421-011-0106-z

Scullin, M. K., McDaniel, M. A., Shelton, J. T., & Lee, J. H. (2010). Focal/nonfocal cue effects in prospective memory: Monitoring difficulty or different retrieval processes? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*(3), 736–749. http://dx.doi.org.ezproxy.sussex.ac.uk/10.1037/a0018971

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning, and Memory*, *6*(2), 174–215. doi:10.1037/0278-7393.6.2.174

Uttl, B. (2006). Age-related changes in event-cued visual and auditory prospective memory proper. *Aging, Neuropsychology, and Cognition*, *13*(2), 141–172. doi:10.1080/138255890969618

Whittlesea, B. W. A., & Williams, L. D. (1998). Why do strangers feel familiar, but friends don't? A discrepancy-attribution account of feelings of familiarity. *Acta Psychologica*, *98*(2–3), 141–165. doi:10.1016/S0001-6918(97)00040-1

Whittlesea, B. W. A., & Williams, L. D. (2001a). The discrepancy-attribution hypothesis: I. The heuristic basis of feelings and familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*(1), 3–13. doi:10.1037/0278-7393.27.1.3

Whittlesea, B. W. A., & Williams, L. D. (2001b). The discrepancy-attribution hypothesis: II. Expectation, uncertainty, surprise, and feelings of familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*(1), 14–33. doi:10.1037/0278-7393.27.1.14

Zimmermann, T. D., & Meier, B. (2006). The rise and decline of prospective memory performance across the lifespan. *The Quarterly Journal of Experimental Psychology*, *59*(12), 2040. doi:10.1080/17470210600917835

Zimmermann, T. D., & Meier, B. (2010). The effect of implementation intentions on prospective memory performance across the lifespan. *Applied Cognitive Psychology*, *24*(5), 645–658. doi:10.1002/acp.1576