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

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

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

Empirical research on emotional cues and prospective memory

Despite the established benefits of emotional stimuli on attention and memory in the broader literature of emotion and cognition, direct empirical evidence for a benefit of emotional cues on prospective memory is mixed. Specifically, there is research reporting a benefit of emotional cues (Altgassen, Phillips, Henry, Rendell, & Kliegel, 2010; May et al., 2015; Rummel, Hepp, Klein, & Silberleitner, 2012); a detrimental effect of emotional cues (Ballhausen, Rendell, Henry, Joeffry, & Kliegel, 2015; Graf & Yu, 2015; Walter & Bayen, 2016); a beneficial effect, but only for one particular valence (Altgassen, Henry, Burgler, & Kliegel, 2011; Mioni et al., 2015; Rendell et al., 2011) and no difference between emotional and neutral cues (Cona, Kliegel, & Bisiacchi, 2015; Marsh et al., 2009).

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

Potential Moderators

Methodological

Differences in the methodologies used in prospective memory experiments may explain the diverse findings of studies investigating prospective memory and emotion. One such difference among experiments investigating the influence of emotion is the type of cues used (words or pictures) in the prospective memory task. Research has shown that when valence is not controlled for, prospective memory is better when pictures compared to words are used as cues (McDaniel, Robinson-Riegler, & Einstein, 1998). Relatedly, De Houwer and Hermans (1994) found that emotional pictures received preferential affective processing compared to emotional words. In their experiment, the affective categorisation of words was influenced by incongruent affective pictures, but the reverse effect was not observed. These results suggest that any potential benefit of emotional cues in prospective memory may be stronger for pictures rather than words. However, there is not yet any research that tests directly how the superior effect of pictures in prospective memory may interact with affective valence, when focusing specifically on behavioural outcomes (cf. neuroimaging research, e.g. Flaisch et al., 2015; Leclerc & Kensinger, 2011).

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

Cue Focality

Another methodological consideration that may influence the effect of emotion on prospective memory is whether the prospective memory experiment employs a focal or non-focal paradigm. Prospective memory experiments typically involve an 'ongoing task', such as a lexical decision task (e.g., May et al., 2015) in which the prospective memory cues are embedded. Whether such cues are 'focal' or 'non-focal' refers to whether the prospective memory cues are processed in a way during the ongoing task that should automatically activate the representation of the prospective memory task to be performed, or whether detection of the cues requires extra cognitive resources outside of those used in the ongoing task. The two types of task are thought to reflect the two types of cue detection behaviour specified in McDaniel and Einstein's (2000) multiprocess theory. According to multiprocess theory, focal cues are thought to use spontaneous retrieval processes to detect, and non-focal cues are thought to require conscious monitoring. As the effect of emotion on prospective memory may work at least in part through attention-based mechanisms, the focality of the cue may be an important moderating factor.

Age

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

Arousal

Variance in the extent to which prospective memory studies have controlled for the arousal level of the emotional cues may also explain discrepant findings in the literature. Arousal refers to the intensity of the emotional stimulus and the effects of this variable on cognition can be dissociated from those of the valence of the stimulus (Hamann, 2001). Several influential theories suggest that it is the arousing nature of emotional stimuli, rather than the relative valence, that underlies the beneficial effects of emotion on perception and memory (e.g. Kensinger, 2009; Mather & Sutherland, 2011, c.f. Adelman & Estes, 2013). The implications of this are that studies that have not adequately controlled for the level of arousal between emotional prospective memory cues may inadvertently be measuring the effect of arousal on prospective memory, rather than the valence of the cues as intended. The present study will code for whether studies adequately controlled for the arousal level of emotional cues in order to investigate whether the effect of arousal and valence can be dissociated.

The Present Research

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

Method

Eligibility Criteria

The inclusion criteria were: Any empirical study that had tested prospective memory performance as a dependent variable (i.e. the proportion of prospective memory cues correctly responded to) and had manipulated the affective valence of prospective memory cues. Both between-participants and within-participants experimental designs were eligible for inclusion[1]. Between-participants designs required that participants were randomly assigned to a condition, and within-participants designs (92.6% of included studies) required that the order of cue valence was randomised or counterbalanced.

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

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.

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

Information Sources

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

Literature Search

The databases listed above were searched using pre-specified key terms. In order to capture studies published in different research fields, several different terms were used to search for concepts relating to both prospective memory and emotion. The keywords relating to emotion were: *emotion, valence, affect*, positiv*, negativ*, fear, disgust,* and *anger.* The keywords relating to prospective memory were: *"prospective memory", "implementation intention*", "action plan*", "future memory"* and *"delayed intention*".* Each possible combination of emotion and prospective memory key words were used as search terms in databases with the AND operator. The ancestor and descendant approaches (DeCoster, 2009) were then employed to identify further literature that may not have been picked up by the search terms used in the database searches. Finally, all lead authors of the included papers were contacted via email to ask for any unpublished research related to the topic, an approach that yielded one additional set of data. The initial literature search returned 61 possible papers to include based on the title and abstract. The ascendancy approach returned 21 papers, and the descendancy approach returned 1 paper for a total of 74 after duplicates had been removed (see Figure 1 for PRISMA flow diagram of review).

[Figure 1 here]

Study Selection

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

Data Collection Process

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

Data Items

The following information was coded for each study by the first author: (1) participant demographics; (2) study design (within- or between-participants); (3) the valences of the emotional cues; (4) the timing of the emotional manipulation (i.e., whether the valence of the cue had been manipulated during encoding only, retrieval only, or both); (5) the format of the cues used (words or pictures); (6) the sample of participants (younger or older adults); (7) the focality of the cue in the ongoing task (focal or non-focal); and (8) whether the study adequately controlled for the arousal level of the emotional cues (yes or no).

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

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

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

Summary Measures

The effect size of d_{unb} was calculated for each experiment[2]. Separate effect sizes were calculated for each emotional valence comparison possible for each study (positive versus negative, positive versus neutral, negative versus neutral). For the positive versus neutral and negative versus neutral comparisons, effect sizes representing a benefit for valenced manipulations (e.g., a greater number of successful prospective memory task responses) were coded as positive (+ve). Effect sizes representing a detrimental effect for valenced manipulations compared to neutral were coded as negative (-ve). For the positive versus negative comparisons, effect sizes representing a benefit for positively-valenced manipulations were coded as +ve and benefits for negatively-valenced manipulations as –ve.

Effect sizes were primarily calculated using means and standard deviations reported in the papers or obtained from the authors. If this was not possible then the data were extracted

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.

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

Synthesis of Results

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

The distinct influences of valenced cues on the separate process of prospective memory discussed in the introduction were investigated with the use of a meta-ANOVA. A separate effect size for the influence of emotional cues on each process (encoding, retrieval, 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.

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

Meta-Analytic Procedure

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

Heterogeneity

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

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

Additional Analyses

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

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

Results

Study Characteristics

From the 17 articles identified from the literature search, 67 different effect sizes were extracted from 27 studies (Table 1). Eight out of 27 studies (30%) manipulated the valence of the cue during encoding only, 7/27 (26%) manipulated the valence of the cue during retrieval only, and 12/27 (44%) manipulated the valence of the cue during both encoding and retrieval. Fourteen out of 27 (52%) studies used words as cues and 13/27 (48%) used images as cues. In terms of age, studies typically sampled younger and older participants separately which meant that age was tested as a categorical rather than continuous moderator. Within these studies, 10/27 (37%) sampled older adults, and 17/27 (63%) sampled younger adults. Nine out of 27 (33%) studies utilised focal cues and 18/27 (67%) utilised non-focal cues. With regards to control for the level of arousal of prospective memory cues, only 4/27 (15%) studies controlled for arousal across all three valences (positive, negative, and neutral), and 23/27 (85%) did not. However, 17/27 (63%) did control for the level of arousal between positive and negative cues, compared to 10/27 (37%) that did not. Table 2 shows the results of the series of meta-analyses, moderator analyses, along with the number of studies (*k*) and total N for each analysis, the measure of heterogeneity (I^2) and the 95% Confidence Interval for each effect size.

[Table 1 near here]

Main Effects

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

[Table 2 near here]

Moderator Analyses

Timing of emotional manipulation

Each valence comparison for the influence of emotional cues was tested to see if the timing of the emotional manipulation, i.e., manipulating the valence during either the encoding phase only, the retrieval phase only, or during both encoding and retrieval, differentially affected prospective memory. There were significant moderating effects of the timing of the manipulation for both the negative versus neutral ($p < .01$) and positive versus negative ($p < .01$) comparisons. The moderating effect of timing of the manipulation for positive versus neutral comparisons was not significant ($p = .506$), suggesting that that the influence of positive cues is relatively more consistent, regardless of which processes are affected.

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

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.

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

Influence of age and cue type

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

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

Influence of control for arousal

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

The coding of whether studies controlled for arousal across all three types of cues was used when considering the positive versus neutral and negative versus neutral analyses, although only a small number of studies (*k* = 4) employed adequate controls. When arousal was not controlled for, negative cues produced a small non-significant benefit compared to neutral cues, (*d* = 0.13 [-0.10, 0.36], *p* = .271), however when arousal was controlled, negative cues produced a small non-significant decrease in performance compared to neutral (*d* = -0.20 [-0.69, 0.28], *p* = .410). The difference between these effect sizes was not significant. For the positive versus neutral effect size, controlling for arousal eliminated any benefit of positive cues (d = 0.01 [-0.48, 0.50], p = .976) compared to when arousal was not controlled for (d = 0.40 [0.15, 0.64], p = .001), although this difference was also non-significant.

Influence of cue focality

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

Discussion

The present research represents the first attempt to review systematically the fragmented literature on the influence of positively- or negatively-valenced cues on prospective memory performance. Three separate meta-analyses were conducted to distinguish between the different valences of the emotional influence. Overall, prospective memory performance was better when positively-valenced cues were used compared to neutral cues (d = 0.32) and negative cues (d = 0.29). In contrast, there was no overall benefit for negative over neutral cues (d = 0.07). However, the effect of emotional cues was found to alter depending on the phase of prospective memory in which the emotional manipulation was employed, i.e. during the encoding phase only, the retrieval phase only, or both the encoding and retrieval phases. During encoding, positively-valenced cues improved prospective memory compared to neutral cues, but negatively-valenced cues produced a detrimental effect on subsequent prospective memory performance. In contrast, when manipulating the valence of the cues during both encoding and retrieval, both positive cues and negative cues improved prospective memory performance in comparison to neutral cues. Furthermore, manipulating the affective valence of the cues only during the retrieval phase showed much weaker effects compared to neutral cues. The difference in the magnitude of the influences of emotional cues - especially negative cues - on the separate processes of prospective memory suggests that multiple mechanisms may underlie the influence of emotional cues on prospective memory.

Whilst the attention-grabbing nature of emotional stimuli (Frischen et al., 2008; Nummenmaa et al., 2006) has been suggested as a possible mechanism underlying the benefit of cue valence on prospective memory (May et al., 2015), the present results do not fully support this suggestion. Studies manipulating the valence of the prospective memory cues only during the retrieval phase did not demonstrate substantial benefits to prospective memory, suggesting that increased attention to prospective memory targets alone is not sufficient to improve prospective memory. The process model of prospective memory (Kliegel, Martin, McDaniel & Einstein, 2002) states that although factors relating to the prospective memory cue itself may influence prospective memory during the retrieval phase, the primary executive processes required during this phase relate to working memory and cognitive flexibility. Thus, manipulating the emotionality of the cues during retrieval alone may not have a strong enough influence to overcome other task demands that influence these executive processes. However, it should be noted that the number of studies that manipulated valence during retrieval only was very small. The analyses of positive versus neutral and negative versus neutral effects contained only 4 and 3 effect sizes respectively. With such a small number of studies, the overall effect size estimates are unlikely to be accurate, and this is reflected in the large confidence intervals. Further research in which the emotional valence of cues is manipulated only during retrieval is necessary to increase the accuracy of these estimates.

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

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

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

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

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

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

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

The effects of two other potential moderators on the influence of valenced cues on prospective memory were also tested. The first variable tested was cue type. There did not appear to be any overall effect of whether the cues used were words or images, suggesting that both have similar influences on prospective memory. However, it is unclear whether the different types of cues may produce differential effects in the separate phases of prospective memory (encoding and retrieval). Insufficient numbers of studies were available to test potential differential effects of words and pictures as a moderator in the sub-analyses, and so the possibility that pictures and words differentially affect the encoding and retrieval phases cannot be ruled out. The relationship between type of stimuli (word or picture) and the default modality of processing (perceptual or semantic) is not straightforward, and instead highly influenced by task demands (Miller, 2001). However, utilising different types of cues may be a viable way of exploring the hypotheses suggested previously regarding differences in modality of processing underlying emotional effects on prospective memory. More data are needed in order to draw conclusions about how different types of cues affect prospective memory, and also whether emotional effects can be extended to cues other than words or pictures, for example auditory or olfactory stimuli.

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

Limitations and Avenues for Future Research

The results of the present set of meta-analyses should be interpreted with several caveats in mind. First, the small number of studies in many of the sub-analyses and the range of different prospective memory tasks used in the studies are likely to have contributed to the high heterogeneity observed in each set of effect sizes. The small magnitude of these non-significant effect sizes suggest that many of the possible influences of emotional cues on prospective memory lack any clear supporting evidence, or are at least highly influenced by other moderating variables that could not be coded for.

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

Third, limitations of the methodologies employed in the studies included in the meta-analysis may represent a source of bias in the results. Overall, of the 27 studies included in the analyses, only two employed between-participant designs with randomization to conditions. The remaining studies used a counterbalanced order of emotional cues. Counterbalancing can minimise the influence of serial order carryover effects associated with repeated-measures designs, however some methods of counterbalancing do not cover all possible carryover effects (Brooks, 2012). Carryover effects may be expected in the context of presenting emotionally-valenced prospective memory cues, as affective responses to stimuli have been shown to persist after the presentation of the stimuli ends (Garrett & Maddock, 2001). Although between-participants designs also have drawbacks when used in emotion research, for example due to the influence of individual differences in emotion perception (Okon-Singer, Lichtenstein-Vidne, & Cohen, 2013); a greater balance of between-participants and within-participants designs in future research on the topic should minimise any drawbacks associated with either design.

Conclusion

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

Disclosure of Interest

The authors report no conflicts of interest.

Acknowledgements

This research was supported by the NIHR Manchester Biomedical Research Centre.

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Appendix A

Effect sizes for within-subjects studies were calculated using the following equation from Cumming (2012):

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

Effect sizes for between-subjects studies were calculated using the following equation from Cumming (2012):

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

Where n_1 is the number of participants in one of the emotional conditions, n_2 is the number of participants in the comparison condition, $\bar{X}_1$ is the mean prospective memory ability score for one of the emotional conditions, $\bar{X}_2$ is the mean prospective memory ability score for the comparison condition, and SD_1 and SD_2 are the respective standard deviations associated with the means.

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

									Effect size d_{unb}					
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

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

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.