1   Domain-specific working memory loads selectively increase negative interpertations of

2   surprised facial expressions

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11 Abstract

12 Individual differences in interpretations of emotional ambiguity are a useful tool for
13 measuring affective biases.

14 While trait-like, these biases are also susceptible to experimental manipulations. In the
15 present study, we capitalize on this malleability to expand on previous research suggesting
16 that subjective interpretations are stable independently of cognitive load.

17 We tested the effects of working memory loads containing either neutral or emotional
18 content on concurrent interpretations of surprised facial expressions.

19 Here we show that interpretations of surprise are more negative during maintenance of
20 working memory loads with emotional content compared to those with neutral content.

21 Two or three sentences explaining what the **main result** reveals in direct comparison
22 to what was thought to be the case previously, or how the main result adds to previous
23 knowledge.

24 One or two sentences to put the results into a more **general context**.

25 Two or three sentences to provide a **broader perspective**, readily comprehensible to
26 a scientist in any discipline.

27 *Keywords:* ambiguity, working memory, bias
28 Word count: X

Domain-specific working memory loads selectively increase negative interterpations of surprised facial expressions

Introduction

Facial expressions are rich with affective information, and correctly interpreting these social cues is critical for successfully navigating the social world. In fact, facial expressions are seen across cultures (**???**) and some evidence suggests expressions are innate (cite). Often, facial expressions serve as a clear social signal, but this is not always the case. While a smile from a friend likely expresses a positive affective state, other cues are not so clear. For instance, a surprised facial expression could signal either a positive (e.g., winning the lottery) or negative (e.g., a snake in the woods) affective state. In the absence of a larger context, individuals differ in their tendency to interpret surprised facial expressions as either positive or negative. Importantly, this affective bias extends beyond facial expressions, as individuals often show a similar bias to both surprised faces and ambiguous scenes (Neta, Kelley, & Whalen, 2013). This bias towards positive or negative interpretations is known as one's valence bias. Interpreting facial expressions requires both bottom-up (e.g., perceptual input) and top-down (e.g., emotion regulation strategies) processes. A growing body of work suggests that the initial interpretation of emotionally ambiguous stimuli is negative and driven by bottom-up processes, and that arriving at a positive interpretation requires additional, top-down regulatory processes. For example, participants reliably rate surprise as negative faster than positive (Neta & Tong, 2016). In fact, forcing participants to slow their responding during interpretations of ambiguous images shifts individuals' biases towards positivity (**???**). Perceptual input also contributes to valence bias. In one recent study, Neta and colleagues (**???**) showed that faster intial fixation, as well as longer overall fixation, on the mouth is related to more positive interpretations of surprised faces and that forcing gaze patterns to match those of modulated interpretations of surprised expressions. In short,

Despite the trait-like nature of this bias (Neta, Norris, & Whalen, 2009), valence bias may be shifted, at least temporarily, by a number of experimental manipulations. As

⁵⁶ mentioned above, simple manipulations like slowing response times will shift bias (**???**).
⁵⁷ Additional work has shown that increases in salivary cortisol after a stressor relate to more
⁵⁸ negative interpretations of surprised faces from baseline to post-stressor (Brown, Raio, &
⁵⁹ Neta, 2017). Similarly, participants with positive biases at baseline will interpret surprise as
⁶⁰ more negative under threat of shock (**???**), suggesting that taxing cognitive resources, in this
⁶¹ case attention, reduces the ability of individuals to interpret surprised faces as positive.

⁶²   Understanding the influences on decision making under ambiguous contexts sheds light
⁶³ on the mechanisms responsible for these individual differences. in the present study we aim
⁶⁴ to better understand how concurrent task demands (i.e., working memory load) may
⁶⁵ influence the cognitive resources used to arrive at more top-down driven interpetations of
⁶⁶ ambiguity, specifically in an emotional context.

⁶⁷   Recent work suggests that ambiguity resolution in this context requires more cognitive
⁶⁸ resources/processing compared to clearly valenced faces (Mattek, Whalen, Berkowitz, &
⁶⁹ Freeman, 2016; Neta & Tong, 2016). The valence bias is trait-like (Neta et al., 2009) and
⁷⁰ generalizes to non-face stimuli (Neta et al., 2013); however, it is also malleable and may
⁷¹ differ depending on experimental manipulations, including stress inductions or instructions
⁷² to slow responding (Brown et al., 2017; Neta & Tong, 2016). Importantly, the valence bias
⁷³ relates to behavior outside of the laboratory; specifically, it is known to relate to depressive
⁷⁴ symptomology (**???**), at least in children. Chronic negativity biases are common in
⁷⁵ numerous psychopathologies, including depression and anxiety (**???**).

⁷⁶   Distractors and task irrelevant stimuli often have detrimental effects on performance in
⁷⁷ a variety of tasks [; cite, cite]. Further, domain-specific interference may further exacerbate
⁷⁸ these effects compared to domain-general stimuli (Gruber, 2001). This effect holds up in the
⁷⁹ emotional domain; for example, the Stroop task (Stroop, 1935) has been modified by some
⁸⁰ researchers to include emotional stimuli (Whalen, Bush, Shin, & Rauch, 2006) which has
⁸¹ pronounced effects when the emotional words are population specific (e.g., trauma words in a

PTSD sample). Indeed, neuroimaging work supports the idea that separate systems handle attentional biasing for domain-specific (emotional vs. non-emotional) task relevancy (Egner, Etkin, Gale, & Hirsch, 2008). Given that a regulatory mechanism likely contributes to positive interpretations of surprised facial expressions, domain-specific interference may cause more negative interpretations of ambiguity compared to a more domain-general interference. Mattek and colleagues (2016) recently showed that different levels of cognitive load (i.e., holding either a single or seven digit number in working memory) does not affect subjective interpretations of surprised facial expressions, but that high cognitive loads do mitigate mouse trajectories. While the authors interpret this as a distinction between trait-like biases and dynamic cognitive-motor processes, there may be more domain-specific processes (e.g., emotional components) that span across these two measures of valence bias. Given the task irrelevance of the numeric distractors in Mattek and colleagues' (2016) work, it follows that the resources required for interpreting ambiguity as positive (Neta et al., 2009) may not have been recruited for working memory maintenance, and thus no change in subjective ratings was observed. In the present study, we aim to test the effects of low and high working memory loads in both emotional and neutral domains. We expect that trials in which participants are maintaining an emotional working memory load will be more negative than neutral trials. Further, we predict that higher working memory laod trials, specifically in the emotional domain, will result in even more exaggerated negative interpretations.

Methods

Participants

Fifty-eight subjects were recruited from the undergraduate research pool at the University of Nebraska-Lincoln. The data from eight subjects were excluded due to technical difficulties resulting from an error in one of the experiment scripts. This left 50 individuals in the final sample for analysis. The mean age of the remaining sample was 18.82 (1.19), a majority of participants were female (82.00%), and all were white/caucasian without

108 hispanic/Latinx ethnicity. All subjects provided written informed consent in accordance with

109 the Declaration of Helsinki and all procedures were approved by the University of

110 Nebraska-Lincoln Institutional Review Board (Approval #20141014670EP). Each participant

111 received course credit for completing the study.

Material

113   **Stimuli.**   The stimuli included faces from the NimStim (Tottenham et al., 2009) and

114 Karolinska Directed Emotional Faces (Lundqvist, Flykt, & Öhman, 1998) stimuli sets, as in

115 previous work (**???**; Brown et al., 2017). The faces consisted of 34 unique identities

116 including 11 angry, 12 happy, and 24 surprised expressions organized pseudorandomly. The

117 scene stimuli were selected from the International Affective Picture System (Lang, Bradley,

118 & Cuthbert, 2008). A total of 288 scenes (72 positive, 72 negative, and 144 neutral) were

119 selected for the image matrices. The positive and negative images did not differ on arousal

120 ($Z = -0.23$, $p = 0.82$). The scenes were organized into low (two images) and high (six images)

121 cognitive load of either neutral or emotional (equal number of positive and negative) images

122 (Figure 1).

Procedure

124   After arriving at the lab, participants provided informed consent prior to completing

125 the task. Participants were randomly assigned to complete one of the task versions, which

126 included 144[1] trials split between working memory probe and face rating trials. The task

127 was completed using MouseTracker software (Freeman & Ambady, 2010) and participants

128 responded with a mouse to indicate the appropriate response for the face ratings (i.e.,

129 "POSITIVE" or "NEGATIVE") and the memory probe (i.e., "YES" or "NO"). The trials

130 were self-initiated; that is, the participant clicked a "start" button at the bottom of the

131 screen at the beginning of each trial at their own pace. After initiating the trial, a fixation

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[1] Some versions of the task only included 142 trials due to a programming error.

132 cross appeared (1000 ms), then participants viewed an image matrix, which the participants

133 were instructed to remember for the duration of the trial. The image matrix was presented

134 for 4000 ms and the image was either a low or high load matrix consisting of either

135 emotional (equal positive and negative) or neutral images. After the image matrix a happy,

136 angry, or surprised face appeared for 1000 ms and the participants rated the face by clicking

137 on either the positive or negative response option. After the face rating, a single image probe

138 appeared (5000 ms), and participants indicated whether or not the image probe was present

139 in the previous image matrix.

Data analysis

141   We used R (Version 3.6.0; **???**) and the R-packages * }dplyr* [@ }R-dplyr],

142 *BayesFactor* (Version 0.9.12.4.2; **???**), *broom* (Version 0.5.2; **???**), *circlize* (Version 0.4.6;

143 **???**), *coda* (Version 0.19.2; **???**), *cstab* (Version 0.2.2; **???**), *diptest* (Version 0.75.7; **???**),

144 *dotCall64* (Version 1.0.0; **???**; **???**), *fastcluster* (Version 1.1.25; **???**), *fields* (Version 9.8.3;

145 **???**), *forcats* (Version 0.4.0; **???**), *foreach* (Version 1.4.7; **???**), *ggplot2* (Version 3.1.1; **???**),

146 *jpeg* (Version 0.1.8; **???**), *lattice* (Version 0.20.38; **???**), *magrittr* (Version 1.5; **???**), *maps*

147 (Version 3.3.0; **???**), *Matrix* (Version 1.2.17; **???**), *mousetrap* (Version 3.1.2; **???**), *openxlsx*

148 (Version 4.1.0; **???**), *papaja* (Version 0.1.0.9842; **???**), *plyr* (Version 1.8.4; @ }R-dplyr; **???**),

149 *pracma* (Version 2.2.5; **???**), *processx* (Version 3.3.1; **???**), *psych* (Version 1.8.12; **???**), *purrr*

150 (Version 0.3.2; **???**), *RColorBrewer* (Version 1.1.2; **???**), *Rcpp* (Version 1.0.1; **???**; **???**),

151 *readbulk* (Version 1.1.2; **???**), *readr* (Version 1.3.1; **???**), *readxl* (Version 1.3.1; **???**), *Rmisc*

152 (Version 1.5; **???**), *scales* (Version 1.0.0; **???**), *spam* (Version 2.2.2; **???**; **???**; **???**), *stringr*

153 (Version 1.4.0; **???**), *tibble* (Version 2.1.3; **???**), *tidyr* (Version 0.8.3.9000; **???**), *tidyverse*

154 (Version 1.2.1; **???**), and *yarrr* (Version 0.1.5; **???**) for all our analyses. Data preprocessing

155 was completed in R using the mousetrap package (**???**). First, percent negative ratings were

156 calculated for happy, angry, and surprised faces across all trial types, as well as a percent

157 correct score for the memory probe trials. After, trials were screened for RT outliers. Any

158 trials that were greater than three standard deviations from the mean were removed from

159 the analyses. Additionally, we removed the preceding face rating trial for any incorrect

160 memory probe trials, as these trials can be considered a manipulation failure.

161   Prior to completing the analyses, all data were assessed for normality using

162 Shapiro-Wilks tests. We tested for differences in valence bias among the different working

163 memory load conditions. Friedman's test was used to assess overall differences and pairwise

164 comparisons were completed using Wilcoxon signed rank tests using Bonferroni correction.

165 Next, we tested for differences among maximum deviations in each working memory load

166 condition using a load (low, high) X domain (emotional, neutral) repeated-measures ANOVA.

167   **Results**

168 **Subjective ratings**

169   Distributions of ratings were first tested for normality using Shapiro-Wilk's test. The

170 results of all four tests were highly significant (p's < .001), so non-parametric tests were used

171 for data analysis. Friedman's test results showed significantly different rank-order

172 distributions across the conditions $\chi^2(3.00) = 27.79$, p < .001. Follow up Wilcoxon signed

173 rank tests revealed that surprise is rated as more negative when holding emotional content in

174 working memory compared to neutral content, and this was true for both low and high loads.

175 Low emotional load ratings were significantly more negative than low, Z = 3.27, p = .001,

176 neutral and high, Z = 3.67, p < .001, neutral loads. The same was true for high emotional

177 load ratings and low, Z = 4.55, p < .001, and high, Z = 3.81, p < .001, neutral loads.

178 However, there was no effect of load. That is, the comparisons between low and high load

179 ratings for both emotional, Z = -1.35, p = .176, and neutral, Z = -0.06, p = .954, load

180 ratings were not significantly different.[2]

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[2] These results are qualitatively the same when analyzing these data with a repeated measures ANOVA.

181
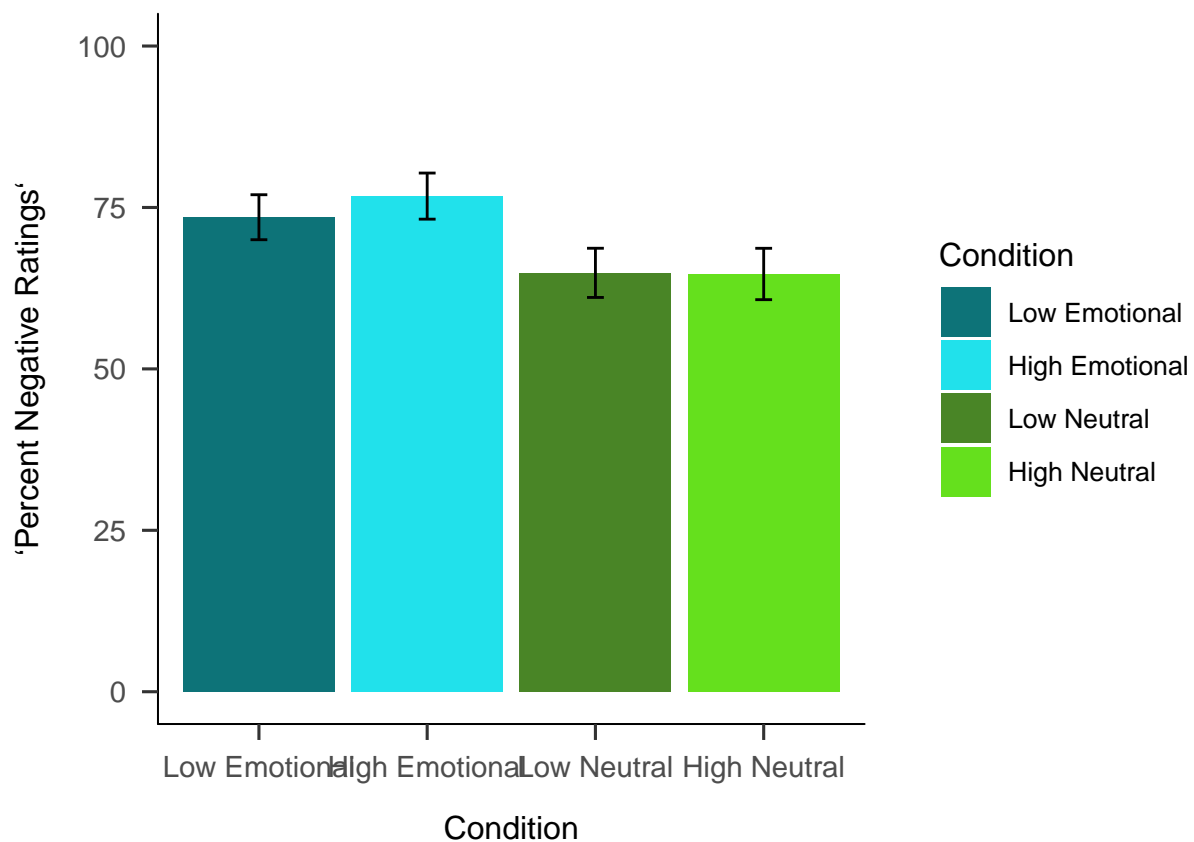
Next, we assessed differences in maximum absolute deviation (MD) across the working memory trial conditions. While one of the conditions, low emotional MD, was not normally distributed (p = .024), all other conditions were normally distributed and repeated-measures ANOVA was used to analyze the MDs across conditions. There was a significant effect of load, $F(1.00, 196.00) = 5.51$, p = .020, such that MDs under high load were larger than trials with low load. There was no significant effect of domain on MDs, $F(1.00\ 196.00) = 0.01$, p = .912, nor an interaction of load by domain, $F(1.00\ 196.00) = 0.00$, p = .960.

189

Discussion

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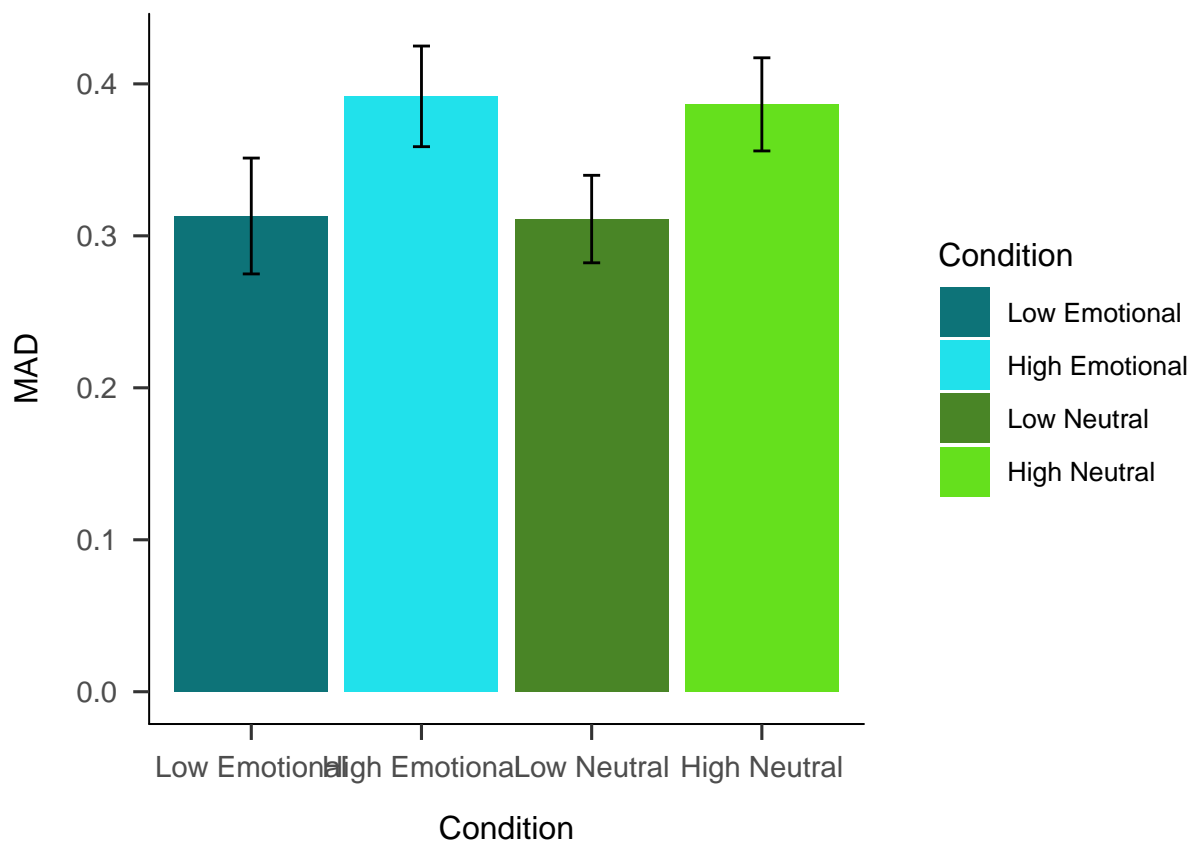
191   The effect of high vs. low load is still not apparent in these data, just like Mattek et

192   al. 2016. An alternative explanation is that the high load manipulation is not sufficiently

193   difficult to recruit the targeted cognitive resources; however, future work will be needed to

194   better test this alternative.

195   Previous work has shown that more positive interpretations of surprised faces are

196   related to slower RTs. Our working hypothesis suggests that this delayed reaction is a result

197   of deliberation and slower, top-down cognitive processing. It is interesting to note that, at

198   least in these data, there is no such difference observed between the neutral and emotional

199   WM trials, *even though* the emotional WM trials are overall more negative. Future work

200   should tease apart why this may be. For instance, . . .

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