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## **The Influence of Emotional Cues on Prospective Memory: A Systematic Review with Meta-Analyses.**

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1 **The Influence of Emotional Cues on Prospective Memory: A Systematic**  
2 **Review with Meta-Analyses.**

3 **Abstract**

4 Remembering to perform a behaviour in the future, *prospective memory*, is essential to  
5 ensuring that people fulfil their intentions. Prospective memory involves committing to memory a cue  
6 to action (encoding), and later recognising and acting upon the cue in the environment (retrieval).  
7 Prospective memory performance is believed to be influenced by the emotionality of the cues,  
8 however the literature is fragmented and inconsistent. We conducted a systematic search to synthesise  
9 research on the influence of emotion on prospective memory. Sixty-seven effect sizes were extracted  
10 from 17 articles and hypothesised effects tested using three meta-analyses. Overall, prospective  
11 memory was enhanced when positively-valenced rather than neutral cues were presented ( $d = 0.32$ ).  
12 In contrast, negatively-valenced cues did not enhance prospective memory overall ( $d = 0.07$ ), but this  
13 effect was moderated by the timing of the emotional manipulation. Prospective memory performance  
14 was improved when negatively-valenced cues were presented during both encoding and retrieval ( $d =$   
15  $0.40$ ), but undermined when presented only during encoding ( $d = -0.25$ ). Moderating effects were also  
16 found for cue-focality and whether studies controlled for the arousal level of the cues. The principal  
17 finding is that positively-valenced cues improve prospective memory performance and that timing of  
18 the manipulation can moderate emotional effects on prospective memory. We offer a new agenda for  
19 future empirical work and theorising in this area.

20 **Key words:** prospective memory, cues, emotion, affect, review, meta-analysis

21 **Article word count:** 8,913

22 The term *prospective memory* is used to describe a person's ability to remember to perform a  
23 behaviour in the future (McDaniel & Einstein, 2000). The successful application of  
24 prospective memory involves encoding a cue to action, and later detecting this cue to retrieve  
25 and execute the planned intention. These actions require the use of several cognitive  
26 processes, including attention (to detect the cue) and retrospective memory (to retrieve the  
27 intention). The prevailing view in the wider literature of emotion and cognition is that  
28 emotion enhances both attention and memory (Brosch, Pourtois, & Sander, 2010; Hamann,  
29 2001; N. A. Murphy & Isaacowitz, 2008; Yiend, 2010), meaning that emotional cues are  
30 likely to improve prospective memory performance. However, the current literature is  
31 contradictory and it is not clear when or how emotion influences prospective memory.  
32 Providing clarity to the possible effects of emotion on prospective memory performance is  
33 important for elucidating prospective memory processes and for informing practical  
34 applications to improve prospective memory. The present research takes the approach of  
35 conducting a systematic review and a series of meta-analyses to establish for the first time  
36 what are the effects of emotion on prospective memory.

### 37 **The Influence of Emotion on Cognition**

38 The feedback theory of emotion (Baumeister, Vohs, DeWall, & Zhang, 2007) describes two  
39 ways in which emotion influences our cognition: Through full-blown conscious moods, and  
40 brief 'twinges' of emotional appraisal that arise automatically when a stimulus is perceived.  
41 The latter of these two mechanisms - the brief 'affective responses' - have been shown to  
42 influence our behaviour indirectly through higher-level cognitive processes (Baumeister et  
43 al., 2007; Robinson, Watkins, & Harmon-Jones, 2013), such as prospective memory.  
44 Accordingly, affective responses to stimuli used as cues to trigger prospective memory can  
45 have an influence on the cognitive processes underlying prospective memory most likely

46 during ‘encoding’ and ‘retrieval’ (Ellis & Freeman, 2012; Hannon & Daneman, 2007;  
47 Kvavilashvili & Ellis, 1996). The encoding process represents the formation of a prospective  
48 memory intention. It is the act of encoding in memory the cue or stimulus that will trigger the  
49 intended behavioural response, and the response itself, and cognitively linking them.  
50 Retrieval refers to the act of later encountering the prospective memory cue and recognising  
51 it as the pre-defined opportunity to enact the response.

52         Emotional stimuli may influence prospective memory through encoding or retrieval  
53 processes, or synergistically through both. The findings from the more general literature of  
54 emotion and cognition suggests that emotion is likely to improve the encoding process  
55 through enhanced attention and visual processing (Calvo & Lang, 2004; Dolan, 2002;  
56 Nummenmaa, Hyona, & Calvo, 2006; Phelps, Ling, & Carrasco, 2006; Pilarczyk &  
57 Kuniecki, 2014). Emotion can also enhance the memory consolidation of stimuli (Mather,  
58 2007) by activating the amygdala (Hamann, 2001) and resulting in enhanced long-term  
59 (Hamann, Ely, Grafton, & Kilts, 1999) and short-term memory (Hamann & Mao, 2001, cited  
60 in Hamann, 2001). Emotion may also enhance retrieval processes such as cue detection, as  
61 emotional stimuli have been shown to attract attention compared to neutral stimuli (see  
62 Brosch et al., 2010; Yiend, 2010 for reviews). This occurs both when stimuli are being  
63 consciously attended to in visual search tasks (Frischen, Eastwood, & Smilek, 2008; Ohman,  
64 Flykt, & Esteves, 2001; Williams, Moss, Bradshaw, & Mattingley, 2005) and involuntarily  
65 when stimuli are presented subliminally (Brosch et al., 2010; Carretie, Hinojosa, Martin-  
66 Loeches, Mercado, & Tapia, 2004; Nummenmaa et al., 2006). This is pertinent as both  
67 conscious monitoring and automatic spontaneous retrieval processes may underlie  
68 prospective memory retrieval (McDaniel & Einstein, 2000).

69           However, the influence of emotion on encoding and retrieval processes may be  
70 valence-specific, due to differences in the mode of processing. Negative stimuli are thought  
71 to promote perceptual processing, whereas positive stimuli prioritise the encoding of ‘gist’  
72 and conceptual information (Kensinger, 2009; Kensinger & Schacter, 2008; Mickley &  
73 Kensinger, 2008). For example, people tend to remember more intrinsic details of negative  
74 pictures compared to positive (Kensinger, Garoff-Eaton, & Schacter, 2007), whereas when  
75 emotional words are presented alongside other semantically-related words, there is a memory  
76 benefit for positive compared to negative words (Kamp, Potts, & Donchin, 2015). More  
77 generally, negative moods tend to narrow focus onto perceptual details, whereas positive  
78 moods promote broader and more conceptual thinking (Clore & Huntsinger, 2007). Both  
79 perceptual and semantic processing can underlie the detection of prospective memory cues  
80 (McGann, Ellis, & Milne, 2003). Therefore, either benefits or impairments to prospective  
81 memory performance could be expected when emotional cues are encoded, depending on the  
82 valence of the prospective memory cues and the type of processing utilised during the  
83 retrieval process. For example, if perceptual processing is primarily used to detect  
84 prospective memory cues, then encoding negative cues should be beneficial to detection,  
85 whereas encoding positive cues should be detrimental.

### 86 ***Empirical research on emotional cues and prospective memory***

87 Despite the established benefits of emotional stimuli on attention and memory in the broader  
88 literature of emotion and cognition, direct empirical evidence for a benefit of emotional cues  
89 on prospective memory is mixed. Specifically, there is research reporting a benefit of  
90 emotional cues (Altgassen, Phillips, Henry, Rendell, & Kliegel, 2010; May et al., 2015;  
91 Rummel, Hepp, Klein, & Silberleitner, 2012); a detrimental effect of emotional cues  
92 (Ballhausen, Rendell, Henry, Joeffry, & Kliegel, 2015; Graf & Yu, 2015; Walter & Bayen,

93 2016); a beneficial effect, but only for one particular valence (Altgassen, Henry, Burgler, &  
94 Kliegel, 2011; Mioni et al., 2015; Rendell et al., 2011) and no difference between emotional  
95 and neutral cues (Cona, Kliegel, & Bisiacchi, 2015; Marsh et al., 2009).

96 The present systematic review and meta-analyses seek to address these contradictions  
97 and clarify the issue of whether emotional cues influence prospective memory. In addition, in  
98 order to investigate the likely mechanisms through which emotional cues influence  
99 prospective memory, the timing of the emotional manipulation (i.e., whether the valence of  
100 the cues is manipulated during the encoding or retrieval phase) is coded and tested as a  
101 moderator in the present meta-analyses. Calculating separate effect sizes for the influence of  
102 emotional cues on the separate processes of prospective memory can help determine the  
103 likely mechanisms underlying any overall effect on prospective memory performance.

#### 104 **Potential Moderators**

##### 105 *Methodological*

106 Differences in the methodologies used in prospective memory experiments may explain the  
107 diverse findings of studies investigating prospective memory and emotion. One such  
108 difference among experiments investigating the influence of emotion is the type of cues used  
109 (words or pictures) in the prospective memory task. Research has shown that when valence is  
110 not controlled for, prospective memory is better when pictures compared to words are used as  
111 cues (McDaniel, Robinson-Riegler, & Einstein, 1998). Relatedly, De Houwer and Hermans  
112 (1994) found that emotional pictures received preferential affective processing compared to  
113 emotional words. In their experiment, the affective categorisation of words was influenced by  
114 incongruent affective pictures, but the reverse effect was not observed. These results suggest  
115 that any potential benefit of emotional cues in prospective memory may be stronger for  
116 pictures rather than words. However, there is not yet any research that tests directly how the

117 superior effect of pictures in prospective memory may interact with affective valence, when  
118 focusing specifically on behavioural outcomes (cf. neuroimaging research, e.g. Flaisch et al.,  
119 2015; Leclerc & Kensinger, 2011).

120 The results from the aforementioned studies suggest a more complex interaction than  
121 an enhanced emotional effect for picture cues. Altgassen et al.'s (2011) study employed  
122 words (e.g., "happiness") but found a benefit only for positive but not negative cues, whereas  
123 May et al. (2015) found benefits for both positive and negative word cues. Graf and Yu  
124 (2015) used picture cues (e.g., a picture of a puppy) but found a detrimental effect of  
125 emotional cues, whereas other studies (e.g., Altgassen et al., 2010) found benefits for  
126 emotional cues in older adults using pictures. Quantitative investigation using meta-analytic  
127 techniques should help to clarify the effects of cue type.

### 128 *Cue Focality*

129 Another methodological consideration that may influence the effect of emotion on  
130 prospective memory is whether the prospective memory experiment employs a focal or non-  
131 focal paradigm. Prospective memory experiments typically involve an 'ongoing task', such as  
132 a lexical decision task (e.g., May et al., 2015) in which the prospective memory cues are  
133 embedded. Whether such cues are 'focal' or 'non-focal' refers to whether the prospective  
134 memory cues are processed in a way during the ongoing task that should automatically  
135 activate the representation of the prospective memory task to be performed, or whether  
136 detection of the cues requires extra cognitive resources outside of those used in the ongoing  
137 task. The two types of task are thought to reflect the two types of cue detection behaviour  
138 specified in McDaniel and Einstein's (2000) multiprocess theory. According to multiprocess  
139 theory, focal cues are thought to use spontaneous retrieval processes to detect, and non-focal  
140 cues are thought to require conscious monitoring. As the effect of emotion on prospective

141 memory may work at least in part through attention-based mechanisms, the focality of the  
142 cue may be an important moderating factor.

### 143 *Age*

144 Age moderates both prospective memory ability and emotional effects on cognition such that  
145 prospective memory ability is poorer in older adults (Henry, MacLeod, Phillips, & Crawford,  
146 2004), yet older adults show enhanced memory and attention for positive stimuli (Mather &  
147 Carstensen, 2005). In addition, age differences in prospective memory can be influenced by  
148 properties of the prospective memory cues and tasks (Ihle, Hering, Mahy, Bisiacchi, &  
149 Kliegel, 2013; Kliegel, Phillips, & Jager, 2008). Several studies have provided direct tests of  
150 the moderating effect of age on the influence of emotion on prospective memory (May et al.,  
151 2015; Schnitzspahn, Horn, Bayen, and Kliegel, 2012; Altgassen et al., 2010) though results  
152 are conflicting. For example, Schnitzspahn et al. (2012) found a benefit for emotional cues in  
153 older adults only. However, May et al. (2015) found benefits for emotional cues in both  
154 younger and older adults. The overall effect of manipulating the valence of cues on younger  
155 and older adults is not clear due to the conflicting results in the literature, and as such, a test  
156 of this moderator would be valuable.

### 157 *Arousal*

158 Variance in the extent to which prospective memory studies have controlled for the arousal  
159 level of the emotional cues may also explain discrepant findings in the literature. Arousal  
160 refers to the intensity of the emotional stimulus and the effects of this variable on cognition  
161 can be dissociated from those of the valence of the stimulus (Hamann, 2001). Several  
162 influential theories suggest that it is the arousing nature of emotional stimuli, rather than the  
163 relative valence, that underlies the beneficial effects of emotion on perception and memory  
164 (e.g. Kensinger, 2009; Mather & Sutherland, 2011, c.f. Adelman & Estes, 2013). The

165 implications of this are that studies that have not adequately controlled for the level of arousal  
166 between emotional prospective memory cues may inadvertently be measuring the effect of  
167 arousal on prospective memory, rather than the valence of the cues as intended. The present  
168 study will code for whether studies adequately controlled for the arousal level of emotional  
169 cues in order to investigate whether the effect of arousal and valence can be dissociated.

## 170 **The Present Research**

171 Overall, the wider literature on emotion and cognition indicates that emotional stimuli have  
172 beneficial effects on memory and attention. The extent to which these cognitive processes are  
173 used in prospective memory suggests that the use of emotional cues may enhance prospective  
174 memory. Enhanced memory effects are likely to come from employing emotional cues in the  
175 prospective memory encoding phase, whereas enhanced attention to emotional cues is likely  
176 to benefit the retrieval phase. The valence of the cues may also be important in determining  
177 their influence on cognitive processes (Kensinger, 2009). However, the literature that has  
178 directly investigated emotional cues and prospective memory has produced conflicting  
179 findings. The present research employs systematic review and three meta-analyses to  
180 aggregate and provide structure to the fragmented literature on prospective memory and  
181 emotion, and to identify unresolved issues regarding the way in which emotions influence the  
182 operation of prospective memory. Furthermore, the use of moderator analysis allows the  
183 identification of potential variables that can limit or increase the effectiveness of emotion at  
184 improving prospective memory.

## 185 **Method**

### 186 **Eligibility Criteria**

187 The inclusion criteria were: Any empirical study that had tested prospective memory  
188 performance as a dependent variable (i.e. the proportion of prospective memory cues

189 correctly responded to) and had manipulated the affective valence of prospective memory  
190 cues. Both between-participants and within-participants experimental designs were eligible  
191 for inclusion<sup>1</sup>. Between-participants designs required that participants were randomly  
192 assigned to a condition, and within-participants designs (92.6% of included studies) required  
193 that the order of cue valence was randomised or counterbalanced.

194         The following exclusion criteria were also applied: First, any studies in which the data  
195 did not allow a comparison between the different emotional valences. The primary way in  
196 which the effect of emotion on prospective memory has been conceptualised in the literature  
197 thus far has been as a comparison between positive, negative and neutral cues. The  
198 aggregated effect sizes calculated in the present meta-analysis followed this position and so  
199 cues from at least two of these valence conditions needed to be utilised in each included study  
200 in order to calculate an effect size. Therefore, studies that only compared between levels of  
201 the same valence of affect (Hallam et al., 2015) or looked only at the level of arousal  
202 regardless of valence (Burkard, Rochat, & Van der Linden, 2013) were excluded. Second,  
203 any studies in which the participants were solely from clinical samples (for example,  
204 diagnosed with anxiety or depression, e.g., Rude, Hertel, Jarrold, Covich, & Hedlund, 1999)  
205 were excluded, as these conditions have been shown to influence prospective memory ability  
206 (Chen, Zhou, Cui, & Chen, 2013; Rude et al., 1999) and susceptibility to emotional  
207 manipulations (Gotlib, Jonides, Buschkuehl, & Joormann, 2011). If sufficient data were  
208 available to allow calculation of effect sizes from non-clinical control groups in these studies,  
209 then these were included. Studies that measured the speed of response to prospective

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1 Although there is some debate over whether including both types in a meta-analysis is suitable (Lipsey & Wilson, 2001), other authors state that it is not a problem (Borenstein, Hedges, Higgins, & Rothstein, 2009; Lakens, 2013). Because of the relatively few studies in the current meta-analyses, it was decided that including these studies would be more beneficial than detrimental.

210 memory cues, rather than the proportion of prospective memory cues successfully responded  
211 to (i.e. prospective memory performance) were also excluded (Maglio, Gollwitzer, &  
212 Oettingen, 2014; Scholz et al., 2009) as this is not a typical measure of prospective memory  
213 performance. Studies not reported in English (Lu, Sun, & Liu, 2008; Yin & Huang, 2016)  
214 were also excluded.

## 215 **Information Sources**

216 The online databases of *Ovid PsychINFO*, *Web of Science*, *EthOS*, *ProQuest Dissertations*  
217 *and Theses Global*, *Google Scholar* and the *Journal of Articles In Support of The Null*  
218 *Hypothesis* were used for the literature search.

## 219 **Literature Search**

220 The databases listed above were searched using pre-specified key terms. In order to capture  
221 studies published in different research fields, several different terms were used to search for  
222 concepts relating to both prospective memory and emotion. The keywords relating to emotion  
223 were: *emotion*, *valence*, *affect\**, *positiv\**, *negativ\**, *fear*, *disgust*, and *anger*. The keywords  
224 relating to prospective memory were: “*prospective memory*”, “*implementation intention\**”,  
225 “*action plan\**”, “*future memory*” and “*delayed intention\**”. Each possible combination of  
226 emotion and prospective memory key words were used as search terms in databases with the  
227 AND operator. The ancestor and descendant approaches (DeCoster, 2009) were then  
228 employed to identify further literature that may not have been picked up by the search terms  
229 used in the database searches. Finally, all lead authors of the included papers were contacted  
230 via email to ask for any unpublished research related to the topic, an approach that yielded  
231 one additional set of data. The initial literature search returned 61 possible papers to include  
232 based on the title and abstract. The ascendancy approach returned 21 papers, and the

233 descendancy approach returned 1 paper for a total of 74 after duplicates had been removed  
234 (see Figure 1 for PRISMA flow diagram of review).

235 [Figure 1 here]

## 236 **Study Selection**

237 The results of the systematic search were assessed for further reading based on the relevance  
238 of the titles and abstracts. Following this, the full text for each of these papers was accessed  
239 and reviewed in detail against the inclusion and exclusion criteria for the meta-analyses. In  
240 total, 57 papers were excluded at this stage as they did not fit the inclusion criteria. The  
241 breakdown of these exclusions was: 25 did not include a test of prospective memory, 15 did  
242 not include emotion as an independent variable, 4 were review studies or experimental  
243 protocols, 4 were not reported in English, 4 did not measure prospective memory accuracy as  
244 a dependent variable, 3 only looked at a clinical sample, 1 measured only the arousal of the  
245 emotional stimuli and not the valence, and 1 presented duplicate data. This left the results  
246 from 17 articles to be analysed.

## 247 **Data Collection Process**

248 All papers were read in detail to extract the required information. If the information was not  
249 presented in the paper, or if clarification was needed on a particular item, then the lead author  
250 of the paper was contacted to obtain it.

## 251 **Data Items**

252 The following information was coded for each study by the first author: (1) participant  
253 demographics; (2) study design (within- or between-participants); (3) the valences of the  
254 emotional cues; (4) the timing of the emotional manipulation (i.e., whether the valence of the  
255 cue had been manipulated during encoding only, retrieval only, or both); (5) the format of the

256 cues used (words or pictures); (6) the sample of participants (younger or older adults); (7) the  
257 focality of the cue in the ongoing task (focal or non-focal); and (8) whether the study  
258 adequately controlled for the arousal level of the emotional cues (yes or no).

259 To code for the timing of the manipulation, the instructions for the prospective memory task  
260 given to participants were inspected. Studies that presented participants with only the  
261 category of the prospective memory cue at encoding (e.g. “animals”, Clark-Foos et al., 2009),  
262 but later manipulated the valence of the actual prospective memory cues embedded in the  
263 ongoing task were coded as manipulating retrieval only. Studies that presented participants  
264 with the exact (emotional or neutral) cues at encoding that they would later see embedded in  
265 the ongoing task were coded as manipulating both encoding and retrieval. Studies classified  
266 as ‘encoding only’ employed manipulations in which the valence of the prospective memory  
267 cues was manipulated during this phase only. For example, Henry et al. (2015) told  
268 participants the semantic category to which the prospective memory cues belonged, and  
269 presented a valenced exemplar of the category during encoding (e.g., a negatively valenced  
270 image from the category of ‘insects’). However, the prospective memory cues presented  
271 during the retrieval phase were neutral in valence. Age was coded using criteria employed by  
272 previous meta-analyses in the field (Henry et al., 2004; Ihle et al., 2013; Kliegel et al., 2008)  
273 et al., 2008) in which samples with a mean age of 60 or above are coded as older adults, and  
274 samples with a mean age of between 18 and 59 are coded as younger adults. Samples for  
275 which mean age was not reported but were described as undergraduate students were  
276 classified as younger adults. In the moderator analysis, the overall mean ages for each group  
277 were: Young adults ( $M=23.92$ ,  $SD=8.22$ ), older adults ( $M=70.73$ ,  $SD=4.01$ ).

278 Cue focality was coded by assessing the relationship between the prospective memory task  
279 and the ongoing task, using the description of focal and non-focal tasks by McDaniel and

280 Einstein (2000). Tasks in which the ongoing task required cognitive processes similar to  
281 those required to detect the prospective memory cue were classed as focal, and those in which  
282 different processes were used coded as non-focal. Studies were also coded for whether they  
283 adequately controlled for the arousal level of the prospective memory cues employed. If a  
284 suitable statistical test showing no significant difference between arousal levels of cues was  
285 reported then this was taken as an adequate level of control. If no such tests were reported  
286 then arousal was classed as uncontrolled. Separate codes were used to classify studies that  
287 controlled the arousal levels between (a) only positive and negative cues, but not neutral, and  
288 (b) all three types of cue.

### 289 **Summary Measures**

290 The effect size of  $d_{imb}$  was calculated for each experiment<sup>2</sup>. Separate effect sizes were  
291 calculated for each emotional valence comparison possible for each study (positive versus  
292 negative, positive versus neutral, negative versus neutral). For the positive versus neutral and  
293 negative versus neutral comparisons, effect sizes representing a benefit for valenced  
294 manipulations (e.g., a greater number of successful prospective memory task responses) were  
295 coded as positive (+ve). Effect sizes representing a detrimental effect for valenced  
296 manipulations compared to neutral were coded as negative (-ve). For the positive versus  
297 negative comparisons, effect sizes representing a benefit for positively-valenced  
298 manipulations were coded as +ve and benefits for negatively-valenced manipulations as -ve.  
299 Effect sizes were primarily calculated using means and standard deviations reported in the  
300 papers or obtained from the authors. If this was not possible then the data were extracted

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2 This notation is used on the advice of Cumming (2012) to avoid confusion over the inconsistent and contradictory use of the terms “Hedges’  $g$ ” and “Cohen’s  $d$ ”. Following the guidelines of Cumming (2012), the equations used to calculate the effect sizes are also reported in Appendix A.

301 from figures using image editing software or were calculated from the reported inferential  
302 test statistics if available. Confounding effects of other variables manipulated in a study were  
303 minimised by calculating effect sizes using control conditions<sup>3</sup>. When a paper included  
304 separate studies in which different samples of participants were tested, separate effect sizes  
305 were calculated for each sample allowed by the inclusion criteria.

## 306 **Synthesis of Results**

307 Three separate meta-analyses were conducted for the different valence comparisons, in order  
308 to investigate whether positive or negative emotional manipulations had differential  
309 influences on prospective memory. This was partly based on the distinct theoretical  
310 differences of the influence of valence (Clore & Huntsinger, 2007) but also the practical  
311 limitations of meta-analysis, which requires independence of effect sizes. Valence was  
312 manipulated as a within-participants variable in the majority of the studies, meaning that only  
313 one emotion effect could be included from each experiment in the same meta-analysis. Thus,  
314 separate meta-analyses were conducted for the effect sizes calculated for the comparison of  
315 negatively-valenced emotional influences compared to neutral, positively-valenced emotional  
316 influences compared to neutral, and positively-valenced emotional influences compared to  
317 negatively-valenced emotional influences.

318         The distinct influences of valenced cues on the separate process of prospective  
319 memory discussed in the introduction were investigated with the use of a meta-ANOVA. A  
320 separate effect size for the influence of emotional cues on each process (encoding, retrieval,  
321 encoding and retrieval) was calculated for each valence comparison. Therefore, nine different

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3 For example, Rummel et al. (2012) manipulated both the affective valence of the prospective memory cues as well as the mood of the participant, and therefore the effect sizes were calculated using the neutral condition of the mood variable to retain consistency with the other studies included in the same meta-analysis.

322 sub-meta-analyses were performed in total to calculate the unique effect of either negative or  
323 positive cues on each prospective memory process, including a comparison between negative  
324 and positive cues.

### 325 **Meta-Analytic Procedure**

326 A random-effects model was used for each meta-analysis to allow for between-studies  
327 variance (Cumming, 2012). Following the advice of Hunter and Schmidt (2004), a correction  
328 for measurement error in the dependent variable was applied to the meta-analyses where  
329 possible. The correction is based on the reliability of the measurement, and was applied  
330 individually to each effect size before the meta-analysis. Mioni, Rendell, Stablum,  
331 Gamberini, and Bisiacchi (2014) provided data on the reliability of the virtual week task used  
332 in three of the studies and Kelemen, Weinberg, Alford, Mulvey, and Kaeochinda (2006)  
333 provided data on the reliability of the dual task paradigm used in the remaining studies. The  
334 results of the corrected analyses are referred to in the text in the present paper, but the  
335 uncorrected results are also presented alongside the corrected results in Table 2. Cohen's  
336 power primer (Cohen, 1988) was used to help interpret the importance of the effects, with  $d$ 's  
337 of 0.2 considered "small", 0.5 "medium", and 0.8 "large". A 95% confidence interval for  
338 each effect size was calculated, and each effect size was tested for statistical significance  
339 using the lower-confidence limit (LCL) test (Hedges, Cooper, & Bushman, 1992). On the  
340 advice of Cumming (2012), interpretation of the results will focus primarily on the magnitude  
341 of the effect sizes and confidence intervals rather than the statistical significance.

### 342 **Heterogeneity**

343 A measure of heterogeneity was calculated for each separate meta-analysis. Although tests  
344 using Q-values are commonly used to assess heterogeneity, these are often underpowered  
345 when the number of studies in the meta-analysis is low, and in these situations the use of the

346  $I^2$  statistic is preferred (Higgins, Thompson, Deeks, & Altman, 2003). The  $I^2$  value represents  
347 the proportion of heterogeneity between studies that cannot be put down to chance, and  
348 should be interpreted as a percentage. Values of  $I^2$  can be classified into low (.25), moderate  
349 (.50) and high (.75) inconsistency among studies (Higgins et al., 2003).

### 350 **Additional Analyses**

351 Meta-one-way ANOVAs were planned to investigate any moderating effects on the influence  
352 of emotion on prospective memory and were executed based on Borenstein et al.'s (2009)  
353 recommendation of a minimum of 10 cases for each meta-ANOVA. The moderating  
354 variables were the age of the sample and the type of cue employed (picture or word).

355 All meta-analyses and meta-ANOVAs were conducted using the SPSS Macros  
356 developed by D.B. Wilson (2005), which simplify the process of conducting such analyses in  
357 SPSS and correct for some minor wrong assumptions that are present when usual statistical  
358 operations are performed on a meta-analytic dataset (Cooper, Hedges, & Valentine, 2009).

359

360

## **Results**

### 361 **Study Characteristics**

362 From the 17 articles identified from the literature search, 67 different effect sizes were  
363 extracted from 27 studies (Table 1). Eight out of 27 studies (30%) manipulated the valence of  
364 the cue during encoding only, 7/27 (26%) manipulated the valence of the cue during retrieval  
365 only, and 12/27 (44%) manipulated the valence of the cue during both encoding and retrieval.  
366 Fourteen out of 27 (52%) studies used words as cues and 13/27 (48%) used images as cues.  
367 In terms of age, studies typically sampled younger and older participants separately which  
368 meant that age was tested as a categorical rather than continuous moderator. Within these

369 studies, 10/27 (37%) sampled older adults, and 17/27 (63%) sampled younger adults. Nine  
370 out of 27 (33%) studies utilised focal cues and 18/27 (67%) utilised non-focal cues. With  
371 regards to control for the level of arousal of prospective memory cues, only 4/27 (15%)  
372 studies controlled for arousal across all three valences (positive, negative, and neutral), and  
373 23/27 (85%) did not. However, 17/27 (63%) did control for the level of arousal between  
374 positive and negative cues, compared to 10/27 (37%) that did not. Table 2 shows the results  
375 of the series of meta-analyses, moderator analyses, along with the number of studies ( $k$ ) and  
376 total  $N$  for each analysis, the measure of heterogeneity ( $I^2$ ) and the 95% Confidence Interval  
377 for each effect size.

378 [Table 1 near here]

### 379 **Main Effects**

380 The magnitude of the influence of emotional cues ranged from  $d = 0.07$  to  $d = 0.32$   
381 for the different valence comparisons. There were small significant effects of the influence of  
382 positive cues (versus neutral:  $d = 0.32$  [0.10, 0.54]  $p < .01$ ; versus negative:  $d = 0.29$  [0.11,  
383 0.48]  $p < .01$ ): Positively-valenced cues resulted in small improvements in prospective  
384 memory compared to either neutral or negative cues. In contrast, negative cues did not have a  
385 significant effect on prospective memory compared to neutral ( $d = 0.07$  [-0.10, 0.24]  $p$   
386  $= .408$ ).

387 [Table 2 near here]

### 388 **Moderator Analyses**

#### 389 *Timing of emotional manipulation*

390 Each valence comparison for the influence of emotional cues was tested to see if the timing  
391 of the emotional manipulation, i.e., manipulating the valence during either the encoding

392 phase only, the retrieval phase only, or during both encoding and retrieval, differentially  
393 affected prospective memory. There were significant moderating effects of the timing of the  
394 manipulation for both the negative versus neutral ( $p < .01$ ) and positive versus negative ( $p <$   
395  $.01$ ) comparisons. The moderating effect of timing of the manipulation for positive versus  
396 neutral comparisons was not significant ( $p = .506$ ), suggesting that that the influence of  
397 positive cues is relatively more consistent, regardless of which processes are affected.

398         When negatively-valenced cues were presented during encoding only, they produced  
399 a detrimental effect on prospective memory compared to neutral cues ( $d = -0.25 [-0.57, 0.06]$   
400  $p = .108$ ). However, when negatively-valenced cues were presented during both encoding and  
401 retrieval, they improved prospective memory performance ( $d = 0.35 [0.08, 0.62]$   $p = .012$ )<sup>4</sup>.  
402 Presenting negative cues during retrieval only did not appear to influence prospective  
403 memory significantly when compared to neutral cues ( $d = -0.12 [-0.56, 0.32]$   $p = .602$ ). In  
404 contrast, the effect of positive cues was similar regardless of which prospective memory  
405 process they influenced. Positive cues presented only during the encoding phase improved  
406 prospective memory ( $d = 0.34 [-0.05, 0.73]$   $p = .080$ ) to a similar extent as presenting them

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4 When performing the meta-analysis and meta-ANOVAs of negative versus neutral cue valence, one effect size (Rea et al., 2011) was identified as an outlier using a funnel plot and was subsequently excluded from the analysis. As a random-effects model was being used, studies with small sample sizes can have a disproportionately large influence on the overall effect size (Borenstein et al., 2009). In this case, the sample size was 13, and the effect size was  $d_{umb} = -1.82$  (after correction for measurement error), meaning that including it would have an undue influence on the calculation of the combined effect size. Separate meta-analyses were conducted both including and excluding the study in question. Although the overall effect size for negative versus neutral cues did not change dramatically when including this study (0.07 without compared to 0.12 with), the effect size of negative versus neutral cues at encoding only did. Including the effect size from the Rea et al. (2011) study resulted in an overall effect size  $d = -0.36$ , but without including this study, the overall effect size was  $d = -0.25$ . Due to the large influence of this study's effect size in comparison to its small sample size ( $N = 13$ ), the decision was taken to exclude it from this and all other analyses to retain consistency.

407 during both encoding and retrieval ( $d = 0.33 [-0.03, 0.69] p = .072$ ). However, presenting  
408 positive cues during retrieval only did not improve prospective memory compared to neutral  
409 cues ( $d = 0.01 [-0.62, 0.64] p = .978$ ). When comparing positive to negative cues, the timing  
410 of the emotional manipulation also moderated the effects. Due to the clear difference between  
411 the effects of negative and positive cues compared to neutral when presented during encoding  
412 only, positive cues unsurprisingly showed a large benefit when compared to negative cues  
413 when presented during encoding only ( $d = 0.62 [0.30, 0.95] p < .001$ ). When the affective  
414 valence of cues was manipulated during both encoding and retrieval, the difference between  
415 positive compared to negative cues was small ( $d = -0.06 [-0.35, 0.23] p = .686$ ). Studies  
416 presenting emotional cues only during the retrieval phase found a benefit for positive over  
417 negative cues ( $d = 0.39 [0.02, 0.75] p = .039$ ).

#### 418 *Influence of age and cue type*

419 The moderators of sample age and cue type (pictures or words) were also tested to see  
420 whether the influence of emotional cues differed between the levels of these variables. These  
421 moderator analyses were, like the analyses above, also performed on the three separate meta-  
422 analyses of the influence of emotional cues for the different valence comparisons. There was  
423 no moderating effect of age for the influence of negative cues on prospective memory  
424 compared to neutral cues ( $p = .872$ ). Negative cues showed no overall influence for either  
425 older adults ( $d = 0.09 [-0.23, 0.41] p = .590$ ) or younger adults ( $d = 0.05 [-0.23, 0.34] p =$   
426  $.719$ ). However, for the overall significant influence of positive cues compared to neutral,  
427 there appeared to be stronger benefits for older adults ( $d = 0.41 [0.07, 0.74] p = .019$ ) than  
428 younger adults ( $d = 0.25 [-0.05, 0.55] p = .105$ ), although this difference was not statistically  
429 significant ( $p = .502$ ). This pattern was repeated for the benefit of positive cues over negative  
430 cues (older:  $d = 0.34 [-0.02, 0.70] p = .061$ ; younger:  $d = 0.28 [0.00, 0.56] p = .052$ ).

431           There were no significant differences for the moderator of cue type for any of the  
432 valence comparisons. Negative cues showed no overall influence compared to neutral  
433 regardless of whether they were words ( $d = 0.11 [-0.20, 0.42], p = .491$ ) or images ( $d = 0.01$   
434  $[-0.25, 0.32] p = .822$ ). Similarly, the significant overall benefit of positive cues compared to  
435 neutral did not differ depending on whether words ( $d = 0.33 [-0.03, 0.69] p = .068$ ) or images  
436 ( $d = 0.31 [0.01, 0.60] p = .041$ ) were used as the cues. The benefit of positive over negative  
437 cues was also similar regardless of cue type (words:  $d = 0.32 [0.00, 0.63] p = .049$ ; images:  $d$   
438  $= 0.29 [-0.02, 0.60] p = .066$ ).

#### 439 *Influence of control for arousal*

440       Two types of control for arousal were recorded during coding: Studies that had controlled for  
441 the arousal level of cues only between positive and negative cues, and studies that had  
442 controlled for arousal level across positive, negative, and neutral cues. The first type of  
443 coding was relevant only for the meta-analysis of the valence comparison of positive versus  
444 negative cues. The moderator analysis showed that there was no difference between the  
445 overall effect size of positive versus negative cues from studies that had controlled for arousal  
446 ( $d = 0.30 [0.03, 0.56], p = .027$ ) and those than had not ( $d = 0.31 [-0.09, 0.71], p = .126$ ).

447       The coding of whether studies controlled for arousal across all three types of cues was used  
448 when considering the positive versus neutral and negative versus neutral analyses, although  
449 only a small number of studies ( $k = 4$ ) employed adequate controls. When arousal was not  
450 controlled for, negative cues produced a small non-significant benefit compared to neutral  
451 cues, ( $d = 0.13 [-0.10, 0.36], p = .271$ ), however when arousal was controlled, negative cues  
452 produced a small non-significant decrease in performance compared to neutral ( $d = -0.20 [-$   
453  $0.69, 0.28], p = .410$ ). The difference between these effect sizes was not significant. For the  
454 positive versus neutral effect size, controlling for arousal eliminated any benefit of positive

455 cues ( $d = 0.01 [-0.48, 0.50], p = .976$ ) compared to when arousal was not controlled for ( $d =$   
456  $0.40 [0.15, 0.64], p = .001$ ), although this difference was also non-significant.

### 457 *Influence of cue focality*

458 Cue focality (whether prospective memory cues were ‘focal’ and able to be detected using  
459 similar cognitive processes to those required for the ongoing task) was also tested as a  
460 moderating variable. For the effect size of negative cues versus neutral cues, focality was  
461 found to be a significant moderator ( $p < .01$ ). Studies that employed focal cue paradigms  
462 found that negative cues enhanced prospective memory compared to neutral ( $d = 0.49 [0.18,$   
463  $0.80], p = .002$ ), whereas studies that used non-focal cues found that negative cues impaired  
464 prospective memory ( $d = -0.12 [-0.34, 0.09], p = .255$ ). However, for positive versus neutral  
465 cues, focality was not a significant moderator. Positive cues were beneficial compared to  
466 neutral regardless of whether they were focal ( $d = 0.50 [0.10, 0.90], p = .014$ ) or non-focal ( $d$   
467  $= 0.24 [-0.03, 0.50], p = .078$ ), although focal cues showed a greater benefit. For the positive  
468 versus negative comparison, focality was a significant moderator ( $p < .05$ ), with positive cues  
469 showing benefit compared to negative in non-focal designs ( $d = 0.42 [0.19, 0.66], p < .001$ ),  
470 but little difference between the cues when both were focal ( $d = -0.04 [-0.43, 0.35], p = .832$ ).

471

## Discussion

472 The present research represents the first attempt to review systematically the fragmented  
473 literature on the influence of positively- or negatively-valenced cues on prospective memory  
474 performance. Three separate meta-analyses were conducted to distinguish between the  
475 different valences of the emotional influence. Overall, prospective memory performance was  
476 better when positively-valenced cues were used compared to neutral cues ( $d = 0.32$ ) and  
477 negative cues ( $d = 0.29$ ). In contrast, there was no overall benefit for negative over neutral  
478 cues ( $d = 0.07$ ). However, the effect of emotional cues was found to alter depending on the

479 phase of prospective memory in which the emotional manipulation was employed, i.e. during  
480 the encoding phase only, the retrieval phase only, or both the encoding and retrieval phases.  
481 During encoding, positively-valenced cues improved prospective memory compared to  
482 neutral cues, but negatively-valenced cues produced a detrimental effect on subsequent  
483 prospective memory performance. In contrast, when manipulating the valence of the cues  
484 during both encoding and retrieval, both positive cues and negative cues improved  
485 prospective memory performance in comparison to neutral cues. Furthermore, manipulating  
486 the affective valence of the cues only during the retrieval phase showed much weaker effects  
487 compared to neutral cues. The difference in the magnitude of the influences of emotional  
488 cues - especially negative cues - on the separate processes of prospective memory suggests  
489 that multiple mechanisms may underlie the influence of emotional cues on prospective  
490 memory.

491         Whilst the attention-grabbing nature of emotional stimuli (Frischen et al., 2008;  
492 Nummenmaa et al., 2006) has been suggested as a possible mechanism underlying the benefit  
493 of cue valence on prospective memory (May et al., 2015), the present results do not fully  
494 support this suggestion. Studies manipulating the valence of the prospective memory cues  
495 only during the retrieval phase did not demonstrate substantial benefits to prospective  
496 memory, suggesting that increased attention to prospective memory targets alone is not  
497 sufficient to improve prospective memory. The process model of prospective memory  
498 (Kliegel, Martin, McDaniel & Einstein, 2002) states that although factors relating to the  
499 prospective memory cue itself may influence prospective memory during the retrieval phase,  
500 the primary executive processes required during this phase relate to working memory and  
501 cognitive flexibility. Thus, manipulating the emotionality of the cues during retrieval alone  
502 may not have a strong enough influence to overcome other task demands that influence these  
503 executive processes. However, it should be noted that the number of studies that manipulated

504 valence during retrieval only was very small. The analyses of positive versus neutral and  
505 negative versus neutral effects contained only 4 and 3 effect sizes respectively. With such a  
506 small number of studies, the overall effect size estimates are unlikely to be accurate, and this  
507 is reflected in the large confidence intervals. Further research in which the emotional valence  
508 of cues is manipulated only during retrieval is necessary to increase the accuracy of these  
509 estimates.

510         Studies presenting emotional cues during both encoding and retrieval showed small-  
511 to-medium benefits for prospective memory (Cohen, 1988). One explanation for why effects  
512 were found when manipulating valence during both encoding and retrieval, but not during  
513 retrieval only, may be that it is necessary to have previously encoded the emotional cues to  
514 reap the benefits of any enhanced attention-grabbing properties provided during the retrieval  
515 process. Studies that manipulated the valence of cues during retrieval only did so by  
516 providing the category to which the cue belonged in the prospective memory instructions  
517 (e.g. “pictures of animals”, Ballhausen et al., 2015), whereas studies manipulating cues  
518 during both encoding and retrieval provided the exact cues that would later be seen in the  
519 retrieval phase. Emotional stimuli are likely to grab attention during the retrieval phase but  
520 may fail to trigger the prospective memory response if the stimuli themselves have not  
521 previously been encoded and linked with the response. In contrast, encoding the exact  
522 emotional stimuli as the prospective memory cue with the response means that not only is  
523 attention drawn to the cue during the retrieval phase, but that the cue is subsequently likely to  
524 be detected as relevant to the prospective memory intention, triggering the response. This  
525 supports the encoding specificity principle (Tulving & Thomson, 1973) that states that  
526 recognition of a cue is improved when the retrieval cue is more similar to the cue that was  
527 originally encoded.

528           The finding that emotional cues seem to enhance the encoding specificity effect is  
529 consistent with the suggestion of Buchanan (2007) that the affective valence of the cue is one  
530 of the variables that contribute to the similarity that prompts recognition. Encountering an  
531 emotional cue in the environment prompts an affective response, which means that memories  
532 associated with the same affective response are more likely to be brought to mind. In this  
533 case, the memories brought to mind are the encoding of the stimuli as a prospective memory  
534 cue and the associated prospective memory response. This suggestion also explains why  
535 manipulating the valence of the cue during retrieval only did not produce reliable effects on  
536 prospective memory: The affective response that occurs in reaction to encountering a  
537 prospective memory cue in the environment cannot prompt the retrieval of the prospective  
538 memory response through the encoding specificity effect because the original prospective  
539 memory cues encoded did not prompt a similar affective response. The present results are  
540 also consistent with the findings of Hannon and Daneman (2007) who conducted the only  
541 empirical study to date that explicitly manipulated the (perceptual) salience of cues during  
542 encoding, retrieval and both encoding and retrieval. They found that whilst manipulating the  
543 salience of cues during retrieval can influence prospective memory, a stronger influence  
544 comes from a direct match between encoded cue and that observed during the retrieval phase.  
545 These authors suggested that during encoding, one should consider multiple aspects of the  
546 retrieval cue that are likely to occur during detection in order to maximise the similarity  
547 between the encoding and retrieval contexts and prompt retrieval. The results of the present  
548 research expand on this by suggesting that one should seek to encode a cue that prompts a  
549 similar affective response to a cue that one expects to encounter in the environment.

550           Positive and negative cues showed similar benefits (compared to neutral) when  
551 presented during both the encoding and retrieval phases. In contrast, positive and negative  
552 cues showed differential effects when manipulated at encoding only. Presenting positive cues

553 at encoding improved prospective memory performance in comparison to neutral cues,  
554 whereas presenting negative cues impaired it. There is evidence from the broader literature  
555 that negatively-valenced stimuli receive enhanced perceptual processing and impaired  
556 semantic processing (Kensinger & Schacter, 2008; Mickley & Kensinger, 2008; Sakaki,  
557 Gorlick, & Mather, 2011). This leads to a focus on and enhanced memory for the intrinsic  
558 perceptual details of the negative item (Kensinger, Garoff-Eaton, & Schacter, 2006; Pierce &  
559 Kensinger, 2011). In the context of prospective memory cues, an enhanced focus on the  
560 perceptual details of a cue would likely enhance subsequent detection and recognition of the  
561 same cues, a finding supported by the results of the present meta-analysis showing improved  
562 prospective memory performance for negative cues presented during both encoding and  
563 retrieval. However, an enhanced focus on the perceptual details of a cue and diminished  
564 processing of the semantic properties of a cue could also explain the detrimental effect of  
565 negative stimuli presented at encoding only. If perceptual rather than semantic processing is  
566 used to encode the cue, then subsequent cues that share the same semantic context as the  
567 encoded cue but are not perceptually similar may not be detected as easily. For example, if  
568 one focused on the perceptual details of a picture of a negatively-valenced image of a rat at  
569 encoding, but the later cues belonging to the category of animals are dogs, then their  
570 detection may be impaired. In contrast, presenting positively-valenced stimuli at encoding  
571 improved prospective memory performance.

572         Processing positive stimuli has been shown to activate semantic and conceptual  
573 processing to a greater extent than perceptual processing (Kensinger, 2009; Kensinger &  
574 Schacter, 2008; Mickley & Kensinger, 2008). This enhanced conceptual processing may  
575 facilitate the subsequent detection of cues that are semantically related to the encoded cues,  
576 even if they are not perceptually similar. The differences between semantic and perceptual  
577 processing in prospective memory cue detection have been investigated using neuroimaging

578 (Cousens et al., 2015), however there is little behavioural data available. Future research  
579 should seek to explain the differences between positive and negative cues when valence is  
580 manipulated during the encoding phase. Overall, the results of the present meta-analyses  
581 suggest that the influence of valenced cues on prospective memory is underpinned by several  
582 different mechanisms that result in different effects depending on the valence of the cues.  
583 Presenting emotional cues at both encoding and detection improved prospective memory  
584 performance for both negative and positive cues.

585         An alternative explanation for the observed differences between the effects of positive  
586 and negative effects on prospective memory emerges from the moderator analyses of cue  
587 focality. This variable significantly moderated the effect of negative cues on prospective  
588 memory, but not positive cues. When negative cues were presented focally in the ongoing  
589 tasks (i.e. cue detection required similar cognitive processes as those used to perform the  
590 ongoing task), they improved prospective memory performance compared to neutral,  
591 however when presented non-focally they did not. In contrast, the benefit of positive cues  
592 compared to neutral was unaffected by whether they were presented focally or non-focally.  
593 This pattern of findings suggests that beneficial effects of negative cues may be reliant on the  
594 automatic spontaneous retrieval process that are thought to underlie cue detection (Einstein et  
595 al, 2005; Scullin et al., 2010). Forcing more effortful cognitive monitoring for cues in non-  
596 focal tasks may therefore preclude such an effect from occurring. In contrast, the benefits of  
597 positive cues may operate via mechanisms that are immune to increased levels of cognitive  
598 demand. However, it should be noted that there was a significant overlap between the coding  
599 outcomes of cue focality and the timing of the emotional manipulations. For example, all  
600 studies coded as being non-focal were necessarily also coded as affecting the retrieval  
601 process only, and all studies coded as focal were necessarily coded as affecting both encoding  
602 and retrieval. This makes it difficult to separate the relative influence of focality and the

603 influence of a match between the cue at encoding and retrieval previously discussed. Further  
604 empirical work would be necessary to disentangle these influences.

605         The moderator analyses performed also highlight another unresolved issue in the  
606 literature, namely the relative influences of valence and arousal of emotional cues. Arousal  
607 has been postulated as a variable that may explain differences in emotional effects, as  
608 opposed to valence (Kensinger, 2009; Mather & Sutherland, 2011). The analyses showed that  
609 the benefit of positive cues compared to neutral was eliminated when considering only  
610 studies that employed strict controls for arousal, suggesting that arousal may indeed play an  
611 important role. However, this finding must be considered in the context that only four studies  
612 employed such controls. Many studies reported attempting to control for arousal but did not  
613 report the necessary statistical tests to confirm that any differences between the arousal levels  
614 of cues were non-significant. This ambiguity means it is still unclear whether differences in  
615 arousal may explain any emotional effects. However, it is clear that more attention needs to  
616 be paid to controlling more carefully for arousal in future research to resolve this issue.

617         The effects of two other potential moderators on the influence of valenced cues on  
618 prospective memory were also tested. The first variable tested was cue type. There did not  
619 appear to be any overall effect of whether the cues used were words or images, suggesting  
620 that both have similar influences on prospective memory. However, it is unclear whether the  
621 different types of cues may produce differential effects in the separate phases of prospective  
622 memory (encoding and retrieval). Insufficient numbers of studies were available to test  
623 potential differential effects of words and pictures as a moderator in the sub-analyses, and so  
624 the possibility that pictures and words differentially affect the encoding and retrieval phases  
625 cannot be ruled out. The relationship between type of stimuli (word or picture) and the  
626 default modality of processing (perceptual or semantic) is not straightforward, and instead

627 highly influenced by task demands (Miller, 2001). However, utilising different types of cues  
628 may be a viable way of exploring the hypotheses suggested previously regarding differences  
629 in modality of processing underlying emotional effects on prospective memory. More data  
630 are needed in order to draw conclusions about how different types of cues affect prospective  
631 memory, and also whether emotional effects can be extended to cues other than words or  
632 pictures, for example auditory or olfactory stimuli.

633         The other moderating variable tested was age, which also showed no significant  
634 moderating effects. The boost in prospective memory performance that positive cues gave  
635 compared to neutral cues was similar for both older and younger adults. Although age  
636 differences were observed in some individual studies (e.g. Altgassen et al., 2011;  
637 Schnitzspahn et al., 2012), overall the present findings are consistent with those of a meta-  
638 analysis by N. A. Murphy and Isaacowitz (2008) who found that older adults did not show a  
639 significantly different preference for positive stimuli compared to younger adults. One  
640 potential reason for discrepancies amongst studies that found age differences and those that  
641 did not may be task difficulty. Prospective memory tasks that are more cognitively  
642 demanding are associated with greater age differences (Henry et al., 2004) and it is plausible  
643 that such an effect interacts also with any effects of emotion. Regrettably, not enough studies  
644 were available to explore such a complex interaction in the present research but this line of  
645 enquiry could be pursued with controlled experiments.

#### 646 **Limitations and Avenues for Future Research**

647 The results of the present set of meta-analyses should be interpreted with several caveats in  
648 mind. First, the small number of studies in many of the sub-analyses and the range of  
649 different prospective memory tasks used in the studies are likely to have contributed to the  
650 high heterogeneity observed in each set of effect sizes. The small magnitude of these non-

651 significant effect sizes suggest that many of the possible influences of emotional cues on  
652 prospective memory lack any clear supporting evidence, or are at least highly influenced by  
653 other moderating variables that could not be coded for.

654         Second, there are limitations within the body of studies analysed that are common to  
655 many areas of emotion research. All the studies analysed in the current set of analyses  
656 employed the trichotomy of ‘positive, negative, neutral’ and conceptualised the effect of  
657 emotion using the dimension of valence, whilst also acknowledging (and in some cases  
658 controlling for) arousal. However, the use of these dimensions ignores the individual effects  
659 that discrete emotions may have. For example, although anger and anxiety are both  
660 ‘negative’ emotions, they have been shown to have distinct effects on cognition (Lench,  
661 Flores, & Bench, 2011). Furthermore, the reliance on arousal and valence measures to  
662 classify emotional stimuli may ignore the contribution of appraisal variables, such as novelty,  
663 personal relevance and ‘emotional impact’ that have not been controlled for in the present set  
664 of studies but have been shown to affect attention and recollection (F. C. Murphy, Hill,  
665 Ramponi, Calder, & Barnard, 2010) and so could also be expected to influence prospective  
666 memory. Despite this, the evidence for the influence of valenced cues on prospective memory  
667 from the present set of meta-analyses demonstrate that the dimensions of arousal and valence  
668 have the ability to capture at least some of the influence of emotional stimuli on prospective  
669 memory.

670         Third, limitations of the methodologies employed in the studies included in the meta-  
671 analysis may represent a source of bias in the results. Overall, of the 27 studies included in  
672 the analyses, only two employed between-participant designs with randomization to  
673 conditions. The remaining studies used a counterbalanced order of emotional cues.  
674 Counterbalancing can minimise the influence of serial order carryover effects associated with

675 repeated-measures designs, however some methods of counterbalancing do not cover all  
676 possible carryover effects (Brooks, 2012). Carryover effects may be expected in the context  
677 of presenting emotionally-valenced prospective memory cues, as affective responses to  
678 stimuli have been shown to persist after the presentation of the stimuli ends (Garrett &  
679 Maddock, 2001). Although between-participants designs also have drawbacks when used in  
680 emotion research, for example due to the influence of individual differences in emotion  
681 perception (Okon-Singer, Lichtenstein-Vidne, & Cohen, 2013); a greater balance of between-  
682 participants and within-participants designs in future research on the topic should minimise  
683 any drawbacks associated with either design.

#### 684 **Conclusion**

685 This systematic review and meta-analyses were conducted to help bring together a disparate  
686 literature on the effect of emotion on prospective memory. The aim was to quantify the  
687 influence of emotional cues on prospective memory and to identify any sources of  
688 inconsistency through moderator analyses. The results showed that whilst emotional cues can  
689 improve prospective memory performance, the influence is dependent on the prospective  
690 memory process affected by the manipulation. Manipulating the valence of the cues during  
691 retrieval only does not improve prospective memory. In addition, manipulating the valence of  
692 cues during encoding only produces differential effects for positive and negative cues:  
693 Negative cues impair prospective memory whilst positive cues enhance it. However,  
694 manipulating the emotional valence of a cue during both encoding and retrieval produces  
695 reliable increases in prospective memory performance and is a promising strategy to improve  
696 intention realisation.

#### 697 **Disclosure of Interest**

698 The authors report no conflicts of interest.

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701

702 **References**

703 \*Studies included in the meta-analyses are marked with an asterisk.

704

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## Appendix A

965

966 Effect sizes for within-subjects studies were calculated using the following equation from

967 Cumming (2012):

$$968 \quad d_{unb} = \left(1 - \frac{3}{4(n_1 + n_2) - 9}\right) \left(\frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{SD_1^2 + SD_2^2}{2}}}\right)$$

969 Effect sizes for between-subjects studies were calculated using the following equation from

970 Cumming (2012):

$$971 \quad d_{unb} = \left(1 - \frac{3}{4(n_1 + n_2) - 9}\right) \left(\frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{(n_1 - 1)SD_1^2 + (n_2 - 1)SD_2^2}{n_1 + n_2 - 2}}}\right)$$

972 Where  $n_1$  is the number of participants in one of the emotional conditions,  $n_2$  is the number

973 of participants in the comparison condition,  $\bar{X}_1$  is the mean prospective memory ability score

974 for one of the emotional conditions,  $\bar{X}_2$  is the mean prospective memory ability score for the

975 comparison condition, and  $SD_1$  and  $SD_2$  are the respective standard deviations associated

976 with the means.

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Table 1. *Characteristics of Studies Included in the Meta-Analyses*

| Study   | Group                  | Emotions       | Process affected | Study design | Cue type | Age | Focal | Control for arousal | N  | Effect size $d_{unb}$ |    |              |    |             |
|---|------------------------|----------------|------------------|--------------|----------|-----|-------|---------------------|----|-----------------------|----|--------------|----|-------------|
|   |                        |                |                  |              |          |     |       |                     |    | Neg vs. Neut          | N  | Pos vs. Neut | N  | Pos vs. Neg |
| Altgassen, Henry, Burgler, & Kliegel (2011)           | Non-depressed controls | Neg, Pos, Neut | E+R              | W            | W        | Y   | F     | N                   | 29 | -0.17                 | 29 | 0.45         | 29 | 0.65        |
| Altgassen, Phillips, Henry, Rendell, & Kliegel (2010) | Young adults           | Neg, Pos, Neut | E+R              | W            | I        | Y   | F     | S                   | 41 | 0.33                  | 41 | -0.12        | 41 | -0.45       |
|   | Older adults           | Neg, Pos, Neut | E+R              | W            | I        | O   | F     | S                   | 41 | 0.95                  | 41 | 0.82         | 41 | -0.24       |
| Ballhausen, Rendell, Henry, Joeffry, & Kliegel (2015) | Experiment 1           | Neg, Pos, Neut | R                | W            | W        | O   | N     | A                   | 24 | -0.80                 | 24 | -0.10        | 24 | 0.70        |
|   | Experiment 2           | Neg, Pos, Neut | E                | W            | W        | O   | N     | A                   | 24 | -0.81                 | 24 | -0.67        | 24 | 0.14        |
| Clark-Foos, Brewer, Marsh & Meeks (2009)              | Experiment 1a          | Pos, Neg       | R                | W            | W        | Y   | N     | S                   |    |                       |    |              | 30 | 0.66        |
|   | Experiment 1b          | Pos, Neg       | R                | W            | W        | Y   | N     | S                   |    |                       |    |              | 30 | 0.37        |
|   | Experiment 1c          | Pos, Neg       | R                | W            | W        | Y   | N     | S                   |    |                       |    |              | 30 | 0.45        |

|   |                                |                   |                     |                 |             |     |       |                        |          |                 |          |                 |          |                |
|---|--------------------------------|-------------------|---------------------|-----------------|-------------|-----|-------|------------------------|----------|-----------------|----------|-----------------|----------|----------------|
| Cona (2015)   |                                | Neg, Pos,<br>Neut | E+R                 | W               | I           | Y   | F     | S                      | 24       | 0.57            | 24       | 0.24            | 24       | -0.43          |
| Graf & Yu (2015)                                    | Experiment 2                   | Neg, Pos,<br>Neut | R                   | B               | I           | Y   | N     | N                      | 130      | -0.42           | 130      | -0.46           | 130      | -0.04          |
| Henry et al.<br>(2015)                              | Young adults                   | Neg, Pos,<br>Neut | E                   | W               | I           | Y   | N     | N                      | 42       | -0.15           | 42       | -0.15           | 42       | 0.00           |
|   | Young-old<br>adults            | Neg, Pos,<br>Neut | E                   | W               | I           | O   | N     | N                      | 38       | -0.10           | 38       | 0.03            | 38       | 0.13           |
| Henry et al.<br>(2015)                              | Old-old adults                 | Neg, Pos,<br>Neut | E                   | W               | I           | O   | N     | N                      | 29       | 0.09            | 29       | -0.06           | 29       | -0.15          |
| Study   | Group                          | Emotions          | Process<br>affected | Study<br>design | Cue<br>type | Age | Focal | Control for<br>arousal | <i>N</i> | Neg vs.<br>Neut | <i>N</i> | Pos vs.<br>Neut | <i>N</i> | Pos vs.<br>Neg |
| Marsh et al.<br>(2009)                              | Non-anxious<br>controls        | Neg, Neut         | R                   | W               | W           | Y   | N     | N                      | 25       | 0.22            |          |                 |          |                |
| May, Manning,<br>Einstein, Becker<br>& Owens (2015) | Experiment 1<br>(young adults) | Neg, Pos,<br>Neut | E+R                 | W               | W           | Y   | F     | S                      | 40       | 0.69            | 40       | 0.87            | 40       | 0.23           |
|   | Experiment 1<br>(older adults) | Neg, Pos,<br>Neut | E+R                 | W               | W           | O   | F     | S                      | 32       | 0.67            | 32       | 0.77            | 32       | 0.06           |
|   | Experiment 2                   | Neg, Neut         | E+R                 | W               | W           | O   | F     | S                      | 24       | 0.04            |          |                 |          |                |
| Mioni et al.<br>(2015)                              | Healthy<br>Controls            | Neg, Pos,<br>Neut | E                   | W               | I           | O   | N     | N                      | 25       | -0.60           | 25       | 0.76            | 25       | 1.46           |
| Rea et al. (2011)                                   |                                | Neg, Neut         | E+R                 | W               | I           | Y   | F     | N                      | 13       | -1.82           |          |                 |          |                |

|  |                      |                |     |   |   |   |   |   |    |       |    |       |    |       |
|--|----------------------|----------------|-----|---|---|---|---|---|----|-------|----|-------|----|-------|
| Rendell et al. (2012)                      |                      | Neg, Pos, Neut | E   | W | I | Y | N | S | 60 | -0.40 | 60 | 0.38  | 60 | 0.83  |
| Rendell et al. (2011)                      | Young adults         | Neg, Pos, Neut | E   | W | I | Y | N | S | 30 | -0.44 | 30 | 1.12  | 30 | 1.54  |
|  | Older adults         | Neg, Pos, Neut | E   | W | I | O | N | S | 30 | 0.28  | 30 | 1.56  | 30 | 1.55  |
| Rummel, Hepp, Klein & Silberleitner (2012) | Neutral mood only    | Neg, Pos, Neut | R   | W | W | Y | N | N | 46 | 0.41  | 46 | 0.55  | 46 | 0.20  |
| Schnitzspahn, Horn, Bayen & Kliegel (2012) | Young adults         | Neg, Pos, Neut | E+R | W | W | Y | N | A | 45 | -0.07 | 45 | 0.10  | 45 | 0.16  |
|  | Older adults         | Neg, Pos, Neut | E+R | W | W | O | N | A | 41 | 0.74  | 41 | 0.63  | 41 | -0.16 |
| Singh & Kashyap (2016)                     |                      | Pos, Neg       | E+R | B | W | Y | F | N |    |       |    |       | 40 | 0.94  |
| Walter & Bayen (2016)                      | Non-alcohol controls | Neg, Pos, Neut | E+R | W | I | Y | N | S | 38 | -0.07 | 38 | -0.10 | 38 | -0.04 |

*Note.* Process affected: E = Encoding only; R = Retrieval only; E+R = Encoding and retrieval. Study design: W = Within participants; B = Between participants. Cue type: W = Words; I = Images. Age: Y = Young adults; O = Older adults. Focality: F = Focal cues; N = Non-focal cues. Control for arousal: A = Controlled for arousal across all cues; S = Controlled for arousal only between positive and negative cues; N = No adequate control for arousal. All effect sizes are corrected for measurement error.

Table 2. *Results of the Meta-Analyses.*

| Influence of Emotion       | Emotional Contrast | <i>k</i> | Total <i>N</i> | Effect Size | 95% CI        | Corrected Effect Size | Corrected 95% CI | <i>p</i> | <i>Q</i> | <i>Q sig.</i> | <i>I</i> <sup>2</sup> |
|----------------------------|--------------------|----------|----------------|-------------|---------------|-----------------------|------------------|----------|----------|---------------|-----------------------|
| Cue (all)                  | Neg vs. Neut       | 22       | 857            | 0.06        | (-0.07, 0.19) | 0.07                  | (-0.10, 0.24)    | .408     | 128.76   | <.001         | 0.85                  |
| Cue (all)                  | Pos vs. Neut       | 20       | 808            | 0.24**      | (0.07, 0.41)  | 0.32**                | (0.10, 0.54)     | <.01     | 114.40   | <.001         | 0.86                  |
| Cue (all)                  | Pos vs. Neg        | 24       | 938            | 0.23**      | (0.09, 0.37)  | 0.29**                | (0.11, 0.48)     | <.01     | 133.91   | <.001         | 0.83                  |
| Cue (encoding only)        | Neg vs. Neut       | 8        | 278            | -0.19       | (-0.41, 0.03) | -0.25                 | (-0.54, 0.03)    | .082     | 18.11    | .012          | 0.61                  |
| Cue (encoding only)        | Pos vs. Neut       | 8        | 278            | 0.24        | (-0.03, 0.51) | 0.34                  | (-0.02, 0.69)    | .061     | 59.92    | <.001         | 0.88                  |
| Cue (encoding only)        | Pos vs. Neg        | 8        | 278            | 0.45**      | (0.21, 0.70)  | 0.62**                | (0.30, 0.95)     | <.001    | 64.54    | <.001         | 0.89                  |
| Cue (encoding & retrieval) | Neg vs. Neut       | 10       | 355            | 0.31**      | (0.12, 0.51)  | 0.40**                | (0.14, 0.65)     | <.01     | 47.75    | <.001         | 0.86                  |
| Cue (encoding & retrieval) | Pos vs. Neut       | 9        | 331            | 0.31*       | (0.07, 0.56)  | 0.40*                 | (0.07, 0.73)     | .016     | 35.80    | <.001         | 0.87                  |
| Cue (encoding & retrieval) | Pos vs. Neg        | 10       | 371            | 0.01        | (-0.21, 0.23) | -0.04                 | (-0.32, 0.25)    | .812     | 28.25    | <.001         | 0.70                  |
| Cue (retrieval only)       | Neg vs. Neut       | 4        | 224            | -0.09       | (-0.40, 0.23) | -0.11                 | (-0.52, 0.29)    | .585     | 21.15    | <.001         | 0.86                  |
| Cue (retrieval only)       | Pos vs. Neut       | 3        | 199            | 0.01        | (-0.42, 0.44) | 0.01                  | (-0.56, 0.59)    | .968     | 13.90    | <.001         | 0.86                  |
| Cue (retrieval only)       | Pos vs. Neg        | 6        | 289            | 0.30*       | (0.02, 0.59)  | 0.39*                 | (0.02, 0.75)     | .038     | 8.28     | .142          | 0.40                  |

*Note.* *k* = number of effect sizes included in the analysis. Total *N* = number of participants included in the analysis. *Q* is a measure of heterogeneity and *I*<sup>2</sup> is a measure of inconsistency. \**p* <.05 \*\**p* <.01.