

Northumbria Research Link

Citation: Rajsic, Jason, Perera, Harendri and Pratt, Jay (2017) Learned value and object perception: Accelerated perception or biased decisions? *Attention, Perception, & Psychophysics*, 79 (2). pp. 603-613. ISSN 1943-3921

Published by: Springer

URL: <http://dx.doi.org/10.3758/s13414-016-1242-0> <<http://dx.doi.org/10.3758/s13414-016-1242-0>>

This version was downloaded from Northumbria Research Link: <http://nrl.northumbria.ac.uk/41669/>

Northumbria University has developed Northumbria Research Link (NRL) to enable users to access the University's research output. Copyright © and moral rights for items on NRL are retained by the individual author(s) and/or other copyright owners. Single copies of full items can be reproduced, displayed or performed, and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided the authors, title and full bibliographic details are given, as well as a hyperlink and/or URL to the original metadata page. The content must not be changed in any way. Full items must not be sold commercially in any format or medium without formal permission of the copyright holder. The full policy is available online: <http://nrl.northumbria.ac.uk/policies.html>

This document may differ from the final, published version of the research and has been made available online in accordance with publisher policies. To read and/or cite from the published version of the research, please visit the publisher's website (a subscription may be required.)



Northumbria
University
NEWCASTLE



UniversityLibrary

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31

Learned value and object perception: Accelerated perception or biased decisions?

Jason Rajsic, Harendri Perera, Jay Pratt

Department of Psychology, University of Toronto

The final publication is available at Springer via <http://rdcu.be/m43v>

Please address correspondence to:

Jason Rajsic

Department of Psychology, University of Toronto

100 St. George St.

Toronto, ON

M5S3G3

416-978-6587

jason.rajsic@mail.utoronto.ca

This work was supported by the Natural Science and Engineering Resource Council of Canada

under Grant 194537

32 Abstract

33 Learned value is known to bias visual search towards valued stimuli. However, some
34 uncertainty exists regarding the stage of visual processing that is modulated by learned value.
35 Here, we directly tested the effect of learned value on pre-attentive processing using temporal
36 order judgments. Across four experiments, we imbued some stimuli with high value and some
37 with low value using a non-monetary reward task. In Experiment 1, we replicated the value-
38 driven distraction effect, validating our non-monetary reward task. Experiment 2 showed that
39 high-value stimuli, but not low-value stimuli, exhibit a prior entry effect. Experiment 3, which
40 reversed the temporal order judgment task (i.e., reporting which stimulus came second) showed
41 no priority entry effect, indicating that while a response bias may be present for high-value
42 stimuli, they are still reported as appearing earlier. However, Experiment 4, using a simultaneity
43 judgment task, showed no shift in temporal perception. Overall, our results support the
44 conclusion that learned value biases perceptual decisions about valued stimuli without speeding
45 pre-attentive stimulus processing.

46 At any given moment, we can only attend to a small subset of the total amount of
47 information in the visual environment. During each moment, there are a number of cognitive
48 processes that collectively determine what information will be attended and what information
49 will fall out of further processing. For the most part, different states of attention have been
50 considered to be due to either bottom-up processes – driven by causes external to the individual –
51 or top-down processes – driven by the goals of the observer. However, recent research has
52 highlighted the contribution of sources of selection that are internal to the observer, yet not
53 determined by his or her current goals (Awh, Belopolsky, & Theeuwes, 2012). The learned value
54 of stimuli is one such source of attentional bias (e.g., Anderson, Laurent, & Yantis, 2011a).
55 These value-driven attention biases can occur even when the value-laden features of stimuli are
56 task-irrelevant (e.g., Anderson et al., 2011a; Raymond and O’Brien, 2009). Although reliably
57 observed in laboratory experiments, the particular stage, or stages, of perceptual processing
58 affected by learned value is not yet understood. In this paper, we assess the ability of learned
59 value to affect visual priority in a task that does not require selective processing. First, however,
60 we review what is known about the ways that learned value bias perceptual processing.

61 To study the effect of learned value on visual selection, studies have employed a two-
62 phase structure, wherein different stimuli are repeatedly paired with different amounts of reward
63 in a learning phase, and then attentional biases to these stimuli are compared in a test phase in
64 which the reward contingency is removed (Raymond & O’Brien, 2009; Anderson, Laurent, &
65 Yantis, 2011a; Anderson, Laurent, & Yantis, 2011b; Anderson, 2014; Miranda & Palmer, 2014;
66 Sali, Anderson, & Yantis, 2014; MacLean & Giesbrecht, 2015). For example, Anderson,
67 Laurent, and Yantis (2011b) trained participants to search for oriented bars within green or red
68 circles amongst other colored distractor circles. For each participant, one target color had a high
69 probability of producing a high reward, and the other target color had a high probability of
70 producing a low reward. After practicing this task, reward contingencies were removed, and
71 participants instead searched for an oriented bar within a unique, diamond shape among
72 distractor circles (similar to the added singleton paradigm pioneered by Theeuwes, 1992).
73 Critically, one of these circles on each trial would be colored in either red or green, and both of
74 these singleton distractors led to slowed search times. Importantly, singletons in the color that
75 had received high reward in the learning phase produced greater interference, indicating that the
76 learned value of stimuli produces an attentional bias over and above that of perceptual salience.

77 As recently noted by Müller, Rothermund, and Wentura (2015), the majority of studies
78 on reward and attention rely on search tasks to assess the prioritization of rewarded stimuli, and
79 it is therefore unclear which stages of visual processing are affected by reward. These authors
80 argued that reward effects in search may be due to delayed disengagement, as opposed to a
81 preattentive boost for visual features with learned value. To support this argument, the authors
82 reported data from a modified dot-probe task. After imbuing visual objects with value in a
83 speeded-discrimination task, previously rewarded objects' ability to orient attention when acting
84 as exogenous cues was compared neutral objects, as well as to objects associated with losses.
85 While rewarded objects led to a larger cue validity effect, comparison with neutral cues showed
86 that the rewarded objects led to slower disengagement (i.e., a larger difference between neutral
87 and invalidly cued response times) but not to speeded orienting (i.e., no difference between
88 neutral and validly cued response times). Müller et al. argued that delayed disengagement from
89 rewarded stimuli could explain the attentional biases measured in search tasks, which are
90 assessed by a slowed response time when an object with learned value appears as a distractor.

91 Using a different paradigm, Hickey, Chelazzi, and Theeuwes (2011) have argued instead
92 that reward is able to affect early stages of target detection and localization, and that this target
93 enhancement mechanism is distinct from a distractor suppression mechanism that operates on a
94 later stage of selection. Although this finding is based on results of tasks where the effect of
95 rewards on inter-trial priming, and not learned value, is measured, their conclusion is consistent
96 with a recent electrophysiological and behavioral study showing that reward history influences
97 the early stages of visual attention selection by altering P1 amplitude (MacLean & Giesbrecht,
98 2015, see Hickey, Chelazzi, & Theeuwes, 2010 for a similar result using immediate reward) and
99 attentional capture, as indicated by the N2PC component (Qi, Zeng, Ding, & Li, 2013). Given
100 that these studies involved associating learned values with stimuli, this result is inconsistent with
101 Müller et al.'s conclusion that rewards solely affect delayed disengagement. Similarly, the
102 suggestion that learned value solely delays disengagement is inconsistent with measures of
103 oculomotor capture (Anderson & Yantis, 2012; Hickey & van Zoest, 2012; Theeuwes &
104 Belopolsky, 2012). Instead, it points to an effect of learned value that is pre-attentive, in the
105 sense that it does not require first focusing attention on a particular object to be measured.
106 Behavioral evidence of preattentive locus of reward comes from Kiss, Driver, and Eimer (2009)
107 who showed that pop-out was enhanced for targets that often deliver higher rewards (see also

108 Lee & Shomstein, 2014), however Kristjánsson, Sigurjónsdóttir, and Driver (2010) subsequently
109 showed that this pop-out advantage rapidly reverses following a change in stimulus-reward
110 contingencies, leaving uncertainty regarding whether learned value, as opposed to expected
111 reward, operates at an early stage. What is missing is a direct, behavioral demonstration that
112 stimuli with imbued learned value are prioritized for perception.

113 Our goal in this study was to directly test the claim that learned value can enhance
114 preattentive processing of visual information. To do so, we employed judgments of stimulus
115 onset (temporal order judgments [TOJs] and simultaneity judgments [SJs]), which are used to
116 measure visual prior entry. Prior entry refers to the accelerated conscious perception of some
117 stimuli at the expense of others, leading to earlier conscious perception of these stimuli (Sharlau,
118 2007; Spence & Parise, 2010). Prior entry is found to occur when attention is exogenously
119 oriented to the location of an upcoming stimulus (Stelmach & Herdman, 1991; Hikosaka,
120 Miyauchi, & Shimojo, 1993; Shore, Spence, & Klein, 2001; Schneider & Bavelier, 2003; Born,
121 Kerzel, & Pratt, 2015). Although ERPs measured alongside TOJs do not always demonstrate
122 accelerated processing (i.e., reduced peak latency of early components of the visual evoked
123 potential), increases in the amplitude of early components (e.g., P1, N1, P2) are reliably
124 observed, indicating that behavioral prior entry effects correspond to changes in early visual
125 processing (McDonald, Teder-Sälejärvi, Di Russo, & Hillyard, 2005; Vibell, Klinge, Zampini,
126 Spence, & Nobre, 2007). Importantly, these tasks can be used as a “cueless” tasks that measure
127 the attentional biases that are intrinsic to stimuli, such as the speeded processing found for low
128 spatial frequency patches (West, Anderson, Bedwell, & Pratt, 2010), emotional faces (West,
129 Anderson, Pratt, 2009; West et al., 2010) and near surfaces (West, Pratt, & Peterson, 2013).
130 Furthermore, they does not require selective processing – in fact, both stimuli must be registered
131 to make a response – and so provides an index of visual priority when all information is equally
132 relevant. Thus, TOJs and SJs provide an window into the perceptual biases that may exist for
133 stimuli with learned value before focal attention is engaged, as it is difficult to envision a
134 mechanism by which delayed disengagement alone could affect the relative perceived onset of
135 stimuli.

136 In the present study we used a learned value paradigm modeled after Anderson, Laurent
137 and Yantis’ (2011b) study, with one major exception: instead of monetary value, we assigned
138 value using a point system. For the Experiment 1, our goal was to replicate the results of the

139 Anderson et al (2011b) study, especially given that our point rewards did not map onto any
140 monetary value. To do this, we followed their modified value-learning task with an additional
141 singleton visual search task to establish that value training was successful. We show that when
142 the additional singleton feature was associated with learned value; it slowed down visual search
143 proportional to the size of its associated value. In Experiment 2, participants completed the same
144 value-learning task as Experiment 1, but were then tested using a novel TOJ paradigm to assess
145 whether learned value would modify visual priority. Experiments 3 and 4 measured the
146 perception of temporal onset for rewarded stimuli using a reversed TOJ and a SJ task to
147 distinguish between three accounts of changes in perceptual judgments: true prior entry, response
148 biases, and decision biases. To preview our results, we observed that although learned value
149 biases temporal onset responses, such that highly valued stimuli are reported to be perceived
150 earlier, they do not bias perception when simultaneity, and not order, is measured. This supports
151 the proposal that learned value has effects on visual processing beyond delayed disengagement;
152 specifically, in biasing perceptual decisions.

153

154

Experiment 1

155 As noted above, the main purpose of this experiment was to verify that rewarding
156 participants with points rather than money would result in typical value-learning effects.

157 **Participants**

158 Twenty-two undergraduate psychology students naïve to the experiment were recruited
159 from University of Toronto. Each participant reported normal or corrected-to-normal visual
160 acuity and color vision. Participants gave written informed consent for the experiment and were
161 provided with a course credit for participating in the experiment. All experimental procedures
162 were approved by University of Toronto's Office of Research Ethics and were in accordance
163 with the Declaration of Helsinki.

164 **Apparatus**

165 The experiment was conducted using a Windows-run PC with a 19" CRT (1024 x 768
166 resolution with 85 Hz refresh rate) in a quiet and dimly lit room. Participants sat and viewed the
167 monitor from a distance of 50cm with their chin rested on the chin-rest throughout the
168 experiment. The experiment was run in MATLAB, using Psychophysics toolbox. Participants
169 entered responses by using a standard keyboard.

170 Stimuli and Procedure

171 Participants were tested in a dimly lit room for a single 1-hour session. Prior to the
172 experiment participants were presented with the instructions of the experiment using a
173 PowerPoint presentation that included images of the visual stimuli used in the experiment
174 alongside with the written instructions. Participants were told to place their chin on the chin-rest
175 and to make fast and accurate responses on each trial of the experiment.

176 Each phase of the experiment began with a screen with instructions reiterating the
177 instructions that had been orally provided to the participants. Stimuli for both phases were
178 presented against a uniform grey background with a white fixation cross, 0.4° in size, centered
179 on the screen.

180 Training phase

181 The training phase of Experiment 1 was used to imbue stimuli with learned value by
182 repeatedly pairing them different rewards. Trials in the training phase were made up of displays
183 composed of four Landolt-Cs, 1.5° in radius, drawn in four different colors, appearing at random
184 positions, all centered 6.4° from fixation. Of these Landolt Cs, three, with their gaps (0.36° in
185 size) on the top or bottom, were distractor stimuli, and one, with its gap on the right or left, was
186 the target stimulus. The possible colors of each the distractor stimuli were orange (RGB: 192,
187 192, 0), blue (RGB: 0, 192, 192), yellow (RGB: 255, 128, 0) and, depending on the trial, the
188 target stimulus could be either red (RGB: 255, 0, 0) or green (RGB: 0, 255, 0). The search
189 display was presented until participants made their response. Participants had to identify if the
190 gap on the colored circle was left or right by pressing the left-arrow or right-arrow keys,
191 respectively. A feedback display followed the response to inform the participant of how many
192 points he or she had earned for the completed trial, which was presented in the center of the
193 screen in white Arial font varying in size depending on the reward magnitude. High-reward (200
194 points) were shown in large text (48 point, approximately 1.8° in height) while low-reward (20
195 points) were shown in smaller text (16 point, approximately 0.6° in height). The total amount of
196 points were presented for 1 second, and added to a running tally that was continuously visible at
197 the top of the screen.

198 Correct responses were followed by visual feedback indicating amount of points earned
199 during the training phase. High-reward targets were followed by 200 points (high reward)
200 feedback on 80% of the trials and low-reward feedback on 20% of the trials. Low-reward targets

201 were followed by 20 points (low reward) feedback on 80% of the trials and high-reward
202 feedback on 20% of the trials. High-reward target color and low-reward target color was
203 randomly assigned as red or green for each participant.

204 The training phase consisted of a variable number of trials grouped into 12 blocks. Prior
205 to completing the training phase, practice trials were provided. Practice trials were identical to
206 actual trials except all visual stimuli were presented in white and points earned on each trial were
207 equal to 0 or 10 points, for incorrect trials and correct trials, respectively. The practice phase
208 ceased when participants had collected 100 points; in other words, once they had correctly
209 completed 10 trials. Between each block and after completion of training phase, participants
210 were provided with a short break. Each block was terminated after the participant had
211 accumulated 2500 points.

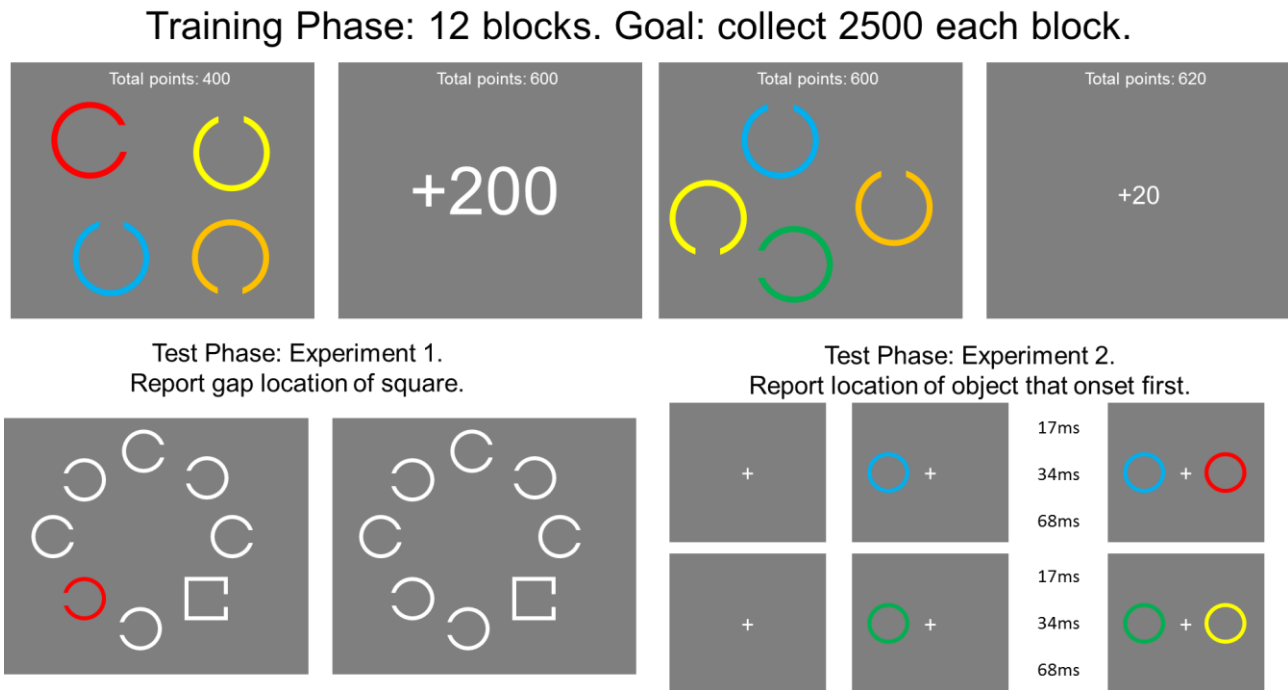
212 **Test phase**

213 For our test phase, we used an additional singleton task (Theeuwes, 1992). During this
214 task, eight stimuli appeared on a search display, where each search stimulus was placed, evenly
215 spaced, the circumference of an imaginary circle, radius 6.4° , centered on fixation. Seven of
216 these stimuli were Landolt Cs, 1.5° in radius, and the eighth stimulus was a Landolt square
217 outline, 3.0° in width and height, Each Landolt had a 0.36° gap on either the left or right side
218 (forward facing or reverse). The target was defined as the square outline with a 0.36° gap on
219 either the left or right side. Depending on the trial type, either all stimuli were colored in white,
220 or all stimuli were colored in white except for one (the additional singleton), which was either
221 drawn in the high-reward associated color or the low-reward associated. There were no feedback
222 or points provided following each trial.

223 The search display was presented until participant made their response. Participant had to
224 identify which side the gap, left or right, is located on the square target by pressing the z or m
225 key, respectively. Response time was measured from the onset of the visual stimuli to the
226 response made by each participant.

227 The test phase of the experiment included 320 trials that were divided into 8 blocks. Once
228 again, practice trials were provided before the test phase was completed. In total there were four
229 conditions in which RTs were compared for the addition singleton: no color, distractor color,
230 high-value color and low-value color. High-value and low-value colors refer to the same colors
231 used for the high-reward and low-reward target for the training phase of the experiment. Target

232 and additional singletons were equally likely to appear in each of the eight positions of the search
 233 array throughout the experiment. The additional singleton always appeared as a distractor. The
 234 search display stayed on the screen until participant made their response and then the next search
 235 display will be presented.
 236



237
 238 **Figure 1.** Upper panel: schematic of the training phase used in Experiments 1 and 2. Point-based
 239 rewards were delivered upon correct response input. Participants' task was to report the gap
 240 location of the red or green Landolt. Lower panel: Schematic of test phases for Experiment 1 and
 241 Experiment 2. Lower left panels depict a high-value singleton trial and a no-singleton trial in
 242 Experiment 1. Lower right panels depict a high-value TOJ trial (top) and a low-value TOJ trial
 243 (bottom). Stimuli are not drawn to scale.

244

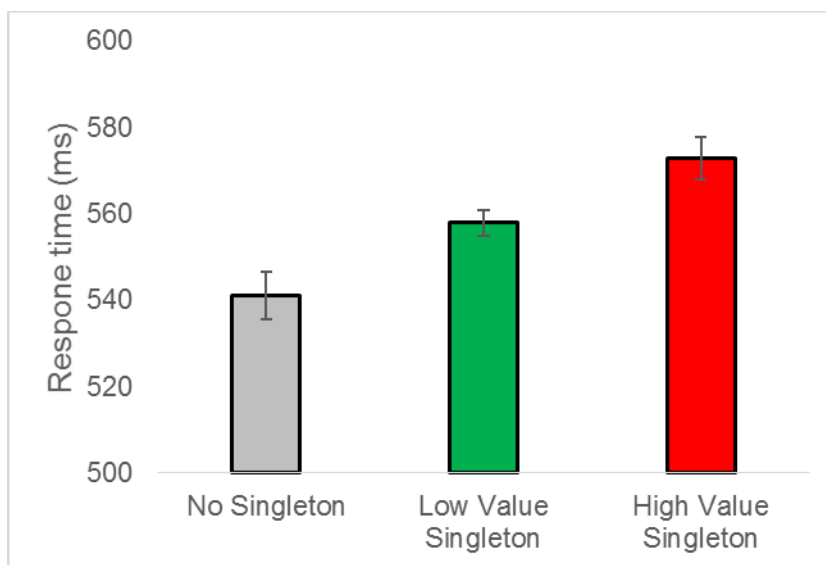
245 Results and Discussion

246 Correct response times in the acquisition were analysed by dividing the training phase
 247 into first and last halves, each of which with high- and low-reward associated targets. Trials were
 248 trimmed within-participants by removing trials with RTs outside of 2 standard deviations of a
 249 participant's mean RT. A Block x Reward ANOVA revealed a main effect of Block, $F(1, 21) =$

250 27.10, $p < .001$, $\eta_p^2 = 0.56$, but no main effect of Reward, $F(1, 21) = 0.84$, $p = .37$, $\eta_p^2 = 0.04$,
 251 and no interaction, $F(1, 21) = 1.03$, $p = .32$, $\eta_p^2 = 0.05$, although response times were
 252 numerically faster for high-reward targets, $M = 519$, $SE = 5$ ms, than low-reward targets, $M =$
 253 531ms, $SE = 4$ ms, in the last half of the training phase. Thus, we did not find reliable evidence of
 254 a difference in response time between high- and low-reward targets in our training phase.

255 In the test phase, correct response times and accuracy were $M = 535$ ms, $SE = 15$ ms, and
 256 $M = 97.2\%$, $SE = 0.6\%$, respectively. To determine whether learned value from the training
 257 phase affected the allocation of attention in the test phase, average correct response times for the
 258 additional singleton effects in the test phase were analysed using a one-way, repeated measures
 259 ANOVA with Singleton Condition (Low Value, High Value, and no Singleton) as a factor.
 260 Averaged correct response times in each condition are shown in Figure 2. A main effect of
 261 singleton type was present, $F(2, 42) = 8.80$, $p = .001$, $\eta_p^2 = 0.30$. Follow-up contrasts revealed
 262 that Low Value Singletons slowed search times relative to No Singleton trials, $F(1, 21) = 4.82$, p
 263 $= .04$, $\eta_p^2 = 0.19$, and, critically, that High Value Singletons slowed search times even further,
 264 relative to Low Value Singletons, $F(1, 21) = 6.15$, $p = .02$, $\eta_p^2 = 0.23$. No differences in accuracy
 265 were observed by Singleton Condition, $F(2, 42) = 0.99$, $p = .38$, $\eta_p^2 = 0.05$. This demonstrates
 266 that, in a task that used points in lieu of monetary reward, learned value led to stable changes in
 267 attentional priority, such that stimuli associated with more reward exhibited increased distraction
 268 in a subsequent task.

269



270

271 **Figure 2.** Correct response times in the test phase of Experiment 1. Error bars represent 1 within-
272 subjects standard error.

273

274 **Experiment 2**

275 Given that we were able to show a learned value effect on the allocation of attention in
276 our version of the task used by Anderson et al. (2011b), we substituted a temporal order
277 judgment task in to the test phase to measure whether learned value affects the speed with which
278 stimuli are processed. If learned value does increase pre-attentive visual priority, we expected
279 that stimuli associated with higher value should be perceived earlier than stimuli with lower
280 value.

281 **Participants**

282 Thirty-one undergraduate psychology students naïve to the experiment were recruited
283 from the University of Toronto. All reported normal or corrected-to-normal visual acuity and
284 color vision. Participants were provided with a course credit in return for the participation of the
285 experiment. None of the participants who participated in Experiment 1 were participants in
286 Experiment 2. All experimental procedures were approved by University of Toronto's Office of
287 Research Ethics and in accordance with the Declaration of Helsinki.

288 **Apparatus**

289 The apparatus used were identical to Experiment 1

290 **Stimuli and Procedure**

291 Similar to Experiment 1, instructions were presented orally using a PowerPoint
292 presentation, which included written instructions along with all the visual stimuli included in the
293 experiment. All procedures used were identical to Experiment 1 with the exception of the test
294 phase. The test phase began with a screen reiterating the instructions presented prior to the
295 experiment. Participants were asked to identify which of the two filled circles they thought
296 appeared first by pressing the z key if the left circle appeared first, or the m key if the right circle
297 appeared first. Similar to the training phase, they were asked to make fast and accurate responses
298 and were given the opportunity to take a break between each block.

299 Similar to the test phase of Experiment 1, participants were provided with 10 practice
300 trials where the task was identical to the actual experiment with the exception that the stimulus
301 circles were white. In total, there were 384 trials that were divided into 8 blocks. Two circles

302 resembling the Landolt C's from the training phase, but with no gap (with a radius of 1.5°) were
303 presented 6.4° away from the fixation cross, on the horizontal meridian. The two circles were
304 drawn in the colors used in the training phase. Two types of trials were used; the high-value
305 color appearing with a distractor color, and the low-value appearing with a distractor color. The
306 first circle appeared on the left or right side of the fixation cross and was followed by the second
307 circle that appeared following a stimulus-onset asynchrony (SOA) of 64 ms, 32ms, or 16 ms. The
308 two circles remained on the screen for 100 ms, after which they offset and a response was
309 collected.

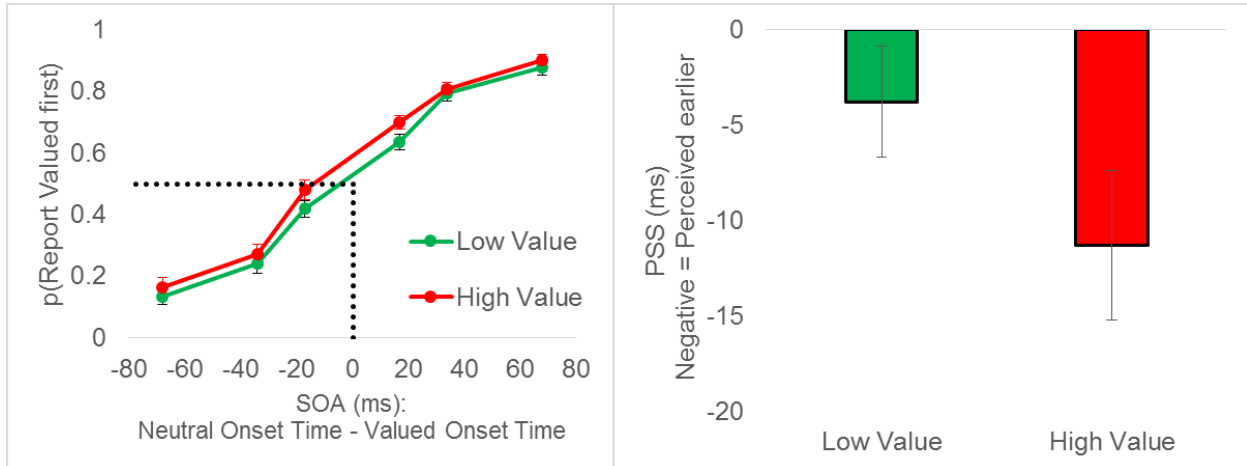
310 **Results and Discussion**

311 Three of the 31 participants were excluded from the TOJ analysis because their response
312 accuracy was not significantly above chance across all reward colors and SOAs (in other words,
313 they did not temporally discriminate the two stimuli). All analyses were performed on the
314 remaining 28 participants. Average correct response time during the training phase were again
315 analysed using a Block X Reward ANOVA. Unlike Experiment 1, the learning phase of
316 Experiment 2 revealed a marginal main effect of Value, $F(1, 27) = 4.31, p = .05, \eta_p^2 = 0.14$, such
317 that High Value targets were reported faster, $M = 549\text{ms}, SE = 14\text{ms}$, than Low Value targets, M
318 $= 560\text{ms}, SE = 15\text{ms}$, as well as a main effect of Block, $F(1, 27) = 37.54, p < .001, \eta_p^2 = 0.58$.

319 For the TOJ task, trials were organized by two factors: the SOA between Valued and
320 Non-Valued color stimuli (six levels: -64 ms, -32 ms, -17 ms, 17 ms, 32 ms, 64 ms), and which
321 Valued Color was used (Low Value, High Value). The responses on these trials were used to fit
322 two Psychometric functions (cumulative Gaussian distributions) for each participant,
323 parametrizing the probability of choosing the color with learned value as having appeared first at
324 each SOA separately for the two valued colors. Fitting was accomplished using a maximum
325 likelihood approach, with Matlab's (by MathWorks) *fminsearch* function used to minimize the
326 negative Log-Likelihood of the parameters of the Psychometric function. As a result, prior entry
327 could be assessed for each Valued Color by comparing the point of subjective equality (PSE)
328 defined by the Psychometric function (the point at which each stimulus is equally likely to be
329 chosen, corresponding the μ , or mean, parameter of the function).

330 The PSS for the Low Value color, $M = -3.78\text{ ms}, SE = 3\text{ ms}$, was not significantly
331 different from 0, $t(27) = 1.30, p = .21$, indicating no prior entry for the Low Value color,
332 compared to a neutral color. Importantly, the PSS for the High Value color, $M = -11\text{ms}, SE = 4$

333 ms, was significantly different from 0, $t(24) = 2.88$, $p = .007$, indicating that High Value colors
 334 did receive prior entry (see Figure 3). A direct comparison of PSS values (Figure 3) yielded the
 335 same conclusion, $t(27) = 2.08$, $p = .047$, while no differences in the slope of temporal order
 336 judgments was evident, $t(27) = 1.07$, $p = .29$. These prior entry results suggest that learned value
 337 is able to affect pre-attentive visual priority.



338
 339 **Figure 3.** Results from Experiment 2's test phase. The left panel depicts across-participant
 340 average probabilities of reporting the valued stimulus as onsetting first for each stimulus onset
 341 asynchrony. The right panel depicts averaged PSS values derived from individual participant fits.
 342 Error bars reflect one standard deviation of the mean.

343

344

Experiment 3

345 Although Experiment 2 provided evidence that learned value leads to prior entry, the
 346 results are equally consistent with the possibility that learned value increases the choice salience
 347 of an object. A number of investigators have remarked that an increase in the probability of an
 348 object being chosen first in a temporal order judgment can be observed because of a true change
 349 in perceived temporal order, or simply a bias to choose a particular object for report (Shore,
 350 Spence, & Klein, 2001; Schneider & Bavelier, 2003). As such we ran a new group of participants
 351 through a task identical to the one we used in Experiment 2, save for the fact that participants
 352 were instructed to report the object that onset last. If the results of Experiment 2 were due to a
 353 bias towards choosing the rewarded stimulus, then we should observe a reversed effect on the
 354 PSS of stimuli with learned value. However, if the results of Experiment 2 were due to
 355 perceptual prior entry, then no such reversal should occur.

356 Participants

357 Thirty one adult volunteers were recruited for Experiment 3. Each participant was
358 compensated with either course credit or \$10 for participation. All participants provided
359 informed consent, and no participants had participated in either Experiment 1 or 2. All
360 experimental procedures were approved by University of Toronto's Office of Research Ethics
361 and in accordance with the Declaration of Helsinki.

362 Apparatus, Stimuli, and Procedure

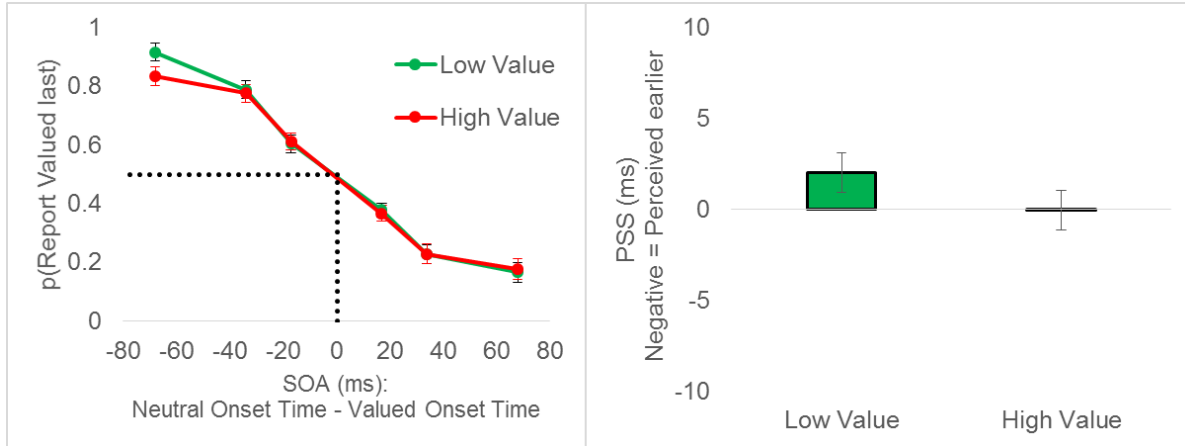
363 All apparatus, stimuli, and procedure were identical to those used in Experiment 2.
364 Participants were simply instructed that, during the temporal order judgment task, they should
365 report which of the two stimuli onset last.

366 Results and Discussion

367 Four participants were excluded, as in Experiment 2, on the basis of poor TOJ
368 performance. Correct mean response times for the training phase were analysed in a Block X
369 Value ANOVA. No main effect of Value was observed, $F(1, 26) = 1.54, p = .23, \eta_p^2 = 0.06$, but
370 RT was affected by Block, $F(1, 26) = 14.82, p = .001, \eta_p^2 = 0.36$, such that RT was lower in the
371 second half. A marginal Value X Block interaction was present, $F(1, 26) = 3.57, p = .07, \eta_p^2 =$
372 0.12 , and so we analysed the effect of Value for the first and last halves of the training phase
373 separately. In the first half, RT did not differ for High- and Low-reward targets, $t(26) = 0.23, p =$
374 $.82$, but did differ for the second half, $t(26) = 2.49, p = .02$, suggesting that an RT benefit for
375 High Value targets emerged later into the training phase.

376 PSS values for High- and Low-value stimuli were estimated again by fitting a cumulative
377 Gaussian distribution, except that now the fitted distribution was inverted (i.e., $1 - \phi$). Unlike
378 Experiment 1, neither Low-value stimuli, $t(26) = 1.35, p = .19$, nor High-value stimuli, $t(26) =$
379 $0.03, p = .97$, showed a PSS shift from 0 (see Figure 4). Following the analysis of TOJ effects by
380 Shore et al., (2001), this indicates that the responses in Experiment 2 were likely due to a mixture
381 of prior entry and decision biases. In the present experiment, the which-came-second task pitted
382 these two effect against each other, and they cancelled each other out. Thus, these results
383 support the conclusion that learned-value affects both perceptual and response biases in temporal
384 order judgments.

385



386
 387 **Figure 4.** Results from Experiment 3's test phase. The left panel depicts across-participant
 388 average probabilities of reporting the valued stimulus as onsetting last for each stimulus onset
 389 asynchrony. The right panel depicts averaged PSS values derived from individual participant fits.
 390 Error bars reflect on standard deviation of the mean.

391

392

Experiment 4

393

394

395

396

397

398

399

400

401

402

403

Experiments 2 and 3 demonstrate that learned value can affect the perception of temporal order. However, whether this reflects true prior entry or not is still unclear. As first argued by Schneider and Bavelier (2003), TOJ tasks may be contaminated by a third type of bias – a decision bias. The TOJ task requires the detection two signals and comparing their onsets. Given the presence of sensory noise, some evidence threshold is necessary for the detection of onsets. A bias to report a valued stimulus may therefore reflect either an increase in the signal strength (i.e., a true change in the stimulus onset signal) or a change in its decision threshold. In Experiment 4, we measured the perception of onset for stimuli with learned value using a SJ task, where participants report whether two stimuli appear at the same time or different times. If stimuli with learned value indeed receive accelerated visual processing, we should observe a shifted PSS using this SJ task.

404 Participants

405 Thirty-one participants were again recruited to participate in Experiment 4. All
406 participants were compensated for their participation with \$10. All experimental procedures were
407 approved by University of Toronto's Office of Research Ethics and in accordance with the
408 Declaration of Helsinki.

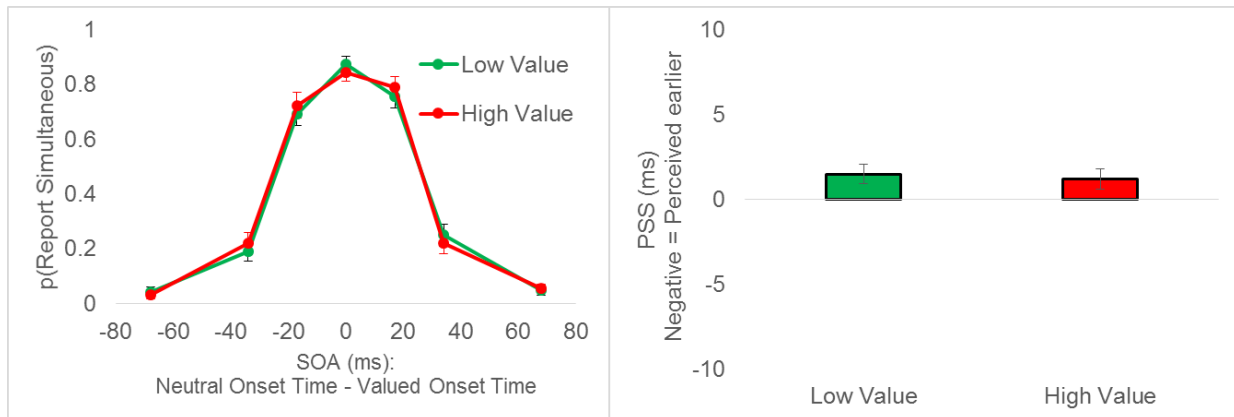
409 Apparatus, Stimuli, and Procedure

410 Identical apparatus, stimuli, and procedure from the previous experiments were used in
411 Experiment 4 with two exceptions. First, because simultaneity was to-be-reported in this task, we
412 introduced trials in the test phase wherein stimuli onset simultaneously, randomly intermixed. To
413 accommodate these extra trials, we increased the number of trials in the test phase from 384 to
414 448. In total, there were 28 trials of the six asynchronous onsets used in Experiments 2 and 3,
415 and 56 trials with simultaneous onsets, per stimulus type (low value vs. neutral, high value vs.
416 neutral). Second, instead of being instructed to report the stimulus that onset first, participants
417 were instructed to report whether the stimuli appeared at the same or different times. The "z" key
418 was used to indicate perceived simultaneous onset and the "/" key was used to indicate perceived
419 asynchronous onset.

420 Results and Discussion

421 Three participants were excluded from analysis due to poor performance in the SJ task.
422 Data from the remaining 28 participants was analysed for both the training and test phases. In the
423 training phase, RTs were faster in the second half than the first, $F(1, 27) = 7.99, p = .009, \eta_p^2 =$
424 0.23 . A main effect of Value was present, $F(1, 27) = 25.18, p < .001, \eta_p^2 = 0.48$, but Value and
425 Block interacted, $F(1, 27) = 4.47, p = .044, \eta_p^2 = 0.14$. Paired-samples *t*-tests indicated that, as in
426 Experiment 3, no difference in RT was present between High- and Low-value trials in the first
427 half of the training phase, $t(27) = 1.01, p = .32$, but RT was faster for High- than Low-value trials
428 in the second half, $t(27) = 3.54, p = .001$.

429 Simultaneity judgments were analysed by fitting responses to the difference between a
 430 cumulative Gaussian distribution and an inverse Gaussian distribution, as in Schneider and
 431 Bavelier (2003). Paired-samples t -tests showed no differences between the parameters fitted for
 432 High- and Low-value SJs, $t(27) < 0.44$, $ps > .66$, and, critically, no difference between the PSS
 433 between High- and Low-value stimuli (see Figure 5), $t(27) = 0.25$, $p = .80$. These results
 434 challenge the conclusion that learned value leads to accelerated visual processing per se, and
 435 instead favor an account wherein perceptual decision thresholds are lowered for valued stimuli,
 436 leaving the speed of sensory processing unchanged. One potential explanation for why we found
 437 a PSS shift in our TOJ tasks, but not the SJ task, comes from van Eijk, Kohlrausch, Juola and van
 438 de Par (2010), who showed that PSS estimates in TOJ tasks can reflect a shift towards the
 439 stimulus with greater temporal sensitivity. Fitting our data with asymmetric slopes (i.e., different
 440 mean and standard deviations for the Value-stimulus leading and Value-stimulus trailing
 441 components of the response distribution), however, did not yield slope differences, $t(27)s < 1.57$,
 442 $ps > .13$. As such, our data cannot speak to this possibility.



443
 444 **Figure 5.** Responses to High- and Low-value stimuli in the SJ task. The left panel depicts
 445 aggregate mean simultaneity reports for each SOA. The right panel depicts average, estimated
 446 PSS values. Error bars depict 1 within-subjects standard error.

447

448 General Discussion

449 The present study sought to establish whether learned value can affect pre-attentive
 450 processing of previously rewarded visual information using a behavioral measurement. In
 451 Experiment 1, we replicated the findings of Anderson et al. (2011b), confirming that our training
 452 procedure was able to produce a value-driven attentional bias. In Experiment 2, we used an

453 identical training phase to imbue stimuli with differential learned value. Using a temporal order
454 judgment task, we observed that stimuli with greater learned value were perceived to onset
455 earlier than stimuli with lower learned value, but equivalent exposure and task-relevance history.
456 Experiment 3 showed that these effects were not entirely due to simple response biases.
457 Critically, however, Experiment 4 showed no such difference in perceived simultaneity between
458 High- and Low-value stimuli. Schneider and Bavelier (2003) argued that such a pattern of results
459 – a shifted PSS for attended stimuli in TOJ tasks, but not in SJ tasks - indicates that no sensory
460 acceleration occurs due to attention, but rather the decision criteria used to estimate onset time
461 are affected. Indeed, research has shown that PSS estimates in TOJ and SJ tasks do not
462 necessarily correlate (van Eijk, Kohlrausch, Juola, & van de Par, 2008). One explanation for why
463 this occurs is that biased PSS values in TOJ tasks occur due to a bias to report the stimulus that
464 has better temporal resolution (van Eijk, Kohlrausch, Juola, & van de Par, 2010). However, we
465 did not observe differences in sensitivity when value-laden stimuli onset first, compared to last,
466 in our SJ task. It is important to note that SJ and TOJ tasks may reflect decisions based on
467 different sensory information; specifically, SJ judgments may often be based on the total
468 duration of both stimuli, if stimulus durations are fixed (see Love, Petrini, Cheng, & Pollick,
469 2013). Therefore, the inference that no prior entry occurs for stimuli with learned value from our
470 data requires the supposition that a lack of a PSS shift in SJ tasks accompanied by shifted PSS
471 values in TOJ tasks should be interpreted as a post-perceptual decision bias, consistent with the
472 dominant view in the prior entry literature (see Schneider & Bavelier, 2003; García-Pérez &
473 Alcalá-Quintana, 2015). As such, we conclude that learned value acquired in our task did not
474 produce prior entry.

475 Several studies measuring the effects of recently delivered rewards on selective attention
476 show what may be considered to be early effects of reward on selection (Hickey, Chelazzi, &
477 Theeuwes, 2010; Hickey, Chelazzi, & Theeuwes, 2011). In particular, priming of pop-out is
478 enhanced after reward delivery (Kiss, Driver, & Eimer, 2009), and visual priming similarly leads
479 to shifts in the PSS for as measured by both TOJ and SJ tasks (Theeuwes & Van der Burg,
480 2013). Given the lack of a clear PSS shift across tasks, despite consistent stimulus value learning,
481 we suggest that the consequences of recent reward and learned value for visual processing may
482 in fact differ. As such, future research should compare the effects of recently delivered reward
483 and learned value with caution; although the distracting effect of stimuli associated with reward

484 over the short- and long-term in search may be similar, the broader visual effects of reward and
485 value may not be identical. While detailed descriptions of how moment-to-moment rewards may
486 result in lasting attentional biases have been advanced (Rombouts, Bohte, Martinez-Trujillo, &
487 Roelfsema, 2015; Failing & Theeuwes, 2016), our results suggest that this process is worth
488 investigating in detail. As noted earlier, Kristjánsson et al. (2010) found that the effect of reward
489 on priming of pop-out rapidly changes when reward contingencies change, leaving open the
490 possibility that the removing reward contingencies (as is necessarily done in studies of learned
491 value) may affect early sensory consequences of reward more than later consequences (i.e.,
492 response and decisions biases). This is, however, inconsistent with the ERP findings of Maclean
493 and Giesbrecht (2015).

494 The issue of how stimulus-reward pairings do or do not accumulate in to lasting value-
495 driven biases may benefit from an integration with the rich literature on the mechanisms of
496 intertrial priming of attention (Becker, 2008; Olivers & Meeters, 2006; Kristjánsson & Campana,
497 2010; Kruijne & Meeter, 2016). Indeed, Sha & Jiang (2106) have recently argued that value-
498 driven attention may rely on target history-related priming. While our results showed value-
499 dependent differences in capture -- that is, high-value stimuli were found and reported as
500 onsetting faster than low-value stimuli -- both stimuli had a history of task-relevance, raising the
501 possibility that stimulus value is learned for attended stimuli only (but see Le Pelley, Pearson,
502 Griffiths, & Beesley, 2015). If the developing literature on learned value and attention seeks to
503 account for real-world attentional biases (e.g., Field & Cox, 2008), then characterizing the
504 mechanisms underlying the learning of stimulus value will be of critical importance.

505 One potentially significant difference between our experiments and those experiments
506 that show an early effect of learned value is that we used a money-less reward-learning task. The
507 majority of value-driven attention studies rely on monetary incentive in order to create stimuli
508 with value associations. Three exceptions are Shomstein and Johnson (2013), who showed a
509 reversal of object-based attention when more points were awarded for the correct detection of
510 targets in non-cued objects, regardless of whether the points led to monetary reward or simply
511 were accumulated, Miranda and Palmer (2014), who showed that combining points and sound
512 effects (as well as a “high-score” counter) could produce similar learned-value effects for stimuli
513 paired with higher reward, and Roper and Vecera (2016), who paired correct responses to
514 different target stimuli with the presentation of different denominations of currency, finding that

515 those stimuli paired with the appearance of larger denominations led to greater attentional
516 capture. While it appears that monetary reward is not necessary to entrain learned value when
517 measured using search times, it is possible that not all rewards affect perception equally, or that
518 the longevity of different rewards' effects on attention differ. Indeed, Miranda and Palmer did
519 not find that points alone could create value-driven attention effects, whereas points alone were
520 sufficient to affect attention in both Shomstein and Johnson's experiments and our experiments.
521 While differences exist in each case between the specific tasks and point values used, we note
522 that, in our task, higher points reduced the number of trials that participants needed to complete,
523 as each block of trials simply required a criterion value of accumulated points in order to be
524 completed. In our paradigm, then, learned value may have been predicated on the reduction in
525 time or effort that accompanied higher point-values. As the old adage goes, time is money, and
526 the subjective impact of a high-reward in our task translates to a reduction in the potential
527 number of trials to be completed. While participants were clearly sensitive to this reward, it may
528 not bias attention in quite the same way as the receipt of money. One reason for this could be that
529 the delivery of money (even symbolic) would be considered positive reinforcement, whereas
530 earning points that reduce the number of trials to be completed could arguably be considered
531 negative reinforcement (the removal of impending effort). As such, these types of rewards may
532 produce different effects on selection.

533 Another salient difference between Miranda and Palmer's experiments, which showed no
534 effect of points alone on attention, and experiments where non-monetary reward led to value-
535 driven attention (Shomstein & Johnson, 2013; Roper & Vecera, 2016; the present experiments)
536 is the difference in feedback complexity. Experiments where non-monetary reward has led to
537 value-driven attention have used consistent mappings between a particular feedback stimulus and
538 high- or low-rewards. In our experiment, high rewards were always "200 points" and low
539 rewards were always "20 points"; in Shomstein and Johnson's experiments, high rewards were
540 always "6 points" and low rewards were always "1 point"; in Roper and Vecera's experiments',
541 high rewards were always depictions of \$20 and low rewards were always depictions of \$5.
542 Indeed, Miranda and Palmer's successful demonstrations of non-monetary, value-driven
543 attention (Experiments 1 and 3) seem to have occurred when a particular sound (an "electric
544 whip") accompanied positive feedback; points, when awarded, varied by participants' response
545 time, meaning that the high reward values, while 5 times larger than the low reward values on

546 average, could change across trials, perhaps making reward-stimulus associations more difficult
547 to learn. This is not to say that consistent mapping is sufficient for reward learning, as Roper and
548 Vecera found no value-driven attentional biases when monetary amounts did not appear as
549 monetary images, but instead as simple numeric amounts (even when preceded by a dollar-sign).
550 However, a consistent mapping between high-value and particular stimulus that conveys high
551 value may be important for the rapid formation of value-driven attentional biases. If this is the
552 case, it suggests that associations between value and attention may be underlain by associations
553 between stimuli (i.e., between target stimuli and the stimuli that signal reward, but not between
554 target stimuli and abstract reward). While the use of a different types of reward may be
555 responsible for conflicting results, insofar as our lack of prior entry conflicts with ERP data,
556 ultimately, we see this as an advantage for the literature on reward, value, and attention. One
557 goal of research into the effects of reward and value on attention must be generalizable theories,
558 and so testing different types of rewards (e.g., positive emotional expressions; Anderson, 2015)
559 is essential to understanding the nuances of motivated attention.

560

561

562

References

- 563 Anderson, B. A. (2014). Value-driven attentional priority is context specific. *Psychonomic*
564 *Bulletin & Review*, 22(3), 750-756.
- 565 Anderson, B. A. (2015). Social reward shapes attentional biases. *Cognitive Neuroscience*, doi:
566 10.1080/17588928.2015.1047823.
- 567 Anderson, B. A., Laurent, P. A., & Yantis, S. (2011). Value-driven attentional capture.
568 *Proceedings of the National Academy of Sciences*, 108(25), 10367-10371.
- 569 Anderson, B. A., Laurent, P. A., & Yantis, S. (2011). Learned value magnifies salience-based
570 attentional capture. *PLoS One*, 6(11), 1-6.
- 571 Anderson, B. A. & Yantis, S. (2012). Value-driven attentional and oculomotor capture during
572 goal-directed, unconstrained viewing. *Attention, Perception & Psychophysics*, 74(8), 1644-
573 1653.
- 574 Awh, E., Belopolsky, A. V., & Theeuwes, J. (2012). Top-down versus bottom-up attentional
575 control: a failed theoretical dichotomy. *Trends in cognitive sciences*, 16(8), 437-443.
- 576 Becker, S. I. (2008). The mechanism of priming: Episodic retrieval or priming of pop-out? *Acta*
577 *Psychologica*, 127(2), 324-339.
- 578 Born, S., Kerzel, D., & Pratt, J. (2015). Contingent Capture Effects in Temporal Order
579 Judgments. *Journal of Experimental Psychology: Human Perception and Performance*,
580 41(4), 995-1006.
- 581 Field, M. & Cox, W. M. (2008). Attentional bias in addictive behaviors: A review of its
582 development, causes, and consequences. *Drug and Alcohol Dependence*, 97, 1-20.
- 583 García-Pérez, M. A. & Alcalá-Quintana, R. (2015). Converging evidence that common timing
584 processes underlie temporal-order and simultaneity judgments: a model-based analysis.
585 *Attention, Perception, & Psychophysics*, 77(5), 1750-1766.
- 586 Hickey, C., Chelazzi, L., & Theeuwes, J. (2010). Reward changes salience in human vision via
587 the anterior cingulate. *The Journal of Neuroscience*, 30(33), 11096-11103.
- 588 Hickey, C., Chelazzi, L., & Theeuwes, J. (2011). Reward has a residual impact on target
589 selection in visual search, but not on the suppression of distractors. *Visual Cognition*,
590 19(1), 117-128.
- 591 Hikosaka, O., Miyauchi, S., & Shimojo, S. (1993). Focal visual attention produces illusory
592 temporal order and motion sensation. *Vision research*, 33(9), 1219-1240.

- 593 Kiss, M., Driver, J., & Eimer, M. (2009). Reward priority of visual target singletons modulates
594 event-related potential signatures of attentional selection. *Psychological Science*, 20(2),
595 245-251.
- 596 Kristjánsson, À. & Campana, G. (2010). Where perception meets memory: A review of
597 repetition priming in visual search tasks. *Attention, Perception, & Psychophysics*, 72(1), 5-
598 18.
- 599 Kristjánsson, À., Sigurjónsdóttir, Ó., & Driver, J. (2010). Fortune and reversals of fortune in
600 visual search: Reward contingencies for pop-out targets affect search efficiency and target
601 repetition effects. *Attention, Perception, & Psychophysics*, 72(5), 1229-1236.
- 602 Kruijne, W. & Meeter, M. (2016). Implicit short- and long-term memory direct our gaze in visual
603 search. *Attention, Perception, & Psychophysics*, 78(3), 761-773.
- 604 Le Pelley, M. E., Pearson, D., Griffiths, O., & Beesley, T. (2015). When goals conflict with
605 values: counterproductive attentional and oculomotor capture by reward-related stimuli.
606 *Journal of Experimental Psychology: General*, 144(1), 158-171.
- 607 Lee, J. & Shomstein, S. (2014). Reward-based transfer from bottom-up to top-down search tasks.
608 *Psychological Science*, 25(2), 466-475.
- 609 Love, S. A., Petrini, K., Cheng, A., & Pollick, F. E. (2013). A psychophysical investigation of
610 differences between synchrony and temporal order judgments. *PLOS One*, 8(1), e54798.
- 611 MacLean, M. H., & Giesbrecht, B. (2015). Neural evidence reveals the rapid effects of reward
612 history on selective attention. *Brain research*, 1606, 86-94.
- 613 McDonald, J. J., Teder-Sälejärvi, W. A., Di Russo, F., & Hillyard, S. A. (2005). Neural basis of
614 auditory-induced shifts in visual time-order perception. *Nature Neuroscience*, 8, 1197-
615 1202.
- 616 Miranda, A. T., & Palmer, E. M. (2014). Intrinsic motivation and attentional capture from
617 gamelike features in a visual search task. *Behavior research methods*, 46(1), 159-172.
- 618 Müller, S., Rothermund, K., & Wentura, D. (2015). Relevance drives attention: Attentional bias
619 for gain- and loss-related stimuli is driven by delayed disengagement. *The Quarterly*
620 *Journal of Experimental Psychology*.
- 621 Olivers, C. N. L. & Meeter, M. (2006). On the dissociation between compound and
622 present/absent tasks in visual search: Intertrial priming is ambiguity driven. *Visual*
623 *Cognition*, 13(1), 1-28.

- 624 Qi, S., Zeng, Q., Ding, C., & Li, H. (2013). Neural correlates of reward-driven attentional
625 capture in visual search. *Brain Research, 1532*, 32-43.
- 626 Raymond, J. E., & O'Brien, J. L. (2009). Selective visual attention and motivation the
627 consequences of value learning in an attentional blink task. *Psychological Science, 20*(8),
628 981-988.
- 629 Rombouts, J. O., Bohte, S. M., Martinez-Trujillo, & Roelfsema, P. R. (2015). A learning rule
630 that explains how rewards teach attention. *Visual Cognition, 23*(1-2), 179-205.
- 631 Roper, Z. J. J. & Vecera, S. (2016). Funny money: The attentional role of monetary feedback
632 detached from expected value. *Attention, Perception, & Psychophysics*. doi:
633 10.3758/s13414-016-1147-ys
- 634 Sali, A. W., Anderson, B. A., & Yantis, S. (2014). The role of reward prediction in the control of
635 attention. *Journal of Experimental Psychology: Human Perception and Performance, 40*(4), 1654.
- 637 Scharlau, I. (2007). Perceptual latency priming: A measure of attentional facilitation.
638 *Psychological Research, 71*(6), 678-686.
- 639 Schneider, K. A., & Bavelier, D. (2003). Components of visual prior entry. *Cognitive*
640 *Psychology, 47*(4), 333-366.
- 641 **Shomstein, S. & Johnson, J. (2013). Shaping attention with reward: Effects of reward on**
642 **space- and object-based selection. *Psychological Science, 24*(12), 2369-2378.**
- 643 Shore, D. I., Spence, C., & Klein, R. M. (2001). Visual prior entry. *Psychological Science, 12*(3),
644 205-212.
- 645 Spence, C., & Parise, C. (2010). Prior-entry: A review. *Consciousness and Cognition, 19*(1),
646 364-379.
- 647 Stelmach, L. B., & Herdman, C. M. (1991). Directed attention and perception of temporal order.
648 *Journal of Experimental Psychology: Human Perception and Performance, 17*(2), 539.
- 649 Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics,*
650 *51*(6), 599-606.
- 651 Theeuwes, J. & Belopolsky, A. V. (2012). Reward grabs the eye: Oculomotor capture by
652 rewarding stimuli. *Vision Research, 74*, 80-85.
- 653 Theeuwes, J. & Van der Burg, E. (2013). Priming makes a stimulus more salient. *Journal of*
654 *Vision, 13*(21), doi:10.1167/13.3.21

- 655 van Eijk, R. L. J., Kohlrausch, A., Juola, J. F., & van de Par, S. (2008). Audiovisual synchrony
656 and temporal order judgments: Effects of experimental method and stimulus type.
657 *Perception & Psychophysics*, *70*(6), 955-968.
- 658 van Eijk, R. L. J., Kohlrausch, A., Juola, J. F., & van de Par, S. (2008). Temporal order judgment
659 criteria are affected by synchrony judgment sensitivity. *Attention, Perception &*
660 *Psychophysics*, *72*(8), 2227-2235.
- 661 Vibell, J., Klinge, C., Zampini, M., Spence, C., & Nobre, A. C. (2007). Temporal order is coded
662 temporally in the brain: Early event-related potential latency shifts underlying prior entry
663 in a cross-model temporal order judgment task. *Journal of Cognitive Neuroscience*, *19*(1),
664 109-120.
- 665 West, G. L., Anderson, A. K., Bedwell, J. S., & Pratt, J. (2010). Red diffuse light suppresses the
666 accelerated perception of fear. *Psychological Science*, *21*(7), 992-999.
- 667 West, G. L., Anderson, A. K., & Pratt, J. (2009). Motivationally significant stimuli show visual
668 prior entry: evidence for attentional capture. *Journal of Experimental Psychology: Human*
669 *Perception and Performance*, *35*(4), 1032-1042.
- 670 West, G. L., Pratt, J., & Peterson, M. A. (2013). Attention is biased to near surfaces.
671 *Psychonomic Bulletin & Review*, *20*, 1213-1220.