# Visual Search Strategies and the Layout of the Display

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## Introduction

The role of visual search in everyday tasks is paramount. Whether we are searching for an item in the grocery store, trying to find our car in a busy parking garage, or looking for an important piece of information on a web page, the visual search mechanism is crucial. We are also quite efficient at performing all of these tasks. The main focus of the current proposal will be to further our understanding and modeling of what makes the process so efficient. The key emphasis here is on the process of visual search – the actual strategies that people utilize as they search for things and the degree to which memory plays a role in aiding in this process.

Visual search as a paradigm has been studied meticulously for the better part of the last 50 years. The paradigm consists of the detection of a target among a varying number of distractors with the dependent measure being whether the search is serial or parallel (Duncan & Humphreys, 1989; Treisman & Gelade, 1980; Wolfe, 1994).

The role of memory within visual search has also been greatly debated. In some instances, researchers have inferred from response time data that memory is not utilized during search because there was not a difference in response time between static and dynamic search conditions (Horowitz & Wolfe, 2003; Korner & Gilchrist, 2007; Melcher & Kowler, 2001; Peterson, Beck, & Wong, 2008; Peterson, Kramer, Wang, Irwin, & McCarley, 2001). In other instances, it has been shown that visual search is guided by memory for previously viewed items (Korner & Gilchrist, 2007; Peterson et al., 2008; Peterson et al., 2001). In particular, eye movement provides a more detailed picture of the underlying search process (Geyer, von Muhlenen, & Muller, 2007). Geyer et. al. used the same search paradigm as Horowitz and Wolfe but analyzed the eye movement behavior in addition to the response time data and found that participants rarely re-fixate items suggesting a role for memory in visual search. Furthermore, path memory has also been shown to exist suggesting that more of the distractor space is represented (Dickinson & Zelinsky, 2007).

In all of these studies, however, it was specifically visual search that was being manipulated and measured. As such, these tasks have been relatively simple – presenting items on the screen for varying lengths of time and measuring how long it took for participants to find the target. In the current work, the visual search process will be analyzed and modeled embedded within the context of a larger task. In particular, I am interested in how the search process is modulated when people are forced to wait for information to appear (during a timed lockout) and by having searched for other items on the same display. In the course of attempting to model performance on this task (using ACT-R), it was found that the model had problems with the basic visual search process. It is therefore the goals of the current work to explore the visual search strategies employed by participants and implement them in the model, which will consequently aid in modeling the rest of the task.

## The Task

A simple radar task was used to determine how people allocate attention when forced to wait for information to appear. As compared to traditional visual search tasks where each trial consists of a single target among varying numbers of distractors, this task had distractors that on another visual pass through the display could be targets. Therefore memory for previous distractors would be beneficial and may guide subsequent searches.

### Procedure

Participants were eye-tracked while they completed 60 trials of the task. A radar screen (Figure 1) was displayed on the left and was comprised of a static display of 20 2-digit numbers arranged randomly on the display. On the right side of the screen was the table of alternatives (TOA).

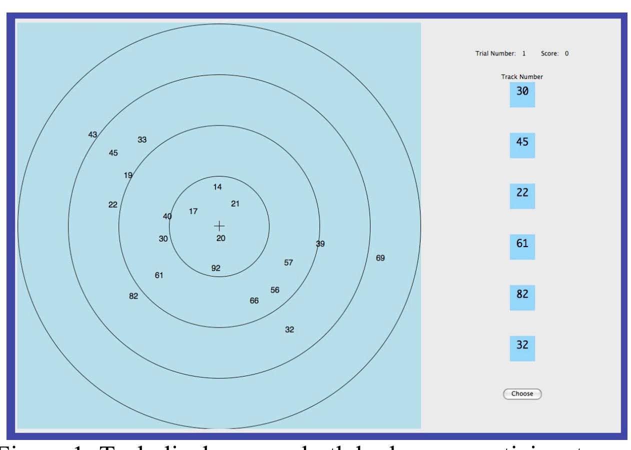


Figure 1: Task display, seen both by human participants and the model.

During the trial, the task of the participant was to determine which of the six targets from the TOA had the highest threat value. Threat values ranged from 0(lowest) to 9(highest). In order to discover the threat value of a particular alternative (target), the participant had to find and click on the target in the radar display. Once a target was clicked (selected), there was a lockout delay of 1, 2, 4 or 8s depending on the participant's condition. The threat value would then appear next to the selected item. Consequently, the participant had to repeat this process with the rest of the items from the TOA until the highest threat-valued target was discovered.

## Preliminary Analyses & Model

Preliminary analyses of the data were done with respect to the first several fixations on each trial to determine the search strategies used to find the first target clicked. A typical sequence of first fixations involved participants looking at 1-2 TOA items and then moving their gaze to the radar. Participants were able to find the first item they selected in an average of 6 fixations, with no differences between the four conditions. Participants also tended to re-fixate items on the radar display in ~15.37% of fixations prior to selecting the first target.

In order to inform the model's search initiation, I also looked at where participants tended to begin their search. There were several possibilities: a) closest to TOA, b) closest to center of the radar, c) closest to one of the corners of the radar, d) to the item that had the most other items around it (most 'clustered'), e) to the item that had the least other items around it (singleton). The results are beyond the scope of this paper, but they will be used to inform the model.

The ACT-R cognitive architecture will be used to model this task because of its ability to ground the model in the same environment that human participants saw (Anderson et al., 2004). The goal of the proposed work will be to use human data to inform the model's visual search process as in its current state it is considerably more inefficient than human participants in finding the targets in the radar. ACT-R currently uses the finst mechanism for ensuring that items previously fixated are not re-fixated within a given amount of time. However, although people find the item they are searching for efficiently (within 6 fixations), they also tend to revisit items they have viewed before suggesting that relying on the finst mechanism is insufficient to model behavior.

## Future Work

Instead of relying on the finst mechanism, the proposed work will determine the degree to which the visual segmentation of the display allows for the efficient search process. Others have shown that fixations and saccades progress in a course-to-fine strategy whereby fixation durations increase while saccade amplitudes decrease as search continues (Over, Hooge, Vlaskamp, & Erkelens, 2007). The current work will explore whether people systematically search the displays such that they look within visual 'clusters' of items, thereby minimizing the number of areas they need to search to find the targets.

Currently, a k-means clustering algorithm has been used to quantitatively assess which items appear to cluster together on each screen. However, k-means has the limitation that it is difficult to know what value of k is appropriate for each screen layout. Therefore, a new study is being run which presents the same screen layouts the original participants saw to naïve participants who are asked to make these judgments.

The modeling work will take into account the findings from this new study and will incorporate the visual search strategies employed both at the beginning of each trial, during subsequent searches, and during lockouts.

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