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Spontaneous retrieval reveals right-ear advantage in prospective memory

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Abstract
The goal of this study was to investigate the impact of individual costs on prospective memory performance. Individual costs were assessed by contrasting participants with high costs and those with low costs. Specifically, we tested whether prospective memory performance is moderated by costs, cue-focality and intention specificity. Participants performed a dichotic listening paradigm where they had to indicate whether a word presented to one ear was abstract or concrete while ignoring the word presented to the other ear. For the prospective memory task, participants had to detect target items; half of them were presented focally to the same ear as the relevant words for the ongoing task and half of them were presented non-focally to the other ear. Moreover, half of the participants were given specific instructions and the other half were given categorical instructions. The results revealed a right-ear advantage for participants with low costs but not for participants with high costs. Moreover, the absence of costs was not necessarily accompanied by worse prospective memory performance. Given differential results under the same task conditions, we conclude that individual costs are an important factor which should be considered when investigating prospective memory processes.

Keywords
Intention memory; individual differences; monitoring; spontaneous retrieval; dichotic listening; dichotic hearing; right-ear advantage

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Introduction

Prospective memory is the ability to remember a previously planned action at the appropriate occasion in the future. The occasion is typically an event or a time. In event-based prospective memory, which is the focus of this article, the event is embedded in an ongoing task and is not necessarily at the focus of attention when encountered. Prospective remembering can occur as a result of systematic monitoring or spontaneous retrieval. In contrast to spontaneous retrieval, monitoring comes at a cost due to the allocation of attentional resources to the prospective memory task (i.e., a performance decrease in the ongoing task). Costs depend on the context such as the features of the ongoing task, the nature of the prospective memory task and the remembering individual (e.g., McDaniel & Einstein, 2000). Hence, it is possible that different individuals adopt different strategies under the same task conditions. The goal of this study was to systematically investigate the impact of individual costs to further our understanding of the processes underlying prospective remembering.

Individual costs refer to an individual's performance difference between the ongoing task while carrying a prospective memory intention and the same task without carrying an intention (i.e., prospective memory load, cf. Meier & Zimmermann, 2015). So far, the research focus was on the effect of experimental manipulations on prospective memory performance and the associated costs in the ongoing task. Here, we introduce costs as a quasi-experimental variable and compare individuals with high versus low costs and test the impact of intention specificity and cue-focality on prospective memory performance.

Different theories make distinct predictions with regard to the costs associated with prospective remembering. The

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Preparatory Attentional and Memory (PAM) process theory poses that costs occur for every prospective memory task because participants engage preparatory attentional processes in order to notice the prospective memory cue (Smith, 2003; Smith & Bayen, 2006). Because the theory regards monitoring as mandatory for successful prospective memory retrieval, the predictions of this theory are that participants with lower costs have worse prospective memory performance than participants with higher costs. In contrast, the discrepancy plus search model poses that noticing a prospective memory cue is an automatic process which is not necessarily associated with costs (Einstein & McDaniel, 1996). Because the theory regards successful prospective memory retrieval as a cost-free process, the predictions of this theory are that participants with no costs have similar prospective memory performance as participants with higher costs.

The multiprocess framework poses that some factors involved in prospective memory retrieval are more likely to produce costs than other factors (Einstein et al., 2005). The proposition of this framework was followed by numerous studies to identify relevant factors under various conditions, some of which will be outlined in the next paragraph. Recently, the *dynamic* multiprocess framework was formulated, which suggests that participants may selectively choose to monitor in contexts where prospective memory cues are expected (Scullin, McDaniel, & Shelton, 2013). Specifically, spontaneous retrieval of a relevant cue was hypothesised as a candidate to trigger strategic monitoring. Empirical evidence was presented in form of costs after the retrieval of a relevant cue in comparison with low costs after missing a relevant cue or in the absence of a prospective memory intention.

Related to the dynamics of resource allocation in ongoing tasks, while carrying a prospective intention, studies suggest that participants primarily rely on transient monitoring rather than on sustained monitoring to support cue detection (Ball, Brewer, Loft, & Bowden, 2014; Kominsky & Reese-Melancon, 2016; Meier, Zimmermann, & Perrig, 2006; for a different interpretation, see Heathcote, Loft, & Remington, 2015). According to theories which assume that successful prospective memory retrieval maybe a product of monitoring and spontaneous processes, different scenarios are possible when comparing individuals with high and those with low costs: First, all participants may predominantly rely on the same retrieval strategy. Depending on the strategy, the predictions would be the same either as under theories which assume that monitoring is mandatory or as under theories which assume that successful prospective memory retrieval is free of costs. Second, based on previous findings (Ball et al., 2014; Scullin et al., 2013; Walter & Meier, 2014, 2015), it is more likely that participants tend to employ different predominant retrieval strategies. Moreover, comparing participants with high versus those with low costs will reveal whether spontaneous retrieval is as efficient as strategic monitoring under any given circumstances.[1]

Two well-known factors to affect prospective memory performance are the specificity of an intention and the focality of the prospective memory cue: There is evidence that specific intentions are associated with lower costs in ongoing task performance than categorical intentions (Marsh, Hicks, & Cook, 2006; Marsh, Hicks, Cook, Hansen, & Pallos, 2003). These findings suggest that specific intentions are less likely to be associated with strategic monitoring than categorical intentions (cf. Meier, von Wartburg, Matter, Rothen, & Reber, 2011). Moreover, it has been found 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 et al., 2003; Meier et al., 2011). For instance, participants who were instructed to press a specific key whenever they saw the picture of an eagle had better prospective memory performance in comparison with participants who were presented with the same picture but were instructed to press the specified key whenever they saw the picture of a bird (Rothen & Meier, 2014).

Cue-focality refers to the degree by which the ongoing task encourages processes of the target (Einstein & McDaniel, 2005). There is evidence that focal prospective memory cues (i.e., processing of the ongoing stimuli does imply processing of the prospective memory cue) are associated with lower costs than non-focal prospective memory cues (i.e., processing of the ongoing stimuli does not imply processing of the prospective memory cue). These findings also suggest that focal cues are less likely to be associated with strategic monitoring than non-focal cues (see also Brewer, Knight, Marsh, & Unsworth, 2010). Moreover, focal cues lead to better prospective memory performance than non-focal cues (Einstein et al., 2005; McDaniel & Einstein, 2000). For instance, participants who were instructed to press a specific key whenever the saw the word tortoise had better prospective memory performance in comparison with participants who were instructed to press the key whenever they saw the syllable 'tor' occurring in three different words (e.g., Einstein et al., 2005). However, typically cue-focality is confounded with cue specificity (i.e., the specific word 'tortoise' vs the syllable 'tor' that can occur in different words). This study addresses this issue by means of a paradigm which allows for the independent manipulation of cue-focality and intention specificity as outlined in the next two paragraphs.

To systematically study individual costs, we adapted a dichotic listening paradigm while we manipulated the specificity of the intention and the focality of the prospective memory cue. Dichotic listening is an experimental technique where two streams of different auditory information are presented simultaneously via headphones. Participants are usually instructed to attend to one stream and ignore the other stream. The paradigm is traditionally used in research concerning selective attention (e.g., Broadbent, 1954; Cherry, 1953; Treisman, 1960) and language processing (e.g., Kimura, 1967). A common finding in dichotic listening paradigms with language stimuli is a performance advantage for stimuli presented to the right ear (i.e., right-ear advantage; Shankweiler & Studdert-Kennedy, 1967). For instance, when presented with different digits simultaneously to both ears, participants are better at recalling digits presented to the right in comparison with digits presented to the left ear. The most prevalent explanation is based on the structural organisation of the brain (Kimura, 1961, 1967; for evidence of a right-ear advantage in the earliest peripheral stages of auditory processing, see Bidelman & Bhagat, 2015): For the majority of the population, especially for right-handed people, language processing is lateralised to the left hemisphere and almost no lexical-semantic analysis takes place in right hemisphere for deliberately ignored speech (Beaman, Bridges, & Scott, 2007). Thus, the dichotic listening paradigm is ideal to mimic the naturalistic characteristics of event-based prospective memory tasks where the events are embedded in an ongoing task and are not necessarily at the focus of attention when they occur.

Here, we chose a cue-focality manipulation that relied on the processing overlap requirements between the prospective memory task and the ongoing task (cf. Maylor, 1996; Meier & Graf, 2000). Cue-focality was manipulated by presenting half of the prospective memory cues on the attended side (i.e., focal condition) and the other half of the prospective memory cues on the unattended side (i.e., non-focal condition). Specificity of the intention was manipulated by giving half of the participants instructions to respond to four specific animal words and the other half of the participants to respond to words belonging to the category animals. The paradigm has the advantage that the same concrete words can be presented in the focal and non-focal conditions and, hence, that the specificity of the intention can be manipulated independent of cue-focality.

From the above literature review, we made the following predictions with regard to the proportion of correctly detected prospective memory cues: Performance is better for specific intentions than categorical intentions and better for focal cues than non-focal cues. We further expected that monitoring will lead to better performance and that this effect might be more prominent in the non-focal condition where monitoring is likely to have a compensatory impact. Moreover, we expected an advantage for cues presented to the right ear as opposed to cues presented to the left ear. This might especially be the case for individuals with a spontaneous retrieval strategy because strategic monitoring might have a compensatory influence on cues presented on the disadvantageous left side.

Methods

Participants

The experiment was conducted in the context of a research method class at the University of Bern. Each student had to recruit and test 20 participants. Inclusion criteria were normal hearing, and students were advised to try and recruit right-handed participants with German as first language. The study was approved by the local ethics committee of the University of Bern. A total of 240 participants volunteered for the study (age M = 26.02 years, standard deviation [SD] = 8.99, range = 18-62). The data were cleaned as described in the 'Analysis' section. The final sample consisted of 205 participants (114 females and 91 males; age M = 23.28 years, SD = 3.60, range = 18-36; 193 right-handed and 12 left-handed; years of formal education M = 14.82, SD = 2.06; 202 native German speakers and 3 fluent in German but different first language or bilingual).

Materials

The word stimuli for the ongoing task of the practice and test phase were selected from the Handbuch deutschsprachiger Wortnormen (Hager & Hasselhorn, 1994). The practice phase consisted of 48 German words (concreteness M = 3.52, SD = 13.62, range = −13.47 to 19.40, with a positive value denoting concreteness and a negative value denoting abstractness). The ongoing task of the test phase (excluding the prospective memory cues) consisted of 200 German words (concreteness M = 3.64, SD = 13.49, range = −14.92 to 19.20). In both phases, half of the words were concrete and half abstract. The German words *Insekt* (insect; concreteness = 14.53), *Pferd* (horse; concreteness = 18.60), *Schlange* (snake; concreteness = 16.33) and *Vogel* (bird; concreteness = 15.73) served as prospective memory cues.

Procedure

Participants were tested individually. They were seated in front of a computer monitor and were to wear headphones. Before the experiment started, they were presented with an example word to adjust the loudness of the headphones according to their needs. Next, they were instructed that they will simultaneously hear words on either side of the headphones. Depending on the condition, they were told to attend to the words on the right side and ignore the words on the left side or vice versa. They were asked to decide whether the words presented on the attended side were concrete or abstract by pressing one of the two keys on the computer keyboard ('b'-key for concrete and 'n'-key for abstract). Next, participants performed the practice phase of the ongoing task. Each of the 48 words of the practice phase appeared once on the right side and once on the left side of the headphones. The word pairs were composed randomly with the only restriction that the two words were different. Each participant was presented with the same word pairs, but in random order. Each trial started with a blank screen and a quiet period of 500 ms. Next, the word pair was presented via the headphones, and the screen stayed blank until the participant responded and the next trial started. If the participant did not respond within 5000 ms, the message 'Please respond!' was presented in German at the centre of the screen until a response was made and the next trial started.

After the practice phase of the ongoing task, the participants were instructed for the prospective memory task. 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. In the specific condition, they were instructed to press the '1'-key on the keyboard every time they heard one of the following words: *bird, horse, insect* and *snake*. In the categorical condition, participants were instructed to press the '1'-key on the keyboard every time they heard a word belonging to the category *animal*. All participants were informed that these words could appear on either side of the headphones, and they were further instructed that they should also press the '1'-key even if they noticed with some delay that a critical word has been presented.

Next, participants were presented with two unrelated distracter tasks which lasted about 15-20 min (i.e., a questionnaire related to potential synaesthetic experiences and a grapheme–colour association task). Then, the ongoing task of the test phase with the embedded prospective memory cues was started without mentioning the prospective memory task again. The task was identical to the ongoing task of the practice phase with the following exceptions. The task consisted of a total of 202 trials (i.e., word pairs). The prospective memory cues were never paired with another prospective memory cue and appeared on the 49th, 98th, 147th, and 196th trial. Each prospective memory cue appeared only once. The presentation side and the order of prospective memory cues were randomised across participants.

Analysis

To make sure that participants entered the analyses only if they understood and followed the task instructions, we further excluded participants whose proportion of correct responses in the ongoing task was less than 0.60 (10 participants). Next, one additional participant was excluded because the median reaction time (RT) for the ongoing task exceeded 3500 ms which was more than 1000 ms slower than the RT of any other participant. Given that age can affect cognitive functions differently under the same task conditions (Rothen & Meier, 2016) and bias the results in non-homogeneous samples, we excluded participants who were outliers in terms of their age. Outliers were defined on a statistical basis as being smaller/greater than 1.5 times the interquartile range of the first and third quartile (24 participants). The remaining participants are referred to as the final sample which is described in the 'Participants' section.

Prospective memory trials and the three subsequent trials were excluded from the analyses of the ongoing task (cf. Meier & Rey-Mermet, 2012). A prospective memory cue was classified as hit if the required action (i.e., press '1'-key) was fulfilled during the presentation of the prospective memory cue or the three subsequent trials. If this was not the case, the prospective memory cue was classified as missed.

The alpha level was set to 0.05 for all statistical analyses, and *t*-tests were two-tailed. Reported effect sizes denote partial eta squared (η_p^2).

Design

Prospective memory performance (i.e., proportion correct) was analysed with a four-factorial mixed analysis of variance (ANOVA) with the within-subject factor *Cue-focality* (focal vs non-focal) and the between-subject factors *Intention specificity* (specific vs categorical), *Attention allocation* (left vs right) and *Cost* (high vs low). High- and low-cost groups were realised by means of a median split. For the number of participants in each condition, see Table 1. In addition, we conducted a regression analysis with the same experimental design, taking into account the continuous nature of the factor *Cost*.

Accuracy and RTs of the ongoing task trials were analysed with a three-factorial mixed ANOVA with the within-subject factor *Phase* (baseline vs test) and the between-subject factors *Intention specificity* (specific vs categorical) and *Attention allocation* (left vs right).

Results

The average prospective memory performance as a function of cue-focality, intention specificity, attention allocation and cost is shown in Table 1. The low- and high-cost group had the following characteristics: $N=103$, $M=-104$ ms, $SD=214$, range $=-766$ to 145 ms and $N=102$, $M=345$ ms, $SD=150$, range $=146$ to 836 ms, respectively.

The four-factorial ANOVA with the within-subject factor *Cue-focality* and the between-subject factors *Intention specificity, Attention allocation* and *Cost* revealed the following main effects: *Intention specificity* was significant due to higher performance for specific intentions in comparison with categorical intentions, $F(1, 197)=4.25$, $p=0.041$, $\eta_p^2 = 0.02$. *Cue-focality* was significant due to higher performance in the focal than the non-focal condition, $F(1, 197)=57.46$, $p<0.001$, $\eta_p^2 = 0.23$. *Cost* was significant because performance was better in the high-cost condition in comparison with the low-cost condition, F(1,

Table 1. Descriptive statistics (mean values and standard errors in parenthesis) for prospective memory performance as a function of *Cost, Intention specificity, Attention allocation* and *Cue-focality*.

Cost:	Low		High	
Attention allocation:	Left	Right	Left	Right
Focal				
Specific	0.48 (0.092)	0.70 (0.093)	0.80 (0.075)	0.75 (0.071)
Categorical	0.32 (0.078)	0.67 (0.076)	0.62 (0.085)	0.59 (0.081)
Non-focal				
Specific	0.26 (0.076)	0.22 (0.069)	0.65 (0.091)	0.53 (0.071)
Categorical	0.14 (.051)	0.34 (.071)	0.48 (.076)	0.48 (0.074)
N				
Specific	23	23	23	30
Categorical	28	29	26	23

Participant numbers (*N*) are always the same for the focal and non-focal conditions because *Cue-focality* was manipulated within subjects.

197)=23.64, $p<0.001$, $\eta_p^2 = 0.11$. Furthermore, there was a significant *Cost* × *Cue-focality* interaction, $F(1, 197)=6.07$, $p=0.015$, $\eta_p^2 = 0.03$, and a significant *Cost* × *Attention allocation* interaction, $F(1, 197)=6.56$, $p=0.011$, $\eta_p^2 = 0.03$. Moreover, there was a trend for an *Attention allocation* × *Cue-Focality interaction,* $F(1, 197)=3.51$, $p=0.062$, $\eta_p^2 = 0.02$. No other effect reached statistical significance, all Fs(1, 197)<2.42, all ps>121.

Most interestingly, the *Cost* × *Attention allocation* interaction was due to a significant difference in prospective memory performance between the low- and high-cost conditions when participants were required to focus to the left, $t(98)=5.00$, $p<0.001$, while the same conditions did not significantly differ when participants were required to focus to the right, $t(103)=1.77$, $p=0.080$. Moreover, prospective memory performance differed significantly between participants who had to focus to the left and participants who had to focus to the right in the low-cost group, $t(101)=2.96$, $p=0.004$. This was not the case in the high-cost group, $t(100)=0.60$, $p=0.553$ (Figure 1).

Because median splits can lead to biased results, we conducted a regression analysis considering the continuous nature of the factor *Cost* to confirm the robustness of our findings. The regression analysis included the following factors with all potential interaction terms: *Cue-focality* (focal vs non-focal), *Intention specificity* (specific vs categorical), *Attention allocation* (left vs right) and *Cost*. The results are presented in Table 2. They confirmed the effects of the preceding four-factorial ANOVA with the only difference that the *Cue-focality* × *Cost* interaction was not significant. Most importantly, the *Cost* × *Attention allocation* interaction was still significant due to the difference in prospective memory performance between the low- and high-cost conditions when participants were required to focus to the left.

We repeated all reported analyses additionally including participants who were regarded as outliers in terms of their age. These additional analyses (with $N=229$) revealed the same pattern of results, however, with a reduced effect of the factor *Intention specificity* (i.e., $p=0.10$ in the regression analysis).

The average proportions of correct responses for the different conditions of the ongoing task are presented on the top of Table 3. The three-factorial mixed ANOVA with the within-subject factor *Phase* and the between-subject factors *Intention specificity* and *Attention allocation* revealed a significant main effect *Phase,* $F(1, 201)=43.41$, $p<0.001$, $\eta_p^2 = 0.18$, due to an increase in accuracy in the test phase. There was also a trend for a *Phase* × *Attention allocation* interaction, $F(1, 201)=3.38$, $p<0.067$, $\eta_p^2 = 0.02$. No other effect reached statistical significance, all Fs<1.97, all ps>0.161. The performance improvement in the ongoing task of the test phase in comparison with the ongoing task of the baseline phase suggests a practice effect.

The average RTs of correct responses for the different conditions of the ongoing task are presented at the bottom of Table 3. The same kind of ANOVA as above was conducted with the RT data. It revealed a significant main effect *Phase* due to slower RTs in the test phase, $F(1, 201)=33.99$, $p<0.001$, $\eta_p^2 = 0.14$. No other effect reached statistical significance, all Fs<0.89, all ps>0.347. The slower RTs in the test phase suggest monitoring due to the additional prospective memory task.

Discussion

In this study, we used an auditory paradigm (i.e., dichotic listening) as ongoing task where prospective memory cues appeared focally on the attended and non-focally on the unattended side to investigate prospective memory performance as a function of individual costs. Participants with low costs but not those with high costs showed a right-ear advantage. In fact, participants with low costs performed similarly to participants with high costs in the case where they had to attend to stimuli that were presented to the

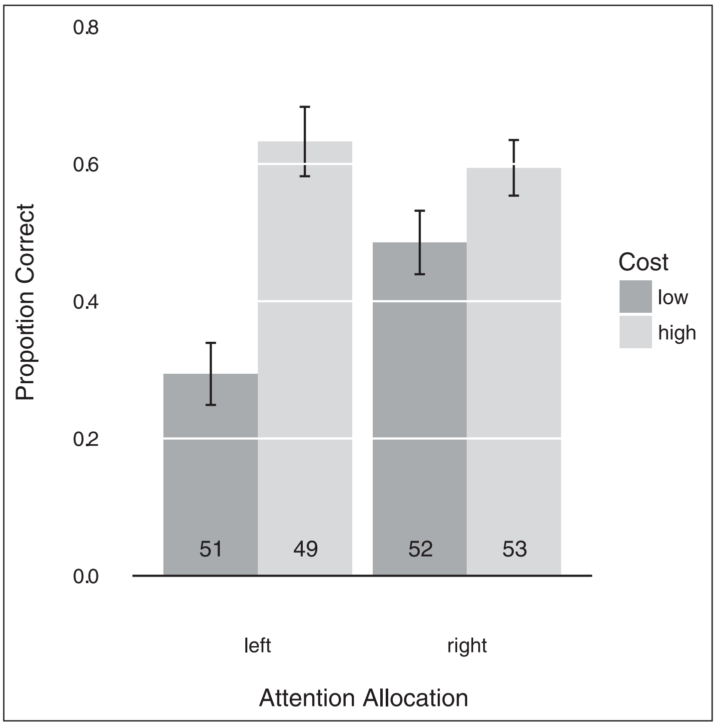

Figure 1. Average prospective memory performance as a function of *Cost* and *Attention allocation*. The figure shows a clear right-ear advantage in the low-cost condition in contrast to the high-cost condition. The error bars represent standard errors. The digits on the bars represent the number of participants in the specific condition.

right ear. Low- and high-cost individuals performed also similarly when prospective memory cues appeared focally. However, low-cost individuals performed worse than high-cost individuals when they had to attend to stimuli that were presented to the left ear or when prospective memory cues appeared non-focally. Nevertheless, prospective memory cues were still successfully retrieved at low costs when presented on the disadvantageous side (i.e., left ear) under minimal attention (i.e., non-focal condition). Independent of cost, prospective memory was increased when the cues appeared focally in comparison with when the cues appeared non-focally. Furthermore, participants with specific intentions outperformed participants with categorical intentions.

The observed differences in individual costs suggest that different individuals employ different retrieval strategies in prospective remembering or at least different *predominant* retrieval strategies. That is, our findings support theoretical frameworks which propose multiple processes in prospective remembering (i.e., multiprocess framework and dynamic multiprocess framework; Ball et al., 2014; Brewer et al., 2010; Einstein et al., 2005; Scullin et al., 2013). Furthermore, our results revealed that spontaneous retrieval can, under specific circumstances, be as efficient as strategic monitoring.

The right-ear advantage in our study was most prominent in the case where prospective memory cues were spontaneously retrieved at low costs in the ongoing task. Our proposal that the right-ear advantage is related to language lateralisation and early peripheral auditory processing is in line with the literature and may reflect a bottom-up influence (Bidelman & Bhagat, 2015; Hugdahl, 2000; for a model with regard to auditory hemispheric specialisation, cf. also J. E. Marsh, Pilgrim, & Sörqvist, 2013). Hence, we would predict that no right-ear advantage can be found when the prospective memory cue is non-verbal (e.g., the sound of an alarm clock). Our findings also show that top-down influences (e.g., in terms of attentional resource allocation for the purpose of strategic monitoring) can be used to compensate for the right-ear advantage at a cost in the unrelated ongoing activity. The finding that the right-ear advantage only occurred under spontaneous retrieval is consistent with the notion that spontaneous retrieval is a probabilistic process with the consequence that prospective memory performance will always be better under optimal task conditions than suboptimal task conditions (e.g., Harrison, Mullet, Whiffen, Ousterhout, & Einstein, 2013). Interestingly, no right-ear advantage was found for the ongoing task. One reason for this might be that prospective memory tasks could be considered dual-task type situations, and perhaps the right-ear advantage on some ongoing task like the concrete/abstract task used in this article is moderated by secondary task demands.[2]

Table 2. Standardised beta values and *t*-test statistics of the regression analysis.

	β	*t*	*p*
Intention specificity	**0.39**	**2.16**	**0.031**
Attention allocation	0.21	1.17	0.242
Cue-focality	**0.44**	**2.33**	**0.020**
Cost	**0.58**	**3.54**	**<0.001**
Intention specificity × Attention allocation	0.18	0.70	0.484
Intention specificity × Cue-focality	0.07	0.26	0.794
Attention allocation × Cue-focality	0.34	1.35	0.179
Intention specificity × Cost	0.29	1.50	0.135
Attention allocation × Cost	**0.50**	**2.42**	**0.016**
Cue-focality × Cost	**0.12**	**0.52**	**0.602**
Intention specificity x Attention allocation × Cue-focality	0.17	0.48	0.632
Intention specificity × Attention allocation × Cost	0.26	0.98	0.329
Intention specificity × Cue-focality × Cost	0.13	0.47	0.637
Attention allocation × Cue-focality × Cost	0.21	0.70	0.484
Intention specificity × Attention allocation × Cue-focality × Cost	0.03	0.07	0.941

ANOVA: analysis of variance.
The results are consistent with the corresponding four-factorial ANOVA (i.e., participants with low but not high cost show a right-ear advantage). For illustration, we highlighted the factors and interactions that were significant in the ANOVA.
$R^2 = 0.22$, adjusted $R^2 = 0.193$.
$F(15, 394) = 7.51$, $p < 0.001$.

Table 3. Descriptive statistics (mean values and standard errors in parenthesis) for accuracy (ACC) and reaction time (RT) data of the ongoing task.

Phase:	Baseline		Test		Cost	
Attention allocation:	Left	Right	Left	Right	Left	Right
ACC						
Specific	0.91 (0.008)	0.91 (0.008)	0.93 (0.006)	0.94 (0.005)	–0.02	–0.03
Categorical	0.90 (0.009)	0.91 (0.007)	0.93 (0.005)	0.95 (0.004)	–0.03	‘0.04
RT						
Specific	1604 (47)	1588 (36)	1730 (49)	1713 (37)	126	125
Categorical	1617 (39)	1655 (42)	1722 (42)	1777 (44)	105	122

Participant numbers in the different conditions: *N* (left, specific) = 46; *N* (right, specific) = 53; *N* (left, categorical) = 54; *N* (right, categorical) = 52.

Furthermore, we also showed that prospective memory retrieval can be successful even when the prospective memory cue occurs in a stream of information that is ignored. This is consistent with the idea that intention-related stimulus material is processed superior to stimulus material which is not related to intentions (Achtziger, Bayer, & Gollwitzer, 2012; Marsh, Cook, Meeks, Clark-Foos, & Hicks, 2007; Walser, Fischer, & Goschke, 2012). The finding suggests that intention-related stimulus material in a to-be-ignored stream of information can be processed sufficiently to trigger the retrieval of an intention. Crucially, this can be the case at low costs for an unrelated ongoing activity and at the same time even when the prospective memory cue occurs under suboptimal conditions (i.e., presented to the left ear in the case of this study).

In line with attentional resource allocation for strategic monitoring, our results suggest also a more general effect of attention on prospective memory retrieval. Namely, prospective memory cues are more easily detected when they occur inside the spotlight of attention (i.e., focal condition) in comparison with when they occur outside of the spotlight of attention (i.e., non-focal condition; cf. Achtziger et al., 2012; Marsh et al., 2007). Interestingly, prospective memory retrieval was similar for low- and high-cost individuals when the cue occurred on the right side. Hence, our findings provide evidence that allocating resources to the prospective memory task is not necessarily beneficial to overall task performance (i.e., prospective memory retrieval and ongoing task performance; cf. also Einstein et al., 2005). Thus, monitoring is inappropriate when equal performance can be achieved without engaging in costly monitoring.

Declaration of conflicting interests

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Notes

1. We acknowledge that different strategies are likely to be used dynamically when performing an ongoing task while carrying a prospective memory intention. Nevertheless, low and high costs can be used as an indication of the predominant strategy.
2. We would like to thank Gene Brewer for bringing this potential explanation to our attention

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