Attention

Aim

Our task is to measure the speed of the attention in the vertical vs horizontal directions; using different conditions such as delayed stimulus and/or smaller/larger distances.

Experimental Design

In this experiment, the subject is first presented with a 'starting screen' that introduces the key to press for input, which is chosen to be 'enter' in this experiment.

- Trial

When the experiment starts, the subject is first presented with a 'focus marker' in the middle of the screen for 0.5 second.

After the focus period, a cue appears in a randomised location on the screen for 0.2 second and it disappears. There is a randomly chosen delay of 100/300 ms before the appearance of the target.

The target is presented after the delay for 0.2 second and then it also disappears. Then the user is expected to press enter after seeing the target, which is recorded to be analysed.

So it is a linear process which looks like figure 1.

Figure 1: Trial structure

- Session

In one session, a total of 1280 trials are done. These trials consist of different phases; valid/invalid trials and delays of 100/300 ms.

A valid trial is a trial in which the cue and the target appear at the same location while an invalid one is where they do not. For every location on the screen, these 2 types of trials must be equally presented.

The delay between the cue and the target is also randomly changed, but the total number of both of these delays must be equal for every location, just as the trial type is.

So considering the total of 1280 trials, for a 4x4 grid size, we have 16 locations, which means 80 trials are done per location. Also considering the 4 different possible trial types (Valid-100, Invalid-100, Valid-300 and Invalid-300), each of the types are presented 20 times to the subject. This is shown graphically in figure 2.
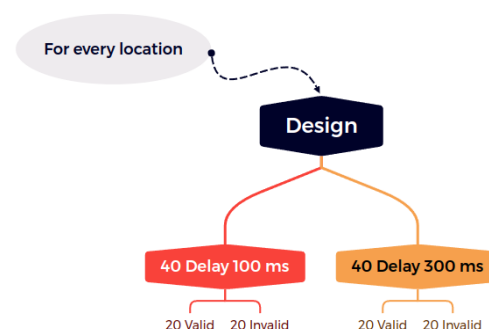

Figure 2: Location counts for different types of trials

Implementation

The screen is first divided into grids so that the cue can appear randomly in a given grid. Cue appearances in every grid are counted so that

the cue appears with the same number on the screen locations. There is also a noise present which shifts the cue location inside the grid.

In the invalid trials, the target location is chosen randomly again with noise to move the target inside the grids. The grid choice is done with weights to equally choose between different distances. What that means is euclidean distances appear with roughly the same frequencies, so the subject is presented with a 'close' cue and a target just as frequent as a 'far away' cue and a target. Of course this is present only for invalid trials since valid trials are the ones where the euclidean distance equals to zero.

In my situation, the counts of euclidean distances are shown below in figure 3, which - even if not equal - are close to each other.
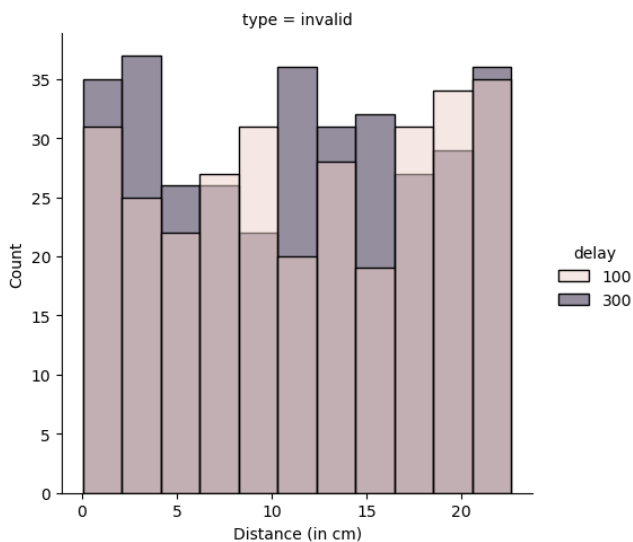

Figure 3: Counts of euclidean distances in one session

We also see in figure 3 that I have turned my units into centimetres. How I have done that is I have taken 2 points 1 unit apart in my figure, then used a ruler to measure the distance between them, and multiplied my distances in the data with that proportion, so that the analysis is done in cm rather than an arbitrary

unit created in Matlab which would change with different screen size.

It is also shown in figure 3 that the delays are also presented roughly in the same counts, and their total numbers are equal.

The user input time is counted with the commands tic and toc, and it is only counted after the figures are created and presented to the subject. This way, the computational time needed to prepare for the next trial is avoided to be taken into the data, and what is taken is only the subject's reaction time.

To sum up, the subject is presented in each type of trial an equal number of times and the subject's reaction time is measured for each type of trial, which is then analysed.

Results

The results presented here are for one subject (that is me) taken in a continuous run, with the same implementation described above.

- Data

My data consists of 1280 rows, each row corresponding to a trial, and the columns are as follows: ['dists', 'v_dists', 'h_dists', 'type', 'delay', 'times', 'bins', 'larger_bins'].

The columns that are collected during the session are 'dists' (euclidean distance between cue and the target), 'v_dists' (distance in the vertical plane), 'h_dists' (distance in the horizontal plane), 'type' (valid or invalid trial), 'delay' (the delay between the appearance of cue and the target) and 'times' (user reaction times). On the other hand, 2 more columns are added in the analysis phase, which are 'bins' and 'larger_bins', and both of them are the intervals of the distances

('bins' containing 23 bins and 'larger_bins' containing 6 bins) in order to determine the change in reaction times according to increasing distance.

The summary of the data can be shown with a violin plot, as in figure below, which at a first look, shows the different means and standard deviations for different types of trials. For example, valid trials seem to have less standard deviation compared to invalid trials. Also the highest mean seems to be in the invalid/100ms trials, which is kind of expected. Let us see statistically if these assumptions are correct, using t-tests for different groups.
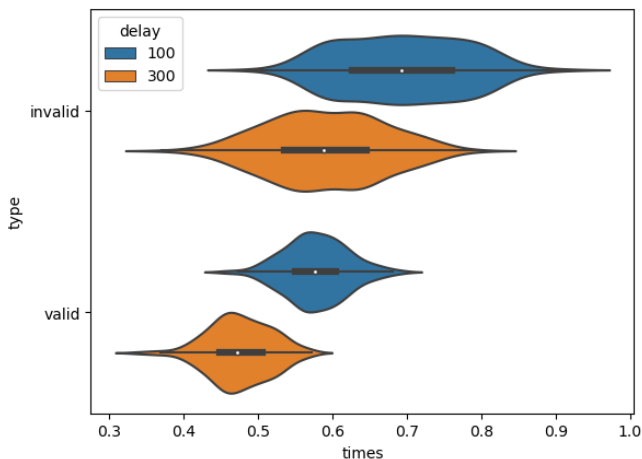

Figure 4: Violin plot of data

● Difference Between Valid and Invalid Trials

Figure 5 below shows graphically the difference between valid and invalid trials, and there clearly is a difference in terms of the mean response time. It seems that for valid trials, the reaction time is lower - which is expected since the cue and the target are presented at the same location.
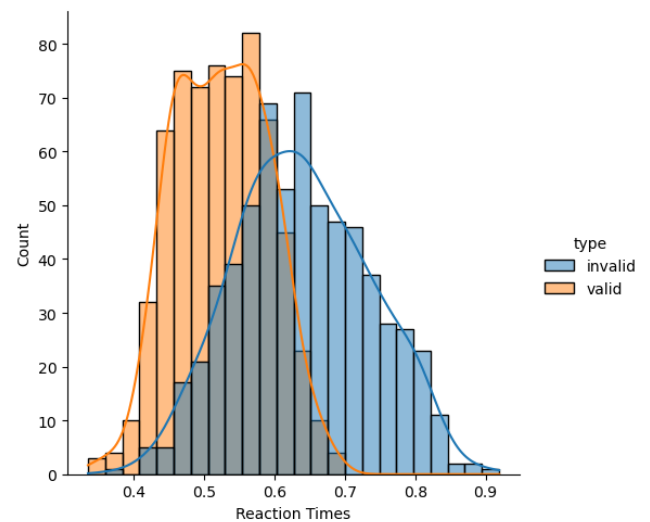

Figure 5: Difference Between Valid and Invalid Trials

We can prove the difference using a t-test (since we have 2 groups). Matlab code '*[h,p] = ttest2(valids, invalids)*' gives '*h=1*' for the data presented here, which means that these two groups significantly differ from each other ($p < 0.001$).

● Difference Between 100 and 300 ms Delay

What is expected beforehand for the delays, is that with a smaller delay (100 ms), the cue sometimes would not be clearly seen, so the subject reaction time might be more. Vice-a-versa, 300 ms delay is long enough to get the attention of the subject, so the subject can react to the target with a smaller reaction time.

I first plot the scatter plot for the data in hand, to see if there is a visible difference from each data. In figure 6, I believe it is clear that different delays have different reaction times, where both increase with the distance too.
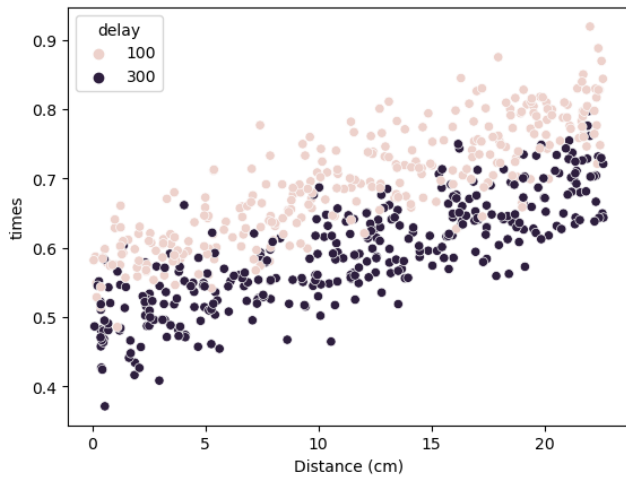
Figure 6: RT and distance compared to delays

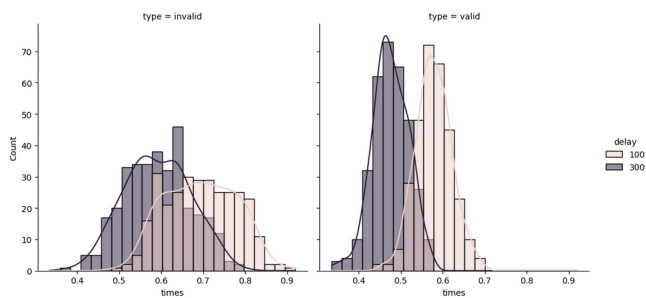Of course this can also be shown by a distribution plot, as in figure 7.

Figure 7: Distribution plot of delay times wrt different type of trials

The counts, even though seem to be different, their sums are equal for invalid and valid trials. Since the standard deviation is lower for valid trials, the counts are higher and there are lower number of bins present, hence, the steeper the curve is for the valid trials.

Note that for both of them, the curves are seemingly different; for the 100 ms delay, mean invalid trial response is around 0.6 s and mean valid response is around 0.45 s while for 300 ms delay, mean invalid response is around 0.7 s and mean valid response time is around 0.55 s. Let us again check the hypothesis that these 2 groups differ significantly, using again a t-test.

From the same matlab function, I again got '*h = 1*' meaning that these 2 groups do differ significantly, which means that the mean response time is lower the longer the delay (p<0.001).

- Difference in Response Times with respect to Euclidean Distance

Figure 5 answered the hypothesis that the reaction time of the subject would differ given a longer delay time, but it also answers the question if it would differ with increasing euclidean distance. While the data is noisy, even the scatter plot clearly shows that this hypothesis holds. Figure 8 shows this with a first degree fit line, where the slope is positive. We also see the distributions where for distances, it is approximately uniform and for reaction times, distribution approximates normal distribution.
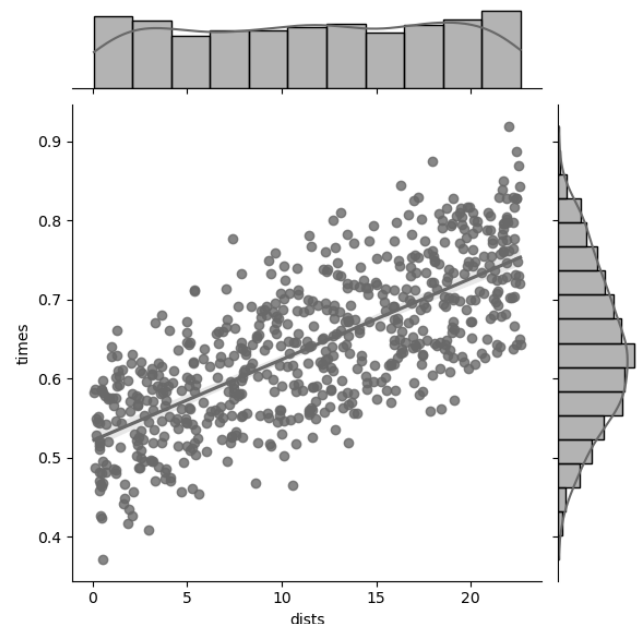

Figure 8: Conjoint plot of reaction times versus euclidean distance

In addition, we can also check vertical and horizontal distances and their respective reaction times. For that, I have created figure 9 shown below which also confirms that for an

increase in any direction, the reaction time gets bigger, regardless of the delay time.
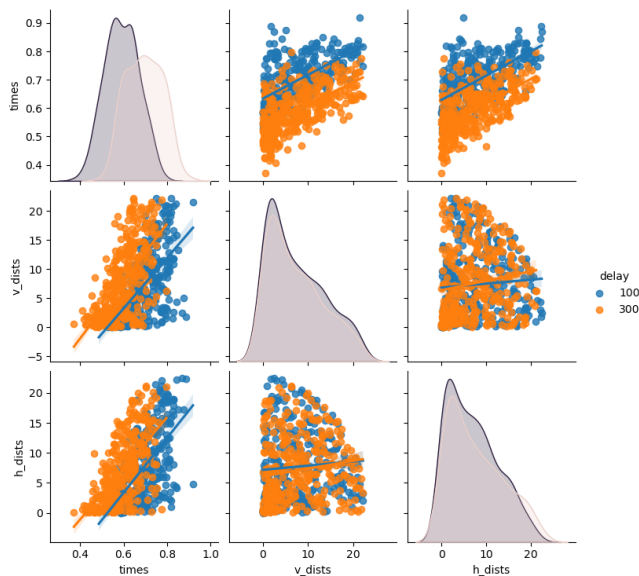

Figure 9: Reaction time vs Horizontal and Vertical Distance

The slopes are approximately equal, with values 0.93 for vertical distances and 0.97 for horizontal, meaning in this session of the experiment, vertical and horizontal searching for the target are not much different from each other.

Remember that these figures are created only for invalid trials, as for valid ones, there is no distance between cue and the target.

- Speed of the Attentional Scanner

I have calculated the speed of the subject by using $v = dx / dt$, where I have taken only the invalid trials and so dx equals to the euclidean distance between cue and the target and dt equals to the user reaction time. For the one subject experiment explained here, I have got the result of 17.25 cm/s of attentional speed.

Appendix

Multiple comparisons show us which groups differ significantly, and once again, we statistically show that trial type and delay both have significant effects on the subject reaction time (p<0.001). We also see that there is no significant interaction effect of type and delay since p is greater than 0.05.

	sum_sq	df	F	PR(>F)
C(type)	4.301474	1.0	1035.772536	7.221191e-167
C(delay)	3.366935	1.0	810.740385	1.843178e-138
C(type):C(delay)	0.000036	1.0	0.008616	9.260588e-01
Residual	5.299118	1276.0	NaN	NaN

Kadir Berat YILDIRIM