Experimental Design Project Report

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Introduction

The goal of the experiment is to test whether two visual variables (size and orientation) are preattentive or not.

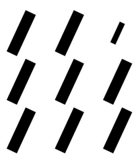
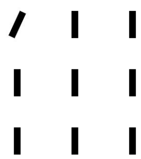
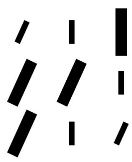
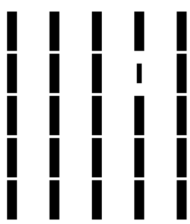
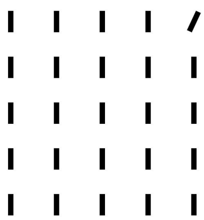
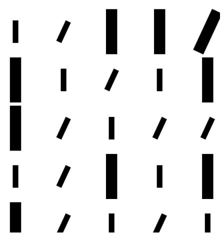
Hypotheses

We have the following hypotheses regarding the visual variables of objects.
H1: Size is preattentive.
H2: Orientation is preattentive.
H3: Size and orientation are preattentive when combined.

Operationalization

Factors:

We choose visual variables and object count as the factors. The Visual Variables have three levels: Size, Orientation and OrientationSize. It means that the target object is different from the rest in terms of size, orientation or orientation & size. While the Object Count also has three levels: Small, Medium and Large. Specifically, the layout would contain 9 objects for small object count, 25 for medium, and 49 for large. Examples are shown in Table1.

		Visual variables		
		Size	Orientation	OrientationSize
Object count	Small			
	Medium			

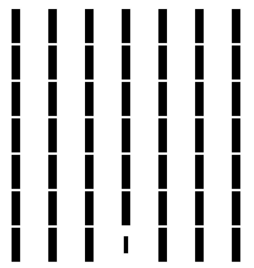
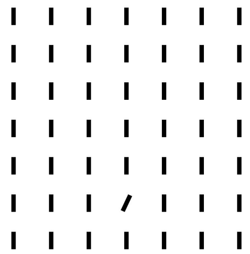
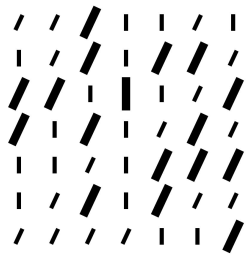
	Large			

Table 1: Experiment overview

Measures:
We measure the reaction time (visual search time) for finding the target. If the visual variable is preattentive, participants won't spend extra or less time to look for the target as the object count changes, which means the number of objects would not influence the visual search time.

Experimental tasks:
The task is for users to find the target object, which is different from the rest.

Procedure

Type of design: 3x3 within-subject design

Number of participants: 6

The number of task replications:
Each participant would have 54 total trials, which is composed of 18 trials for each visual variable. Within each Visual Variable, every object count (small, medium, large) would be repeated 6 times.

Task presentation order:
We used the Latin square method to counterbalance the order effect. The visual variable was conducted in an order described in the following table, while the object count is assigned randomly with each condition (small, medium, large) for 6 times.

Participant	Block 1	Block 2	Block 3
1	Size	Orientation	OrientationSize
2	OrientationSize	Size	Orientation
3	Orientation	OrientationSize	Size
4	Size	Orientation	OrientationSize
5	OrientationSize	Size	Orientation
6	Orientation	OrientationSize	Size

Table 2. Latin square design

Experiment design:

1. Show numbers of rectangles (the number switches from 9, 25 and 49 during trials), which includes a target rectangle that differs from others
2. Participants are asked to press space when they find out the target rectangle.
3. After pressing space, all rectangles would be replaced with blank grids.
4. Ask users to click the grid that was the target rectangle.
5. If the user chose the right grid, the experiment would continue, and the search time would be recorded. If the user selected the wrong grid, the error would be counted, and the trial would be repeated. The search time would only be recorded for the trial that the participant chose the correct grid.

Participants

Six unpaid adult volunteers (Two male, four female), aged from 20 to 26 (average 23.12), all with normal or corrected to normal vision, with diverse backgrounds (1fluid mechanic, 2 data science, 3 HCI), served in the experiment.

Apparatus

We used a Lenovo Xiaoxin 15 laptop to run the experiment for participant 5&6, and used a Macbook 13 for the others. All the experiments on both devices are conducted on Chrome.

Results

For all trials, visual search time has a mean of 2035ms, a median of 1080ms, the first quartile of 743ms, and the third quartile of 2468ms. Data distributions of our sample are shown in Figure 1 and Figure 2, which show positive skew.

Table 3 shows the mean Visual Search Time of each condition, suggesting that when the visual variable is OrientationSize, the Mean Visual Search Time will increase as Object Count increases, which might contradict our H3. Therefore, we conducted ANOVA later to check more details and see if these differences were significant.

		Object Count			
		Small	Medium	Large	Total
Visual Variable	Size	903.06	1134.36	1168.5	1068.64
	Orientation	790.92	1022.86	988.19	933.99
	OrientationSize	2573.67	4341.81	5392.61	4102.69
	Total	1422.55	2166.34	2516.44	2035.11

Table 3. Mean Visual Search Time of each condition

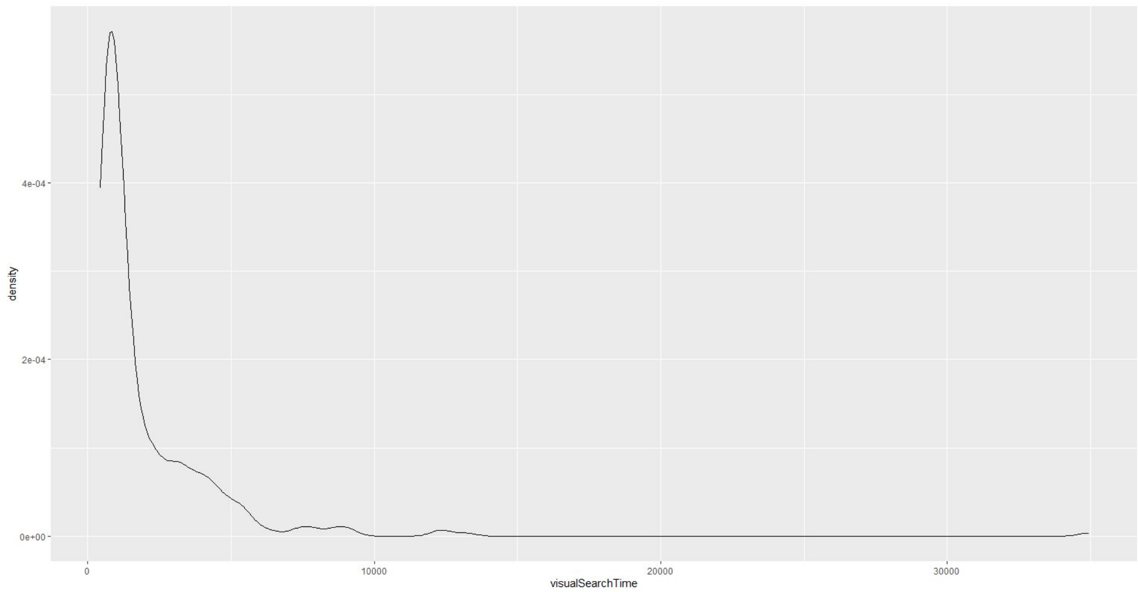


Figure 1. Data distribution

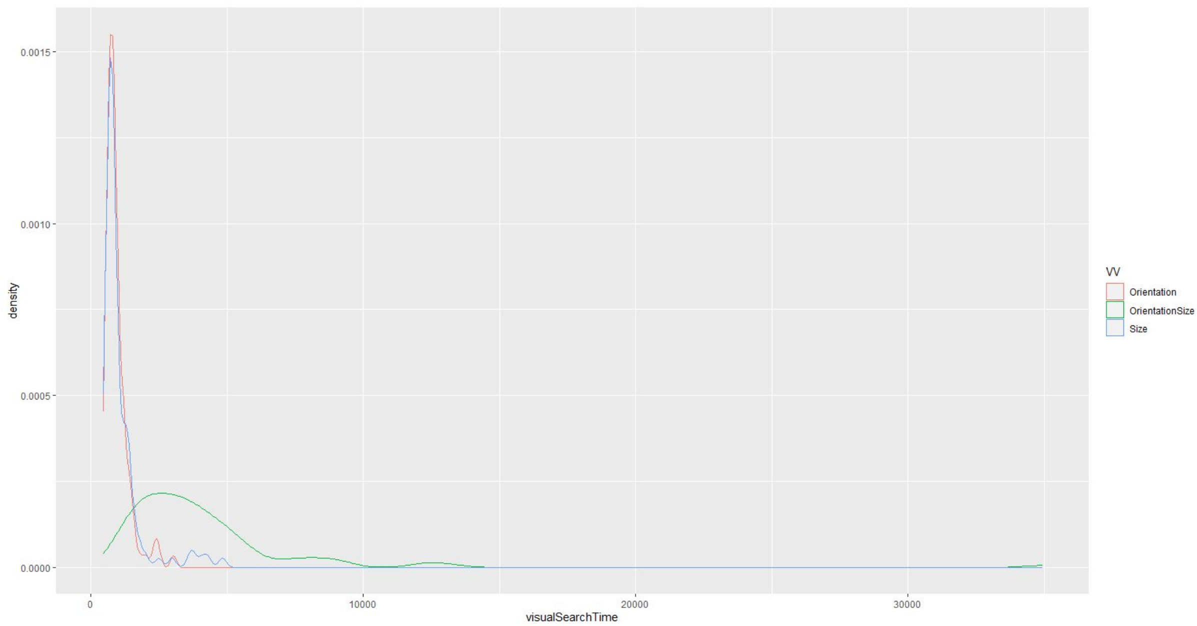


Figure 2. Data distribution per VV

For H3, a two-way ANOVA test revealed a significant effect of Visual Variable on Visual Search Time ($F(2,10) = 25.22$, $p < 0.001$, $\eta2=0.73$) (see Figure 3), a significant effect of Object Count on Visual Search Time ($F(2,10) = 6.77$, $p < 0.05$, $\eta2=0.21$) (see Figure 4), as well as a significant Visual Variable x Object Count interaction effect ($F(4,20) = 5.74$, $p < 0.001$, $\eta2=0.24$).

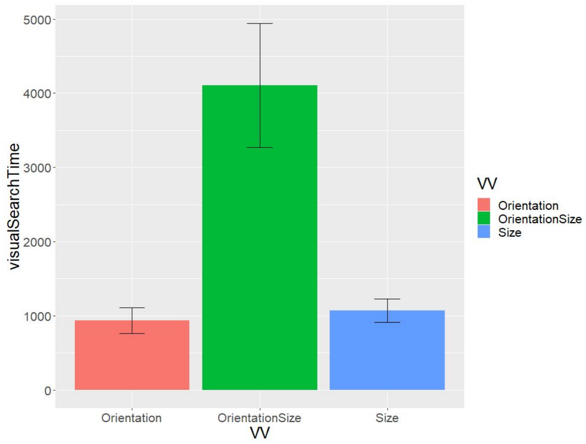


Figure 3. Mean Visual Search Time per VV

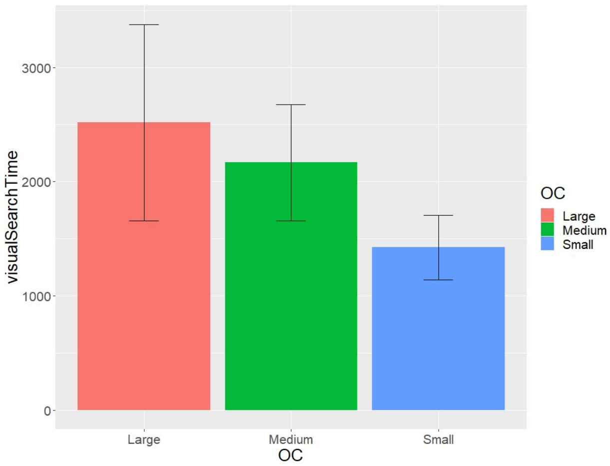


Figure 4. Mean Visual Search Time per OC

Pairwise comparisons show that the mean Visual Search Time was significantly different between Orientation and OrientationSize in all Object Count conditions, and between Size and OrientationSize group in all Object Count conditions. However, there are no significant differences between Orientation and Size in all Object Count conditions ($p=0.19$ at Small level, $p=0.54$ at Medium level, and $p=0.23$ at Large level). These results mean during each same OC level, participants would significantly spend more time searching the target of OrientationSize, while there were no significant time differences between searching the target of Orientation and searching the target of Size.

Pairwise comparisons also show that when the Visual Variable is OrientationSize, there is a significant mean Visual Search Time difference between Small and Large level of OC ($p=0.0081$), and between Small and Medium level of OC ($p=0.0038$), but not between Large and Medium level of OC ($p=0.2587$). It is also visualized in Figure 5.

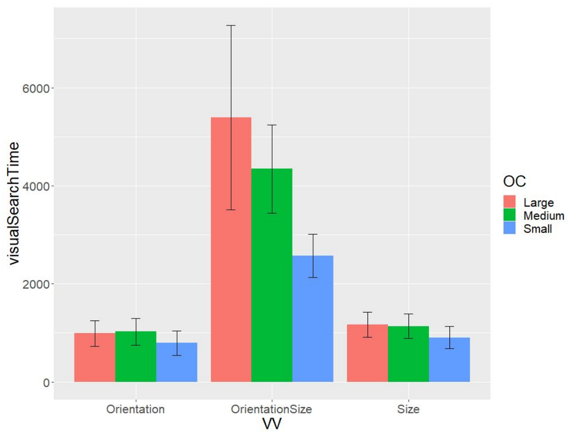


Figure 5. Mean Visual Search Time per VV x OC conditions

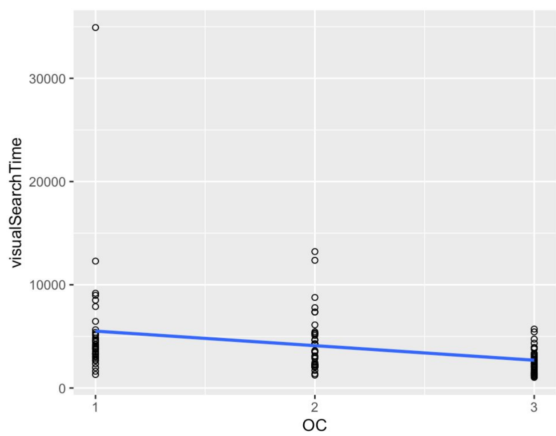


Figure 6. Linear regression on Visual Search Time when VV=OrientationSize

We also conducted a linear regression on Visual Search Time, choosing OC as the factor and confining VV to OrientationSize. A significant regression equation was found, with an r-square of 0.0914 ($p=0.0014$). Visual Search Time in ms is equal to 6921.6 - 1409.5 x OC. (we converted 'Large' to '1', 'Medium' to '2' and 'Small' to '3') (see Figure 6) This means when the number of objects increases, participants would spend more time to find the target in the VV=OrientationSize condition.

From the results above, we can learn that H3 is partially rejected.

For H1, a one-way ANOVA test revealed that the Visual Search Time was not significantly different at different Object Count levels when VV is Size ($F(2,10) = 3.02$, $p = 0.094$, $\eta 2=0.04$). It means that if the object number changes, the research time for finding the target with the Size feature won't be significantly affected. Therefore, H1 is accepted. Size is preattentive.

For H2, a one-way ANOVA test revealed that the Visual Search Time was not significantly different at different Object Count levels when VV is Orientation ($F(2,10) = 3.19$, $p = 0.085$, $\eta 2=0.14$). It means that if the object number changes, the research time for finding the target with the Orientation feature won't be significantly affected. Therefore, H2 is accepted. Orientation is preattentive.

Conclusion

Our analysis supports Hypothesis 1 and Hypothesis 2, and it rejects Hypothesis 3. The highlights, potential limits and threats of validity are discussed as follows

Highlights

1. In our experiment design, we chose two very great visual variables: the orientation and the size. As shown in Table 1, we can see that the target is very distinguishable from the others.

Potential limits

1. Lack of practice
   We didn't design a practice section for the participants to get used to the tasks and the interface. In the first few trials, we noticed that participants were not used to the keyboard operation, i.e., press `Enter` to start the next trial and press `Space` when spotting the target. Participants tended to confuse the keys and their functions. However, after around 10 to 15 trials, participants were able to operate intuitively.
2. Extreme outliers
   Some data is exceptionally different from the others and could be considered as noises. These data could be filtered while it is worth discussing the border between unlikely values and noises.

Threats of validity

1. Insufficient guidance
   When experimenting on-site, we noticed that the participants are still confused about what to do after reading the instructions. Then the instructors still need to demonstrate and to explain step by step. However, some participants experimented remotely without additional help, which may make these results not as valid.
2. Participants

Three of the participants are experiment designers who are very familiar with the experiment's instructions and goals. It could cause a selection bias as half of the participants are experts in the sense.

Appendix

Here is the Github link to our codes and participants' data, which can be accessed freely for reproduction.
https://github.com/Eurus-J-Zhang/ProjectExperience/tree/main/ExperimentDesign
Here is the link for accessing the experiment.
https://eurus-j-zhang.github.io/ProjectExperience/ExperimentDesign/experiment