STATISTICAL REPRESENTATIONS IN A TARGET-SEARCH TASK

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ABSTRACT

Our objective was to explore the nature of the statistics learned over time by individuals completing a target-search task. Humans have access to a wide variety of statistical representations of their environments, and make use of these in conscious and unconscious ways. 17 participants from the University of Waterloo were recruited to perform a 300-trial target-search task, as well as to complete a survey about their explicit understanding of their performance. Preliminary results show that individuals use a variety of strategies to improve, and that these vary depending on target information. This type of exploratory study is valuable in that it provides a foundation for directing further studies involving statistical learning in target-search tasks.

ON LEARNING STATISTICS…

It has been suggested (Chong & Treisman, 2005; Chukoskie, Schwartz, Sejnowski, & Krauzlis, 2010) that individuals have some statistical understanding of their environments and the input they receive, often related to the mean. The presentation of multiple stimuli leads to an eventual ability to consider all components simultaneously. Ariely (2001) noted that the visual system is able to represent overall statistical properties when experiencing sets of similar objects. Chukoskie et al. (2010) showed that participants were able to learn over time not only the central peak of a distribution, but a rough knowledge of its shape as well. Chukoskie et al. used a structured, pink noise background for their trials. The researchers found that even though noise landmarks were unrelated to target location, subjects still used them as markers for their guesses.

EXPERIMENTAL DESIGN

Participants and Hardware

Seventeen undergraduate students from the University of Waterloo participated in our study for participation credit. The study used a standard desktop computer and joystick. The search area was the computer screen. The trials took place in a windowless room (shown in Figure 1), lit to a comfortable level. Participants were naïve to the study.

Figure 1. Photograph of the room in which the trials took place. Individuals were seated in front of the desktop computer and used the joystick to navigate the search area (computer screen).

Target-search task trials

Our target search trials emulated the pattern of those administered by Chukoskie et al. (2010). Participants were shown a demonstration of the task, and then they were allowed to complete practice trials in order to familiarize themselves with the computer and joystick set-up. Trials were shown in 3 blocks of 100.

A target was obscured on the screen, in a location randomly selected by the program, within one of four pre-determined distributions to which the participant was naïve. The participant had ten chances per trial with which to locate each hidden target by means of selecting the target area with a joystick. Each unsuccessful attempt was followed by an increase in area with which to select the target, such that the participant had a greater chance of hitting the target. The diameter of the trigger area increased by a factor of 1.5, approximately doubling this area, as depicted in Figure 2.

Participant questionnaire

Upon completion of the target-search trials, participants completed a questionnaire. The questionnaire was designed to assess the participant's explicit knowledge of their use of statistics when completing the target-search task, as well as to probe any suspicions or intuitions they may have had about the distribution of their set of targets. Example questions included "Did you think the location of the target in earlier trials influenced its position in later trials? Explain," and "Did you think there was any pattern to the location of the targets? If so, please provide a description (words or pictures) of what you experienced."

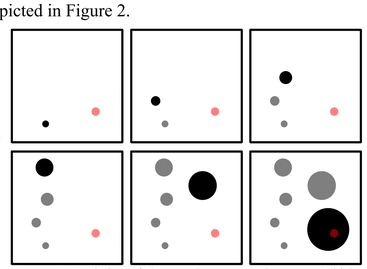

Figure 2. Depiction of the search process. The target (which would be obscured in the actual trials) is shown in red. Progression of the increasing search area is shown across the six frames, with the final frame showing the target being located.

Participant questionnaires were noted and recorded, but have yet to be used for any analysis thus far.

TARGET DISTRIBUTIONS

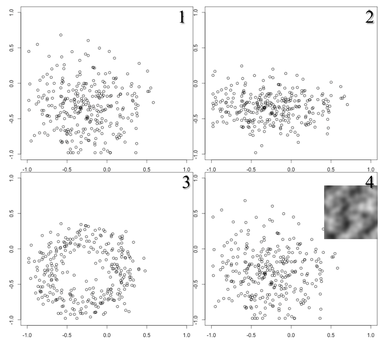

Figure 3. The distributions. Distributions 1 and 4 are identical.

Target distributions

During the trials, targets were randomly selected according to one of four pre-programmed distributions:

1. A normal Gaussian curve,
2. A normal curve but with different variance in the x and y directions
3. A 'volcano' shaped distribution in which the mean never occurs as one of the target locations,
4. A normal Gaussian curve with a visible, random pink noise background underlying the entire search area. (Shown here as a clip.)

Each participant experienced only one of the distributions. Target locations were the same on corresponding blocks for each participant (ie. the target location on trial 5 of block 1 was the same as trial 5 of block 2, and trial 5 of block 3). Distribution 1 and Distribution 4 were exactly the same, except for the random pink noise background. Additionally, the means of all four distributions were quite similar, though not exactly the same (except for distributions 1 and 4, which were identical).

PRELIMINARY RESULTS AND FINDINGS

There was no significant effect of trial number on first shot accuracy (by linear regression for all participants, $p > 0.05$) This means that subjects did not move their first guesses closer to the mean of the distribution over time. However, comparing the distance from the mean coordinate of the shots of each trial to the mean of the distribution found significant negative effects for 9 of the 16 participants (by linear regression, comparing distance from mean to trial number). Regression lines are shown in Figure 4; summary statistics are displayed in the table below and to the right.

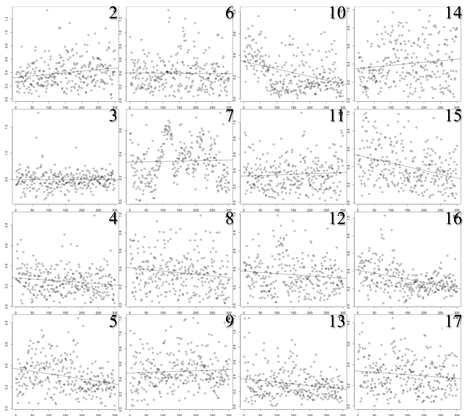

Figure 4. Linear regressions of distance from shots-per-trial mean to mean of the distribution across trials. Negative slopes indicate the distance between these two became shorter over time.

Linear Regression of Mean Shots-per-trial to Distribution Mean

SUBJECT	T-VALUE	DEGREES OF FREEDOM	SIGNIFICANCE
2~	3.434	1, 298	0.000***
3	-0.175	1, 293	0.861
4	-2.742	1, 298	0.007***
5	-5.017	1, 298	0.000***
6	-0.282	1, 298	0.778
7	0.548	1, 298	0.584
8	-2.734	1, 298	0.007***
9	1.049	1, 298	0.295
10	-6.874	1, 298	0.000***
11	1.156	1, 298	0.248
12	-2.127	1, 298	0.343
13	-3.726	1, 298	0.000***
14~	2.331	1, 298	0.020*
15	-6.353	1, 298	0.000***
16	-7.545	1, 296	0.000***
17	0.031	1, 298	0.031*

Notes: Significance results for linear regression comparing distance from mean of shots per trial to mean of the distribution to trial number. *p < .01, **p <.001, ***p <0. Participants marked with ~ showed significant positive results., meaning the regressions had positive slopes. This means the distances between the shots-per-trial mean and the distribution mean actually increased for these individuals.

Additionally, participants showed evidence of both mean and distribution learning; however, this was related less to the first shot of each trial, and more to the mean of their shots over the trial, similar to the phenomena found for distance from target mean. Participants in the normal and the normal/noise distributions were able to approximate the spread with great accuracy.

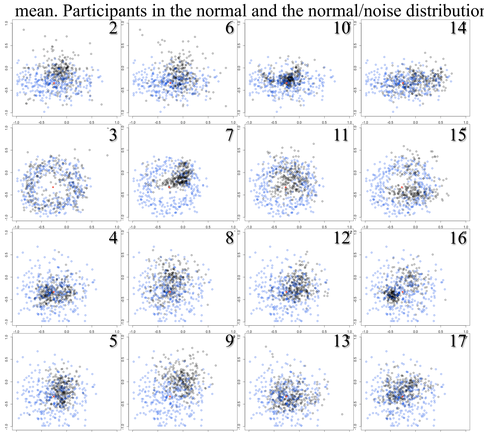

Figure 5. Distributions and means of shots-per-trial. The distributions are shown in blue, their means in red, and the shots-per-trial means in black.

Due to the target distributions remaining the same across the three trial blocks, distribution approximation is seen to improve across blocks for some participants. The following two examples, show approximation of the distribution mean across the three blocks. Both participants had significant results on their shots-per-trial regressions.

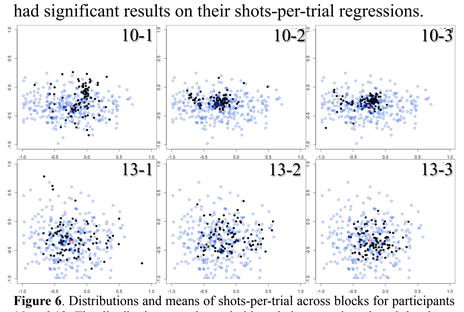

Figure 6. Distributions and means of shots-per-trial across blocks for participants 10 and 13. The distributions are shown in blue, their means in red, and the shots-per-trial means in black.

By and large, for all participants the first shot of each trial fell on the exact centre of the search area (computer screen), or directly vertical or horizontal from this point, as shown by Participant 5 in Figure 6. This is perhaps an artefact of the trigger placement at the beginning of each trial. However, in the cases of two participants, the first shots approximated the distribution almost as well as the mean of the shots-per-trial. This is especially clear in the distributions of Participant 14, as shown to the left in Figure 6.

Finally, we compared the mean of the distance between first shot of trial 'n' to the target of trial 'n-1' as a function of trial number. We took the true mean of this distance for the participant, stored it, randomized the trial numbers, and looped the analysis one hundred more times using each participant's randomized data. Results in the table below and to the right indicate that perhaps some participant's significant regressions could possibly be explained by the participant increasingly choosing to search where the previous trial's target was, as this distance is related to trial number. Histograms of the random distance mean distributions compared to the true mean are shown below in Figure 8 for each participant.

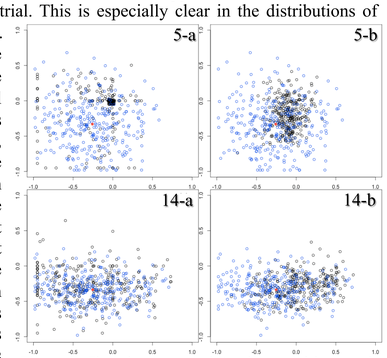

Figure 7. First shots compared to shots-per-trial mean for Participants 5 and 14. The distribution is blue; shots are black. Column 'a' shows first shots; column 'b' shots-per-trial mean.

Figure 8. Histograms of random mean distributions vs. true mean (depicted as an 'X') for first-shot-to-last-target distances across trial number. Note all x-axes are (0.5-0.9) except for participants 7 and 14.

Looped Mean Summations

SUBJECT	MEAN	SIG
2	0.586	0.01**
3	0.669	0.16
4	0.513	0.01**
5	0.613	0.29
6	0.652	0.01**
7	0.928	0.05*
8	0.619	0.16
9	0.774	0.22
10	0.608	0.01**
11	0.684	0.37
12	0.554	0.01**
13	0.539	0.01**
14	0.133	0.01**
15	0.646	0.03*
16	0.651	0.91
17	0.488	0.01**

Notes: Significance results for looped mean summations, comparing distance from first shot of trial (n) to target of trial (n-1) as a function of trial number *p < .05, **p <.01.

DIRECTIONS FOR FUTURE RESEARCH

Due to the exploratory nature of our study, it is crucial that we maintain a sense of skepticism when interpreting results. While our pilot set up is an excellent platform from which to develop further studies, there are some shortcomings. Our participant pool is quite small: in further studies, a much larger population pool would be helpful. It would be optimal to conduct analyses across conditions. Additionally, the 'growing' of our trigger area was included in order to include some sense of control into our participant, however it does create some problems. In further studies, optimizing the trigger size in relation to the target distributions, and fixing its size to a single area would greatly increase the reliability of results. It would also be worthwhile to use information from the participant questionnaires to gather insight on participants' explicit understanding of the task.

Finally, our protocol is limited in that its simplicity is both its strength and its weakness. Real-world validity would be greatly increased if such statistical target-search tasks were done in real world settings, outside of 'familiar' landscapes. To gather more data about how we learn what we learn, further studies will have to be done with similar steps, yet outside of a laboratory setting, for example in a situation like an airport scanner. A target search within a 'scanner like' set up would remove environmental priors from the search, and also allow a greater sense of real-world validity. Such real-world searches are extremely common, and could be emulated.

AS REFERENCED

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