November 15, 2021

Re: Revision of PP-ORIG-21-249

Dr. Joy Geng

Action Editor, Attention, Perception, & Psychophysics

*Dear Dr. Geng,*

Kindly consider our revised manuscript entitled *"* *Target detection and discrimination in pop-out visual search with two targets"* by Wilmott, Makwana & Song for publication in *Attention, Perception, & Psychophysics.*

We thank you and the reviewers for the constructive and positive comments and have made a concerted effort to address every concern that was raised. For your convenience, major revisions are shown in red ink in the manuscript.

To summarize, first, we substantially revised the manuscript to improve readability and the coherence of our findings following both reviewers’ comments. We also improved our statistical approach for both experiments, and recontextualized our findings in the improved and streamlined analyses as Reviewer 1 suggested.

The Response to the Reviewers details our effort to address all the points raised by the reviewers. We hope that you agree with our assessment and consider this revised manuscript for publication.

Sincerely,

James Wilmott, Mukesh Makwana & Joo-Hyun Song

**Response to the Reviewers**

We are grateful to the editor and reviewers for their insightful and detailed comments. We believe that we have addressed their concerns below: Original comments are in *italics*. For convenience, major revisions are printed in red ink in the manuscript.

**Responses to Reviewer #1**

*This study sets out to assess the effect of redundant target information in the context of pop out search in both a detection task and a discrimination task. The authors interpret their results to reflect a redundancy gain for detection and a redundancy cost for discrimination (Exp 1) and that the redundancy cost for discrimination is mitigated by grouping (Exp 2) and driven by conflict at the response level (Exp 3). I have major concerns regarding the interpretation and the statistical power that prevent me from recommending the manuscript without further experiments and reframing of the argument.*

**Response #1:**  We thank reviewer 1 for the valid constructive comments, we have addressed all the comments below.

*Major Concerns:*

*Interpreting the task*

· *The detection task in Exp 1 is hard to call search, the task is really are there 1 or 2 colors here. This decision is made easier when there is more of the less represented color in the two-target condition.*

**Response #2:**  We appreciate the constructive feedback on the best terminology to use to describe our task. There are many potential characterizations of what defines visual search. A common theme throughout the visual search literature is to define search as any task where “an observer looks for one or more targets in a display containing some distractor” (Wolfe, 2014 Oxford Handbook of Attention). Classically, many studies investigating visual search have used variants of the ‘odd color’ paradigm where targets are defined as the object with a different color, as in our study here (see Treisman & Gelade, 1980; Wolfe, 1994; Majkovic & Nakayama, 1994, 1996; Nakayama & Joseph, 1998 for just a few examples). Moreover, previous studies investigating redundancy effects with experimental designs similar to the ones used here (e.g, identify the presence or absence of an odd colored shape) have classified their tasks as visual search (Krummenacher et al., 2001; Krummenacher et al., 2002; Grubert et al., 2011; Krummenacher et al., 2014). Given these historical characterizations of what defines visual search, we feel justified in using this term to describe the tasks conducted in this study.

· *Similarly, the discrimination task is odd in Exp 1 because the multiple target conditions makes it harder to determine which color is the target on each trail, so the decrement likely reflects this difficulty more than a redundancy cost in search.*

**Response #3:**  This comment leads us to believe we should better clarify our use of the terms redundancy cost and redundancy gain. Traditionally, the term redundancy gain has been used to refer to a performance benefit (either higher accuracy or faster reaction times) when multiple targets are present in a search array compared to when one target is present (as in Mordkoff & Yantis, 1993; Mordkoff & Miller, 1993; Krummenacher et al., 2001 etc.) and is thus agnostic to the mechanisms underlying this benefit. Here, we use the term redundancy gain in the same manner, and similarly use the term redundancy cost to describe the performance decrease when comparing the one vs. two target conditions of the discrimination tasks conducted in this study.

As the reviewer mentions, one potential explanation for this redundancy cost could be that multiple targets make it harder to determine which color is the target. In fact, we investigate this possibility in Experiment 2 and find some evidence for this explanation when we observe that matching perceptual grouping (the ratio of targets to distractors) reduces the redundancy cost such that reaction times in the one target and the two target conditions (including both same shape and different shape trials together) are not significantly different. However, we also observed a reduction in performance when comparing the same shape and different shape conditions, which we conclude is caused by response competition based on the outcome of Experiment 3. Given that the search task employed in this study requires a set of subtasks including target identification (which will be dictated by perceptual grouping process), attentional selection, and response selection, we feel justified to conclude that we observe a redundancy cost in visual search discrimination performance in our study.

· *In fact, a redundancy gain is seen in the RT for the two same vs. two different targets, so I disagree with the interpretation that there is a redundancy cost in discrimination here.*

**Response #4:**  We appreciate the reviewer’s comment. As discussed above, the traditional definition of a redundancy gain refers to a performance benefit when comparing one vs. two target conditions. In the tasks conducted in our study, we define a target as an odd-colored object and participants are explicitly made aware of this target definition prior to the experiment. Importantly, in the discrimination task we do not define a target based on the shape or response (i.e., the correct response is the response associated with the odd-colored object’s shape, whatever that may be). We agree with the reviewer that if we were to define a target based on the shape/response, e.g., if the observer had to identify the odd-colored shape with a cut off side on top, then one could conclude that the targets same condition exhibits a redundancy gain compared to the targets different condition based on the presence of one (targets same) or two (targets different) shapes/responses. However, we feel this is an inappropriate characterization because the task-defined targets were based on color and not shape/response, and that the correct comparison to make when determining whether there is a redundancy gain/cost is to compare the one odd-colored target vs. two odd-colored targets conditions - which exhibits a redundancy cost.

· *In Exp 2 they go on to make the process of determining which color is the target color in the first place more equivalent between the one- and two target conditions by equating the ratios of target and distractors. They then see less of what they are calling redundancy cost, but the same versus different conditions within the two-target scenario again show a redundancy gain.*

**Response #5:**  As discussed in Response #4, we believe the correct characterization of redundancy gain/cost is based on the comparison between the one odd-colored target vs. two odd-colored targets conditions, rather than the targets same vs. targets different conditions. Based on this characterization, we do see a reduction in the redundancy cost in Experiment 2 when perceptual grouping processes are approximately matched between the one and two target conditions. However, we still observe a reduction in performance (longer reaction times) for the targets different compared to targets same conditions, which we conclude is due to response competition in the targets different condition based on the findings in Experiment 3. We do not believe it is appropriate to refer to this as a redundancy gain because of how we define targets in this task (as discussed above).

· *In my opinion, Exp 3 gets it right, because it compares the different two target conditions directly (but see my next point about low N/lack of power).*

**Response #6:**  We thank the reviewer for this feedback and attend to their suggestions regarding number of participants and power in turn below.

*Low statistical power*

· *The three experiments all have low N (Exp 1, N=15; Exp 2, N=15; Exp 3, N=19) and are at risk of being underpowered to detect medium sized effects.*

**Response #7:**

· *There is no mention of an a priori power analysis or justification for the chosen N’s.*

**Response #8:**

· *In Exp 1, one- versus two-target accuracy has a medium effect size and potentially fails to reach Bonferroni corrected significance due to ceiling effects/low power.*

**Response #9:**

· *In Exp 3, again, there a medium effect size for accuracy that does not reach significance (Ssame-Rsame vs. Sdiff-Rsame).*

**Response #10:**

· *Lastly, low power in Exp 3 could account for the lack of a significant difference between RTs for “same shape/same response” vs. “different shape/different response” which should be different according to the response competition account the authors are arguing for.*

**Response #11:**

· *Bayesian analyses to show support for the null hypotheses in these cases could be done, but running a replication with more subjects would be best (especially for the RT result in Exp 3 which should be different according to the response interference account).*

**Response #12:**

*I like the framing in the intro about race models vs. co-activation models but the*

*results do not go on to be interpreted as supporting one or the other.*

**Response #13:**

*Minor Concerns:*

*Hebert et al., 2020 is cited and discussed in the intro but is not in the reference list*

**Response #14:**

*It was unclear to me if the RT was measured as the release of the 5 key or the pressing of 2/8*

**Response #15:**

*Exp 1 used three fixed distances between the dual targets. Was there an effect of distance between dual targets?*

**Response #16:**

*Discussion states that the “same shape/same response” is faster than the “diff. shape/diff. response” though the results failed to show a significant effect there. pg. 29, ln. 14-17*

**Response #17:**

**Responses to Reviewer #2**

*This paper investigates how people perform target discrimination among distractors when there are two targets instead of one. They found that compared to target detection, target discrimination takes longer when there are two targets instead of one. They further test some hypotheses into why this is the case, for example, perceptual grouping of distractors.*

*Overall, I found this manuscript well-written and clear. The experiments were well motivated and analysed and the discussion was relatively straightforward.*

**Response #18:**  We thank the reviewer for their helpful comments and address them in turn below.

*I have only a few minor comments to help improve the readability of the manuscript.*

*Page 3, Line 52 – it would be helpful to clarify the actual task the participants have to do to improve understanding, i.e. they should detect either of the two targets. At least one is somewhat confusing…*

**Response #19:**

*Page 4, Line 15 – use of “” seems unnecessary and throws the reader (at least me) off.*

**Response #20:**

*Page 8, line 36 – two things were unclear to me in the procedure of the experiment and it would be helpful to explain the rationale for them.*

*1)* *why did the participants have to hold down a button and then release it to press another button, instead of just pressing a button? I didn’t see any movement times analysed, did I miss this?*

**Response #21:**  We believe the reviewer is indicating Page 9, line 36 (rather than Page 8) where we describe the response method for the Detection task. Participants self-initiated the beginning of a trial by pressing the 5 key. We then asked participants to hold this 'start' button until they were ready to make their response in an effort to simplify the task for the observer: they always knew that the response buttons were above or below where their finger was located ('8' or '2').

*2)* *why did they have to fixate on the fixation cross throughout the trial? Would free eye movements have made a difference?*

**Response #22:**  This is an excellent question. We required participants to maintain fixation at a central fixation cross to be consistent with previous studies investigating attentional constraints on search (CITE here: Joo-Hyun/Ken’s stuff? ). There is also a theoretical motivation. Previous studies have indicated that participants’ search strategies can proceed in ‘parallel’ (i.e., attending all or a subset of the search array simultaneously) or ‘serially’ (i.e., sequentially attending objects until a target is found), and that whether and how participants adopt such strategies depends on the task - discrimination is thought to require serial search while detection can proceed in parallel (CITE here: Egeth?). It is possible that allowing free eye movements may have encouraged some participants to adopt a purely serial strategy in both the detection and discrimination task, which may have masked any differences in search performance that the participant would have otherwise used. Thus, requiring participants to maintain fixation at the fixation cross encourages participants to choose the most efficient search strategy for a given task.

*Page 10, line 50 – I missed this at first that reaction times were only for correct trials. It would be helpful to put this in the data analysis section and also maybe to add reaction times for correct trials at the beginning of each section analysing the reaction times.*

**Response #23:**

*Page 13, line 20 – It seems to me to make more sense to first do an ANOVA with one-target, 2 target same and 2 target different, then do post-hoc analyses. Here, with multiple t-tests comparing to the one-target condition, there should be a family-wise correction.*

**Response #24:**

*Page 16, line 22 – why was the distance to between the 2 targets fixed at 5 degrees in experiment 2? Doesn’t it provide information to the participants about where to find the 2nd target, once the 1st target has been found? In experiment one, the distance was varied specifically to prevent anticipation of the second target location, why was this no longer an issue for experiment 2?*

**Response #25:**  In experiment 1 when distance was varied, we found no evidence that search performance varied as a function of target distance across the range we tested as evidenced by not. Given that null effect, we affixed distance at 5 degrees going forward to have one less variable that may have contributed to variance in participant responses (albeit at a less than statistically significant level).

While it is possible that the set distance between targets provided information about the magnitude of the difference between targets to the observers, we do not believe this would have significantly impacted our participant’s search strategies for two reasons. First, while the distance between targets was always the same, both the angular direction of the location of the second target relative the first and the actual positions of both targets in the display were randomized, which would make it difficult to use the knowledge about the distance between targets in a meaningful way. Second and most crucially, participants were instructed to discriminate and report the shape of only a single target, meaning that successful task performance did not require ever finding both targets. Thus, even if participants could identify the location of the second target more efficiently because of the fixed distance, there was no need for them ever to do so.

*Page 22 – line 19 – The addition of the tEC theory explanation here is confusing. I believe it’s easier to understand when it is just mentioned in the discussion as already has been done. At this point the first two explanations of perceptual competition and response competition to introduce the 3rd experiment seem enough. It got me thinking about a same stimulus/different response condition, would this evoke two event files? And wouldn’t even the Sdifferent-Rsame result in two different event files? Why would the same response only evoke one event file if it is really about a stimulus-response association, rather than about responses? The explanation here and in the discussion section seems to assume that the response determines the event file, i.e. one response = one event file regardless of number of stimuli. This should be addressed in the discussion section. Also related to this, another future experiment would be to somehow include a condition of same stimulus/different response (no idea how), which would be good to further confirm the very interesting same response results here.*

**Response #26:**

*Page 30, line 3 – The motivation and logic about why visual attention is included here is unclear. Since attention wasn’t modulated in this task, it’s difficult to understand why attention is used to explain the results here. It may be related to the idea that detection requires broad attention and discrimination requires focused attention that was mentioned earlier but this hasn’t really been explained well here. I suggest a rewording of this section to more clearly spell out to readers how attention might be involved and how the results might speak to attentional mechanisms exactly. Related to this, on page 31, line 13, the authors conclude with the strong statement that attentional explanation involving perceptual grouping is a better explanation for the results, which again, seems to be too strong for something that wasn’t directly tested in the experiment. I think it would be helpful to more carefully explain the link between the type of task, the presumed associated attentional distribution in the task (including how this links to perceptual grouping) and how this explains the results. It may be that because the points related to this are spread out across the discussion section, it’s hard to put together.*

**Response #27:**