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

2 surprised facial expressions

3 Nicholas R. Harp[1] & Maital Neta[1]

4 [1] University of Nebraska-Lincoln

5 Author Note

6 Nicholas R. Harp, Department of Psychology, Center for Brain, Biology, and Behavior,

7 University of Nebraska-Lincoln Maital Neta, Department of Psychology, Center for Brain,

8 Biology, and Behavior, University of Nebraska-Lincoln

9 Correspondence concerning this article should be addressed to Nicholas R. Harp,

10 Postal address. E-mail: nharp@huskers.unl.edu

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

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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 mean age of the sample was 18.82 (1.19), a majority of participants were female (82.00%). All subjects provided written informed consent in accordance with the Declaration of Helsinki and all procedures were approved by the local Institutional Review Board (Approval #20141014670EP). All participants received course

108 credit for completing the study. The data from eight subjects were excluded due to technical

109 difficulties or an error in the experiment script. This left 50 individuals in the final sample.

Material

111 **Stimuli.**   The stimuli included faces taken from the NimStim (Tottenham et al.,

112 2009) and Karolinska Directed Emotional Faces (Lundqvist, Flykt, & Öhman, 1998) stimuli

113 sets. The faces consisted of 34 unique identities including 11 angry, 12 happy, and 24

114 surprised expressions organized pseudorandomly. The scenes were taken from the

115 International Affective Picture System (Lang, Bradley, & Cuthbert, 2008). A total of 288

116 scenes (72 positive, 72 negative, and 144 neutral) were selected for the image matrices. The

117 positive and negative images did not differ on arousal (Z = -0.23, p = 0.82). The scenes were

118 organized into low (two images) and high (six images) cognitive load of either neutral or

119 emotional (equal number of positive and negative) images (Figure 1).

120 **Software.**   The task was completed in MouseTracker (Freeman & Ambady, 2010) and

121 participants used a mouse to click the appropriate response for the face ratings (i.e.,

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

Procedure

124 Participants were randomly assigned to complete one of the task versions. The tasks

125 included 144[1] trials split between working memory probe and face rating trials. On each

126 trial, participants first viewed an image matrix of either neutral or emotional images, which

127 the participants were instructed to remember for the duration of the trial. The image matrix

128 was presented for four seconds and the images were swapped from low and high load

129 matrices across versions of the task. After the image matrix a happy, angry, or surprised face

130 appeared for one second and the participants rated the face by clicking on either the positive

131 or negative response option. After the face rating, a single image probe appeared, and

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

132 participants indicated whether or not the image probe was present in the previous image

133 matrix.

Data analysis

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

156 Shapiro-Wilks test. Data that met the normality assumption were submitted to repeated

157 measures ANOVA, while data that failed to meet this assumption was analyzed using

non-parametric tests. We tested for differences in valence bias among the different working

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

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

The same analysis strategy was also used to assess differences in reaction times, collapsed

across both positive and negative interpretations of surprised facial expressions. Finally, we

checked for differences between reaction times for both positive and negative ratings of

surprise in each working memory load condition. Due to a large amount of missing data

(almost 50% of the subjects), as a result of some subjects only choosing the positive or

negative response option in a given working memory load condition, we were unable to

analyze these data with Friedman's test. Thus, we conducted a series of Wilcoxon signed

rank tests for each of the four conditions with Bonferroni correction.

Results

Subjective ratings

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

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

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

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

revealed that surprise is rated as more negative when holding emotional content in working

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

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

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

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

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

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

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.

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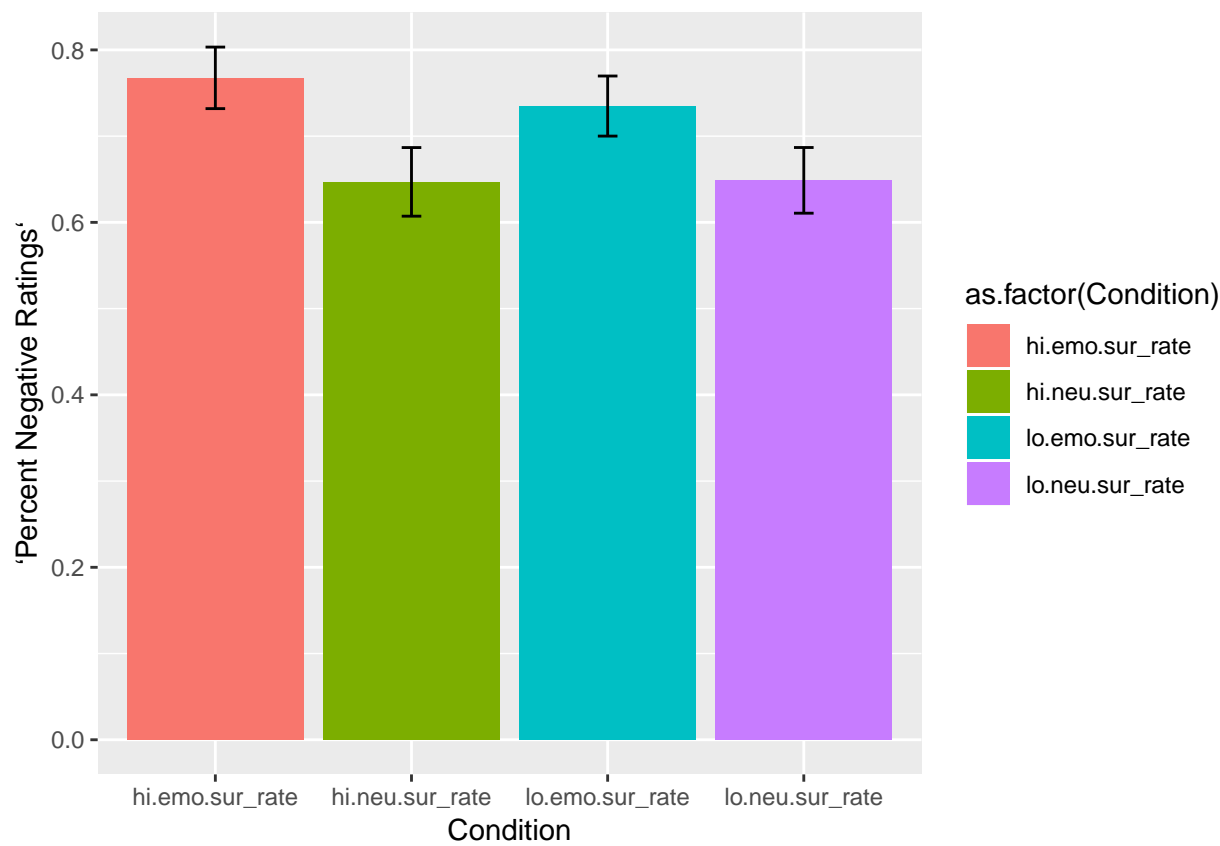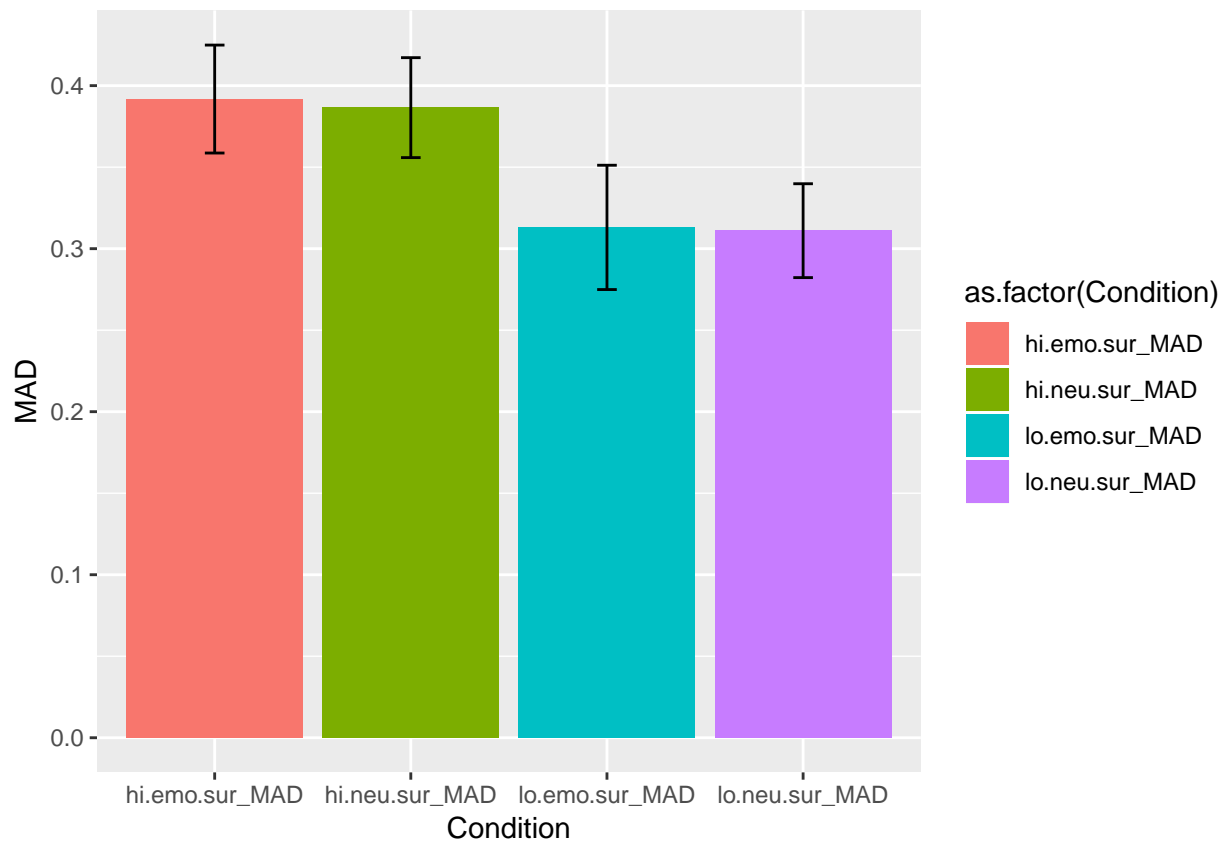
185 Finally, we assessed differences in maximum absolute deviation (MAD) across the WM

186 trial conditions. While one of the conditions, low emotional MDs, was not normally

187 distributed (p = .024), all other conditions were normally distributed and repeated-measures

188 ANOVA was used to analyze the MDs across conditions. There was a significant effect of

189 load, $F(1.00,196.00) = 5.51$, p = .020, such that MDs under high load were larger than trials

190 with low load. There was no significant effect of domain on MDs, $F(1.00\ 196.00) = 0.01$, p =

191 .912, nor an interaction of load by domain, $F(1.00\ 196.00) = 0.00$, p = .960.

Discussion

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

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

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

196 better test this alternative.

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

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

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

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

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

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

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