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

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Abstract

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

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

Article word count: 8,913

The term *prospective memory* is used to describe a person's ability to remember to perform a

behaviour in the future (McDaniel & Einstein, 2000). The successful application of

prospective memory involves encoding a cue to action, and later detecting this cue to retrieve

and execute the planned intention. These actions require the use of several cognitive

processes, including attention (to detect the cue) and retrospective memory (to retrieve the

intention). The prevailing view in the wider literature of emotion and cognition is that

emotion enhances both attention and memory (Brosch, Pourtois, & Sander, 2010; Hamann,

2001; N. A. Murphy & Isaacowitz, 2008; Yiend, 2010), meaning that emotional cues are

likely to improve prospective memory performance. However, the current literature is

contradictory and it is not clear when or how emotion influences prospective memory.

Providing clarity to the possible effects of emotion on prospective memory performance is

important for elucidating prospective memory processes and for informing practical

applications to improve prospective memory. The present research takes the approach of

conducting a systematic review and a series of meta-analyses to establish for the first time

what are the effects of emotion on prospective memory.

The Influence of Emotion on Cognition

The feedback theory of emotion (Baumeister, Vohs, DeWall, & Zhang, 2007) describes two

ways in which emotion influences our cognition: Through full-blown conscious moods, and

brief 'twinges' of emotional appraisal that arise automatically when a stimulus is perceived.

The latter of these two mechanisms - the brief 'affective responses' - have been shown to

influence our behaviour indirectly through higher-level cognitive processes (Baumeister et

al., 2007; Robinson, Watkins, & Harmon-Jones, 2013), such as prospective memory.

Accordingly, affective responses to stimuli used as cues to trigger prospective memory can

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 acitvating 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

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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[1]. 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.

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.

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

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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

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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_{unb} was calculated for each experiment[2]. 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[3]. 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

---

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

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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 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]

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]

Moderator Analyses

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

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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] $p = .012$)[4].

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 $d_{unb} = -1.82$ (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] $p = .052$).

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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.

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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

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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.

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.

Disclosure of Interest

698 The authors report no conflicts of interest.

702 <div align="center">**References**</div>

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

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975 **Appendix A**

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

977 Cumming (2012):

$$978 \quad d_{unb} = \left(1 - \frac{3}{4(n_1 + n_2) - 9}\right)\left(\frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{SD_1^2 + SD_2^2}{2}}}\right)$$

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

980 Cumming (2012):

$$981 \quad d_{unb} = \left(1 - \frac{3}{4(n_1 + n_2) - 9}\right)\left(\frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{(n_1 - 1)SD_1^2 + (n_2 - 1)SD_2^2}{n_1 + n_2 - 2}}}\right)$$

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

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

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

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

986   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	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)	Experiment1	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

The effect size columns are grouped under the heading: Effect size d_{unb}

Study	Subgroup	Emotion							N	ES	N	ES	N	ES
Cona et al. (2015)		Neg, Pos, Neut	E+R	W	I	Y	F	S	24	0.57	24	0.24	24	-0.43
Graf & Yu (2015)	Experiment 2	Neg, Pos, Neut	R	B	I	Y	N	N	130	-0.42	130	-0.46	130	-0.04
Henry et al. (2015)	Young adults	Neg, Pos, Neut	E	W	I	Y	N	N	42	-0.15	42	-0.15	42	0.00
	Young-old adults	Neg, Pos, Neut	E	W	I	O	N	N	38	-0.10	38	0.03	38	0.13
Henry et al. (2015)	Old-old adults	Neg, Pos, Neut	E	W	I	O	N	N	29	0.09	29	-0.06	29	-0.15
Marsh et al. (2009)	Non-anxious controls	Neg, Neut	R	W	W	Y	N	N	25	0.22				
May, Manning, Einstein, Becker & Owens (2015)	Experiment 1 (young adults)	Neg, Pos, Neut	E+R	W	W	Y	F	S	40	0.69	40	0.87	40	0.23
	Experiment 1 (older adults)	Neg, Pos, 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. (2015)	Healthy Controls	Neg, Pos, 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

Study	Group	Valence	Process	Design	Cue	Age	Focality	Control	n	ES	n	ES	n	ES
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	k	Total N	Effect Size	95% CI	Corrected Effect Size	Corrected 95% CI	p	Q	Q sig.	I^2
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^2 is a measure of inconsistency. *p <.05 **p <.01.