- Domain-specific working memory loads selectively increase negative interpertations of surprised facial expressions
- Nicholas R. Harp<sup>1</sup> & Maital Neta<sup>1</sup>
- <sup>1</sup> University of Nebraska-Lincoln

Author Note

5

- Nicholas R. Harp, Department of Psychology, Center for Brain, Biology, and Behavior,
- <sup>7</sup> University of Nebraska-Lincoln Maital Neta, Department of Psychology, Center for Brain,
- 8 Biology, and Behavior, University of Nebraska-Lincoln
- Correspondence concerning this article should be addressed to Nicholas R. Harp,
- Postal address. E-mail: nharp@huskers.unl.edu

DOMAIN-SPECIFIC WORKING MEMORY AND SURPRISED EXPRESSIONS

2

Abstract

Individual differences in interpretations of emotional ambiguity are a useful tool for 12

measuring affective biases.

11

While trait-like, these biases are also susceptible to experimental manipulations. In the 14

present study, we capitalize on this malleability to expand on previous research suggesting 15

that subjective interpretations are stable independently of cognitive load. 16

We tested the effects of working memory loads containing either neutral or emotional 17

content on concurrent interpretations of surprised facial expressions. 18

Here we show that interpretations of surprise are more negative during maintenance of 19

working memory loads with emotional content compared to those with neutral content. 20

Two or three sentences explaining what the main result reveals in direct comparison 21

to what was thought to be the case previously, or how the main result adds to previous 22

knowledge. 23

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

Two or three sentences to provide a **broader perspective**, readily comprehensible to 25

a scientist in any discipline. 26

27

Keywords: ambiguity, working memory, bias

Word count: X 28

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

Introduction

Facial expressions are rich with affective information, and correctly interpreting these 32 social cues is critical for successfully navigating the social world. In fact, facial expressions 33 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 35 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 37 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 48 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 51 the mouth is related to more positive interpretations of surprised faces and that forcing gaze 52 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 54 may be shifted, at least temporarily, by a number of experimental manipulations. As

- mentioned above, simple manipulations like slowing response times will shift bias (???).

  Additional work has shown that increases in salivary cortisol after a stressor relate to more negative interpretations of surprised faces from baseline to post-stressor (Brown, Raio, & Neta, 2017). Similarly, participants with positive biases at baseline will interpret surprise as more negative under threat of shock (???), suggesting that taxing cognitive resources, in this case attention, reduces the ability of individuals to interpret surprised faces as positive.
- Understanding the influences on decision making under ambiguous contexts sheds light 62 on the mechanisms responsible for these individual differences. in the present study we aim 63 to better understand how concurrent task demands (i.e., working memory load) may influence the cognitive resources used to arrive at more top-down driven interpetations of ambiguity, specifically in an emotional context. Recent work suggests that ambiguity resolution in this context requires more cognitive 67 resources/processing compared to clearly valenced faces (Mattek, Whalen, Berkowitz, & Freeman, 2016; Neta & Tong, 2016). The valence bias is trait-like (Neta et al., 2009) and generalizes to non-face stimuli (Neta et al., 2013); however, it is also malleable and may differ depending on experimental manipulations, including stress inductions or instructions to slow responding (Brown et al., 2017; Neta & Tong, 2016). Importantly, the valence bias relates to behavior outside of the laboratory; specifically, it is known to relate to depressive symptomology (???), at least in children. Chronic negativity biases are common in numerous psychopathologies, including depression and anxiety (???). 75
- Distractors and task irrelevant stimuli often have detrimental effects on performance in a variety of tasks [; cite, cite]. Further, domain-specific interference may further exacerbate these effects compared to domain-general stimuli (Gruber, 2001). This effect holds up in the emotional domain; for example, the Stroop task (Stroop, 1935) has been modified by some researchers to include emotional stimuli (Whalen, Bush, Shin, & Rauch, 2006) which has 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 91 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. 100

101 Methods

#### 102 Participants

58 subjects were recruited from the University of Nebraska-Lincoln. 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). The data from eight subjects were excluded due to technical difficulties
or an error in the experiment script. This left 50 individuals in the final sample.

#### 108 Material

The stimuli included faces taken from the NimStim (Tottenham et al., 109 2009) and Karolinska Directed Emotional Faces (Lundqvist, Flykt, & Öhman, 1998) stimuli 110 sets. The faces consisted of 34 unique identities including 11 angry, 12 happy, and 24 111 surprised expressions organized pseudorandomly. The scenes were taken from the 112 International Affective Picture System (Lang, Bradley, & Cuthbert, 2008). A total of 288 113 scenes (72 positive, 72 negative, and 144 neutral) were selected for the image matrices. The 114 positive and negative images did not differ on arousal (Z = -0.23, p = 0.82). The scenes were 115 organized into low (two images) and high (six images) cognitive load of either neutral or 116 emotional (equal number of positive and negative) images (Figure 1). 117 The task was completed in MouseTracker (Freeman & Ambady, 2010) and 118 participants used a mouse to click the appropriate response for the face ratings (i.e., 119 "POSITIVE" or "NEGATIVE") and the memory probe (i.e., "YES" or "NO"). 120

## 121 Procedure

Participants were randomly assigned to complete one of the task versions. The tasks 122 included  $144^1$  trials split between working memory probe and face rating trials. On each 123 trial, participants first viewed an image matrix of either neutral or emotional images, which 124 the participants were instructed to remember for the duration of the trial. The image matrix 125 was presented for four seconds and the images were swapped from low and high load 126 matrices across versions of the task. After the image matrix a happy, angry, or surprised face 127 appeared for one second and the participants rated the face by clicking on either the positive 128 or negative response option. After the face rating, a single image probe appeared, and 129 participants indicated whether or not the image probe was present in the previous image 130 matrix. 131

<sup>&</sup>lt;sup>1</sup> Some versions of the task only included 142 trials due to a programming error.

### 132 Data analysis

We used R (Version 3.6.0; ???) and the R-packages \* }dplyr\* [@ }R-dplyr], broom 133 (Version 0.5.2; ???), forcats (Version 0.4.0; ???), ggplot2 (Version 3.1.1; ???), lattice 134 (Version 0.20.38; ???), openxlsx (Version 4.1.0; ???), papaja (Version 0.1.0.9842; ???), plyr 135 (Version 1.8.4; @ R-dplyr; ???), purrr (Version 0.3.2; ???), readr (Version 1.3.1; ???), 136 readxl (Version 1.3.1; ???), Rmisc (Version 1.5; ???), stringr (Version 1.4.0; ???), tibble 137 (Version 2.1.3; ???), tidyr (Version 0.8.3.9000; ???), and tidyverse (Version 1.2.1; ???) for 138 all our analyses. Data preprocessing was completed in R using the mousetrap package (???). 139 First, percent negative ratings were calculated for happy, angry, and surprised faces across 140 all trial types, as well as a percent correct score for the memory probe trials. After, trials 141 were screened for RT outliers. Any trials that were greater than three standard deviations 142 from the mean were removed from the analyses. Additionally, we removed the preceding face 143 rating trial for any incorrect memory probe trials, as these trials can be considered a 144 manipulation failure. 145

Prior to completing the analyses, the data were assessed for normality using the 146 Shapiro-Wilks test. Data that met the normality assumption were submitted to repeated 147 measures ANOVA, while data that failed to meet this assumption was analyzed using 148 non-parametric tests. We tested for differences in valence bias among the different working 149 memory load conditions. Friedman's test was used to assess overall differences and pairwise 150 comparisons were completed using Wilcoxon signed rank tests using Bonferroni correction. 151 The same analysis strategy was also used to assess differences in reaction times, collapsed 152 across both positive and negative interpretations of surprised facial expressions. Finally, we 153 checked for differences between reaction times for both positive and negative ratings of 154 surprise in each working memory load condition. Due to a large amount of missing data 155 (almost 50% of the subjects), as a result of some subjects only choosing the positive or 156 negative response option in a given working memory load condition, we were unable to 157

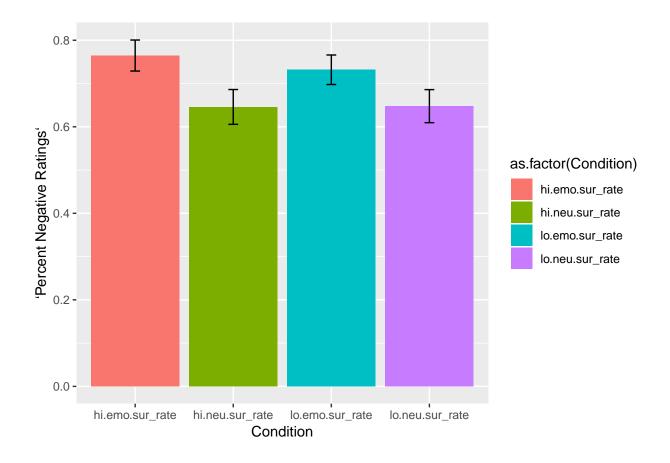
analyze these data with Friedman's test. Thus, we conducted a series of Wilcoxon signed rank tests for each of the four conditions with Bonferroni correction.

Results

# 61 Subjective ratings

Distributions of ratings were first tested for normality using Shapiro-Wilk's test. The 162 results of all four tests were highly significant (p's < .001), so non-parametric tests were used 163 for data analysis. Friedman's test results showed significantly different distributions across 164 the conditions  $\chi^2(3.00) = 27.41$ , p < .001. Follow up Wilcoxon signed rank tests revealed 165 that surprise is rated as more negative when holding emotional content in working memory 166 compared to neutral content. Low emotional load ratings were significantly more negative 167 than low, Z = 3.31, p = .001, neutral and high, Z = 3.62, p < .001, neutral loads. The same 168 was true for high emotional load ratings and low, Z = 4.52, p < .001, and high, Z = 3.72, p 169 < .001, neutral loads. However, there was no discernable effect of load. That is, the 170 comparisons between low and high load ratings for both emotional, Z = -1.10, p = .273, and 171 neutral, Z = -0.03, p = .975, load ratings were not significantly different.  $^2$ 172

<sup>&</sup>lt;sup>2</sup> These results are qualitatively the same when analyzing these data with a repeated measures ANOVA.

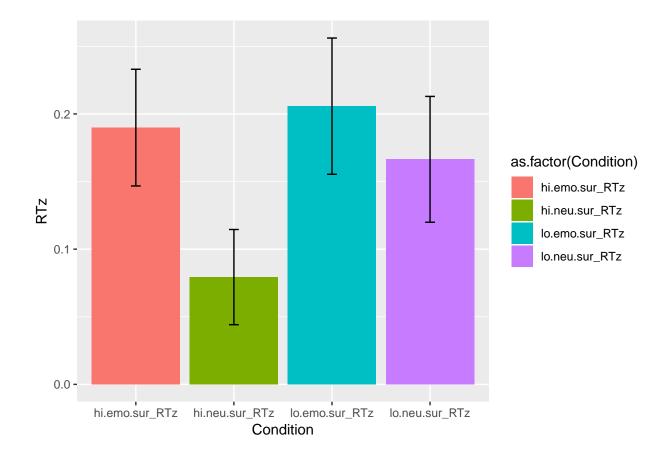


### <sup>74</sup> Reaction times

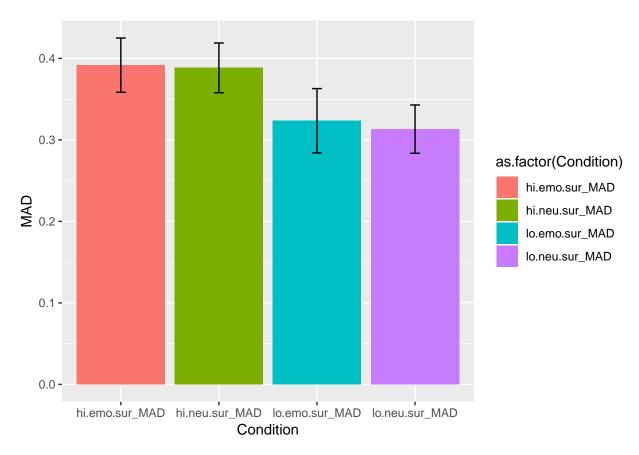
173

To assess for normality, the data were first tested with Shapiro-Wilk's test. Two 175 conditions did not appear to be sampled from normal distributions, so non-parametric tests 176 were used. Overall, there was a trending difference across the four conditions,  $\chi^2(3.00) =$ 177 7.15, p.067. Wilcoxon signed rank tests were used to assess post-hoc comparisons and 178 Bonferroni corrected p-value = 0.01. While none of the post-hoc comparisons reached the 179 adjusted significance level, there was a trending difference between emotional and neutral 180 RTs in the high load condition, Z = 2.51, p = .012, such that high emotional WM loads had 181 slower RTs. Two other comparisons were trending for traditional levels of significance. Low 182 emotional WM loads tended to take marginally longer than high neutral WM loads, Z = 183 1.96, p = .050, and low neutral WM loads took marginally longer than high neutral WM 184 laods, Z = -1.75, p = 0.08. All other comparisons were not significant. 185

186



Next, we tested for reaciton time differences between positive and negative interpretations of surprised facial expressions within each working memory load condition. Given the non-normality of these data, we used paired-sample Wilcoxon signed rank tests for assessing differences between positive and negative ratings of surprise RTs. This difference was significant *only* for the low emotional load trials, with surprise rated as positive taking significantly longer than surprise rated as negative (.009). All other comparisons were not significant (p's > .200). Further, this effect survived Bonferroni correction (p = .012).



Finally, we assessed differences in maximum absolute deviation (MAD) across the WM trial conditions.

197 Discussion

The effect of high vs. low load is still not apparent in these data, just like Mattek et al. 2016. An alternative explanation is that the high load manipulation is not sufficiently difficult to recruit the targeted cognitive resources; however, future work will be needed to better test this alternative.

Previous work has shown that more positive interpretations of surprised faces are related to slower RTs. Our working hypothesis suggests that this delayed reaction is a result of deliberation and slower, top-down cognitive processing. It is interesting to note that, at least in these data, there is no such difference observed between the neutral and emotional WM trials, even though the emotional WM trials are overall more negative. Future work

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

208 References

- Brown, C. C., Raio, C. M., & Neta, M. (2017). Cortisol responses enhance negative valence
  perception for ambiguous facial expressions. *Scientific Reports*, 7(1), 15107.
  doi:10.1038/s41598-017-14846-3
- Egner, T., Etkin, A., Gale, S., & Hirsch, J. (2008). Dissociable neural systems resolve

  conflict from emotional versus nonemotional distracters. *Cerebral Cortex (New York,*N.Y.: 1991), 18(6), 1475–1484. doi:10.1093/cercor/bhm179
- Freeman, J. B., & Ambady, N. (2010). MouseTracker: Software for studying real-time
  mental processing using a computer mouse-tracking method. Behavior Research

  Methods, 42(1), 226–241. doi:10.3758/BRM.42.1.226
- Gruber, O. (2001). Effects of domain-specific interference on brain activation associated with verbal working memory task performance. Cerebral Cortex (New York, N.Y.: 1991), 11(11), 1047–1055. doi:10.1093/cercor/11.11.1047
- Lang, P., Bradley, M. M., & Cuthbert, B. N. (2008). International affective picture system
  (IAPS): Affective ratings of pictures and instruction manual., Technical Report A–8.
  University of Florida, Gainesville, FL.
- Lundqvist, D., Flykt, A., & Öhman, A. (1998). The karolinska directed emotional
   faces—KDEF (CD ROM)., Stockholm: Karolinska Institute, Department of Clinical
   Neuroscience, PsychologySection.
- Mattek, A. M., Whalen, P. J., Berkowitz, J. L., & Freeman, J. B. (2016). Differential effects
  of cognitive load on subjective versus motor responses to ambiguously valenced facial
  expressions. *Emotion*, 16(6), 929–936. doi:10.1037/emo0000148
- Neta, M., Kelley, W. M., & Whalen, P. J. (2013). Neural responses to ambiguity involve

- domain-general and domain-specific emotion processing systems. Journal of Cognitive

  Neuroscience, 25(4), 547–557. doi:10.1162/jocn\_a\_00363
- Neta, M., Norris, C. J., & Whalen, P. J. (2009). Corrugator muscle responses are associated with individual differences in positivity-negativity bias. *Emotion (Washington, D.C.)*, 9(5), 640–648. doi:10.1037/a0016819
- Neta, M., & Tong, T. T. (2016). Don't like what you see? Give it time: Longer reaction
  times associated with increased positive affect. *Emotion (Washington, D.C.)*, 16(5),
  730–739. doi:10.1037/emo0000181
- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18(6), 643–662. doi:10.1037/h0054651
- Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., ...

  Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained
  research participants. *Psychiatry Research*, 168(3), 242–249.

  doi:10.1016/j.psychres.2008.05.006
- Whalen, P. J., Bush, G., Shin, L. M., & Rauch, S. L. (2006). The emotional counting stroop:

  A task for assessing emotional interference during brain imaging. *Nature Protocols*,

  1(1), 293–296. doi:10.1038/nprot.2006.45