Metacognitive contributions to visual search termination

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**Introduction**

While a significant amount of research investigates the mechanisms behind target detection, less work has been conducted on what brings us to abandon a search and conclude that a target is absent. The present study is the second of a series of experiments investigating the contribution of metacognitive knowledge to search termination when a target is absent.

To understand visual search behaviour, the classic experimental paradigm involves the study of response time (time taken to report the presence/absence of a target) as a function of set size (the number of items in the search display; see Wolfe, 1998 for a review). Depending on the type of stimuli and target’s salience, search efficiency varies with set size and as a result so does the slope of the function relating set size to response time. Several cognitive models of visual search such as the Guided Search Model 4.0 (GS4) and the Competitive Guided Search Model (CGS) generate computational simulations that successfully reproduce empirical RT x set size slopes (Wolfe & Gray, 2007; Moran et al., 2013).

However, when it comes to understanding the mechanisms underlying search termination on target-absent (TA) trials, cognitive models of visual search vouch for a poor understanding of the mechanisms underlying this process. For example, Chun and Wolfe’s (1996) model of search termination is based on an assumption: the decision to terminate a search on TA trials relies on experience with the task. In the CGS model, the probability of quitting a search increases each time an item is rejected as a distractor. The value of this increase is a free parameter “under strategic control of the observer”, but the origins of that strategy is left unspecified. This series of experiments argues that search termination on TA trials relies on metacognitive expectations of search time, prior to experience with the task. The questions at the heart of this line of research are:

What proportion, if any, of metacognitive expectations about search time do participants have prior to the task?

How is this knowledge shaped or extended by experience with the task?

To investigate this, experiment 1 (Mazor & Fleming, 2020) uses colour search, where the target item can be identified solely by its colour. Colour is one of a limited class of visual properties that give rise to ‘visual pop out’, wherethe target item so salient that it pops out immediately (e.g. red item among blue items), leading to very efficient search, independently of set size. Empirical RT x set size slopes for pop-out search tasks are flat, near zero ms/item (Wolfe, 1998). Experiment 1 differs from classic colour pop-out experiments in that the order of trials is predetermined. By starting with TA trials, participant’s ability to base search termination on experience with target-present trials is controlled for, and only metacognitive knowledge is probed. Results are clear evidence for a colour pop-out effect on TA trials, prior to experience with target-present (TP) trials, suggesting that participants used metacognitive expectations about pop-out search time to terminate their search.

The present experiment will attempt to extend the findings of experiment 1 to shape pop-out search, as well as attempt to specify the nature of the metacognitive knowledge involved in shape search termination (implicit or explicit).

**Hypotheses**

Hypothesis 1: We expect to witness a shape pop-out effect on target-present trials i.e a flat RT x set size slope for shape search.

Hypothesis 2: Based on the results of experiment 1, we expect a shape pop-out effect on the target-absent trials preceding target-present trials. This would indicate metacognitive expectations of shape pop-out prior to experience with the task.

Hypothesis 3: We expect no learning effect based on experience with TP trials. That is to say that we expect no significant difference between RT x set size slopes for shape search on TA trials that precede TP trials versus those that follow TP trials.

Hypothesis 4: We expect no significant difference between in search slopes between participants reporting past experience with a similar experiment versus those reporting no such experience. Testing this hypothesis controls for contributions of past experience to search termination.

Hypothesis 5: We expect participants to have implicit (not explicit) metacognitive expectations of shape pop-out search time.

**Method**

This study was approved by the Research Ethics Committee of University College London (study ID number 1260/003).

**Participants**

Participants will be native English speakers recruited via Prolific. They will be compensated £0.38. A power analysis on G\*Power for a small effect size of 0.20 (Cohen, 1992) with a statistical power of 95% indicated that data should be collected until obtention of 320 included participants for each hypothesis.

**Pre-registered exclusion criteria**

Participants making over one error in the main part of the experiment will be excluded. Subjects with RTs below 250ms or above 5000ms in over 25% of trials will be excluded. Participants who give blank answers to questions 1 and/or 2 will excluded.

**Procedure and Design**

Participants will give informed consent before participation. They will be asked the following question (Q1): "In a recent experiment, we found that participants take 500 ms on average to find a triangle among 5 ellipses. How long (on average) did it take them to find the triangle among 10 ellipses?". We will give instructions on the visual search task: state whether a target item is present or absent (pressing “J” or “F” respectively), being as accurate and as fast as possible. Participants will complete practice trials (See Figure 1) followed by 12 trials (structure of each trial in Figure 2) forming the main part of the experiment (see Figure 3).

Diagram

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*Figure 1.* To familiarize with the task, participants will complete practice trials in blocks of 6, until they produce correct responses for at least 5 out of 6 trials. In practice trials, set size is fixed to 3 and participants search for a rotated T among rotated Ls (from Mazor & Fleming, 2020)

Graphical user interface, application

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*Figure 2.* Each trial begins with a screen showing the target stimulus. Next, the search display is presented until a response is given. The feedback screen is displayed for 1000ms after correct responses and 4000ms after errors, to boost speed and accuracy (figure from Mazor & Fleming, 2020).

Diagram

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*Figure 3.* The main part of the experiment consists of 12 trials. Unbeknown to participants, blocks 1 and 3 (trials 1-4 and 9-12) are target-absent and block 2 (trials 5-8) are target-present. Participants search for a red circle (target item) among red squares (shape search) or among red squares and blue circles (conjunction search). The number of items in the search display (set size) is 4 or 8. The following 2x2 design is applied: Type of search (shape, conjunction) X Set size (4,8). Item position is randomised. Trial order within each block is randomised.

After completing the main part of the experiment, participants will be asked the following question (Q2): “Have you had any experience with this type of experiment in the past (i.e. searching for a target of a certain shape among items of a different shape)? If so, explain.”.

**Analysis**

Trials with response times below 250ms or above 1000ms, as well as error trials, will be excluded from the analysis. Throughout the analysis, we will consider that slopes significantly lower than 10ms/item indicate a pop-out effect. Slopes will be computed using simple linear regression, controlling for serial trial order.

Hypotheses 1 and 2: Within-subjects t-tests will determine whether there is a significant difference between conjunction and search slopes, and whether the search slope is significantly below 10ms/item. That analysis will be repeated for each block.

Hypothesis 3: A within-subjects t-test will compare the shape search slope in block 1 with the shape search slope in block 3.

Hypotheses 4 and 5: Participants will be divided into two groups for analysis, those who answered “Yes” to Q2 (group 1) and those who answered “No” to Q2 (group 2). A between-subjects t-test will compare the shape search slope in block 1 between groups. Participants’ answers to Q1 will be added as a covariate to the model.

**Anticipated results and implications**

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*Figure 4.* Typical search times for conjunction versus shape trials. TP: target-present, TA: target-absent.

*Figure 5.* Obtaining the above results will indicate that the chosen stimuli induces a shape pop-out effect on TP trials and thus validate our methods.

If our methods are validated (see Figure 5), three patterns of results are conceivable:

*Figure 6.* These findings would indicate that search termination on TA trials is based on metacognitive expectations of a shape pop-out effect, and not experience with the task, since no learning effect is found between blocks 1 and 3. If, in addition to the results above, no significant difference is found between groups 1 and 2, we will be able to infer that metacognitive knowledge alone contributes to search termination. However, if the difference between groups is significant, we cannot rule out the contribution of past experience to search termination.

*Figure 7.* This pattern of data would suggest that contributions to search termination are partly metacognitive and partly experiential.

*Figure 8.* Alternatively, we could find that search termination is based on experience alone.

References

Chun, M. M., & Wolfe, J. M. (1996). Just say no: How are visual searches terminated when

there is no target present?. *Cognitive psychology*, *30*(1), 39-78.

Matan, M., Fleming, S. (2020). Metacognitive contributions to visual search termination.

Manuscript in preparation.

Moran, R., Zehetleitner, M., Müller, H. J., & Usher, M. (2013). Competitive guided search:

Meeting the challenge of benchmark RT distributions. *Journal of Vision*, *13*(8), 24

24.

Wolfe, J. M. (1998). What can 1 million trials tell us about visual search?. *Psychological*

*Science*, *9*(1), 33-39.

Wolfe, J. M., & Gray, W. (2007). Guided search 4.0. Integrated Models of Cognitive

Systems, 99–119.