UBL201-L Introductory Biology III - Neurobiology

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Psychophysics and cognition

The experiment

This experiment is an introduction to psychophysics and cognition.

Psychophysics quantitatively investigates the relationship between physical stimuli and the sensations and perceptions they produce. It has been described as the study of the relation between stimulus and sensation or, more completely, as the analysis of perceptual processes by studying the effect on a subject's experience or behavior by systematically varying the properties of a stimulus along one or more physical dimensions.

Cognition is the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses. It encompasses many aspects of intellectual functions and processes such as attention, the formation of knowledge, memory and working memory, judgment and evaluation, reasoning and computation, problem solving and decision making, comprehension and production of language. Cognitive processes use existing knowledge and generate new knowledge.

In this experiment we study cognitive processes like visual attention, working memory and priming. The experiment consists of 6 tasks, each of which is designed to test a different aspect of cognition. The tasks are as follows:

1. Color Pop-out Task
2. Orientation Pop-out Task
3. Color-Orientation Conjunction Task
4. Color-Color Conjunction Task
5. Working Memory Task
6. Priming Task

The first four tasks are visual search tasks.

Visual search is a type of perceptual task requiring attention that typically involves an active scan of the visual environment for a particular object or feature (the target) among other objects or features (the distractors). It has a limited capacity for information processing and the ability to filter out unwanted information. The first two tasks are feature search tasks; the next two tasks are conjunction search tasks.

The last two tasks are memory tasks that test the working memory and priming. Priming is a phenomenon whereby exposure to one stimulus influences a response to a subsequent stimulus, without conscious guidance or intention. Working memory is a cognitive system with a limited capacity that is responsible for temporarily holding information available for processing.

We will infer the cognitive processes from the reaction time and accuracy of the subject in performing the tasks.

1. Color Pop-out Task

The color pop-out effect is a phenomenon in which a single feature, such as color, is sufficient to guide attention to a target item, regardless of the number of distractors or the similarity of the distractors to the target. In our task we observed that one of the objects pops out because of its dissimilarity to the other items, which have the same color.

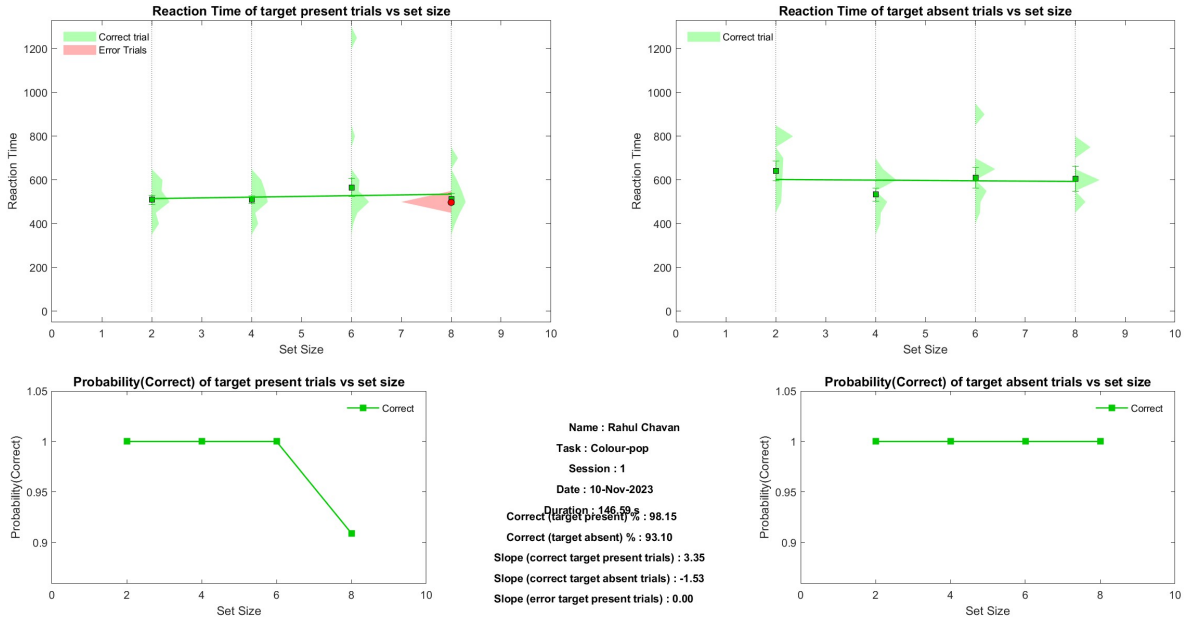

Figure 1: Plots for color pop-out task.

This is bottom-up processing where the visual system can detect these properties in parallel across the visual field. Here, the number of distractors does not matter in both the cases where the target is present and where the target is absent. This is concluded by the fact that the reaction time and accuracy (probability correct) is almost constant for different set sizes. A dip in the probability correct for large set size is observed in the target present condition. This could be due to the fatigue (impatience) of the subject and is not of significant interest.

2. Orientation Pop-out Task

The orientation pop-out effect is a phenomenon in which a single feature, such as orientation, is sufficient to guide attention to a target item, regardless of the number of distractors or the similarity of the distractors to the target.

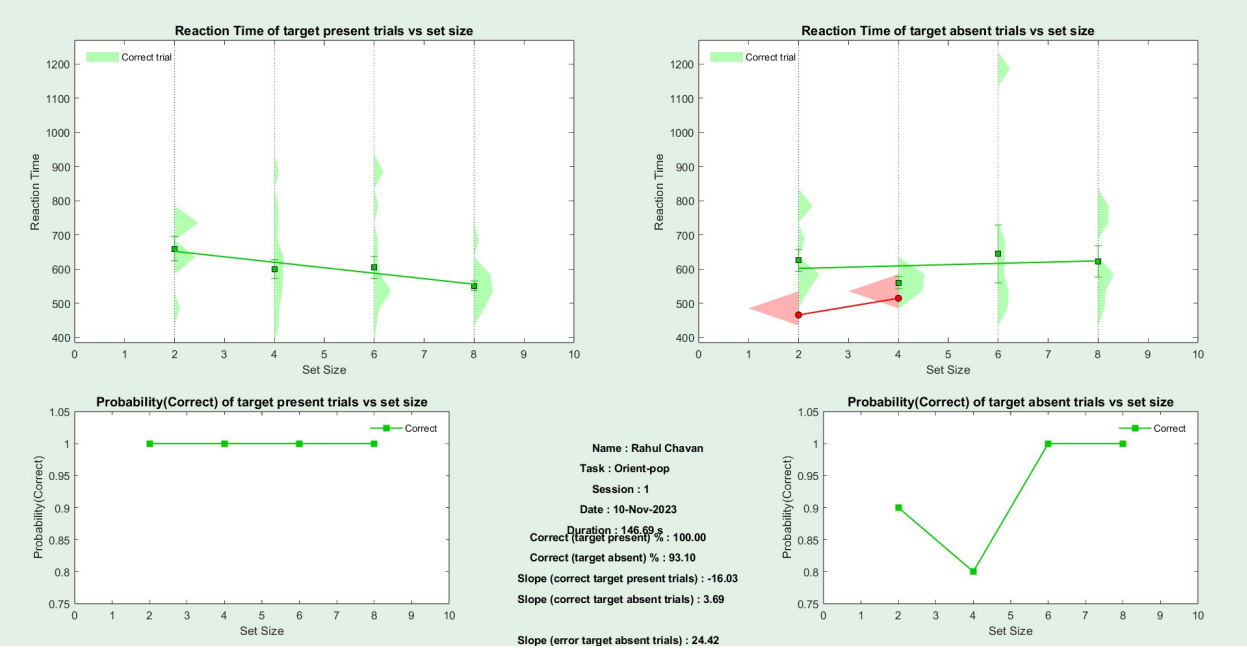

Figure 2: Plots for orientation pop-out task

In our task, when the color, length, and thickness of both the target and distractors are same but only the orientation of the distractors is different, the target pops out. Even with distributed attention, a single target object should be detected in the same amount of time, no matter how many distractors are present

In fact, the reaction time in target present condition decreased in the sets with more distractors. This could be due the fact that the distractors are more similar to each other than to the target, making it easier to detect the target and also because the subject is more attentive in the target present condition and has strategized to recognize it faster, which should not be hard as the target continuously pops out.

Here again, the number of distractors does not matter in both the cases where the target is present and where the target is absent, which is concluded by the fact that the reaction time and accuracy (probability correct) is almost constant for different set sizes (except for some errors in target absent condition leading to a dip in probability correct and can be accounted for by subject fatigue).

3. Color-Orientation Conjunction Task

The color-orientation conjunction effect is a phenomenon in which a single feature, such as color or orientation, is not sufficient to guide attention to a target item, but both features are required to guide attention to a target item. Here, the target is dissimilar from distractors in both color and orientation.

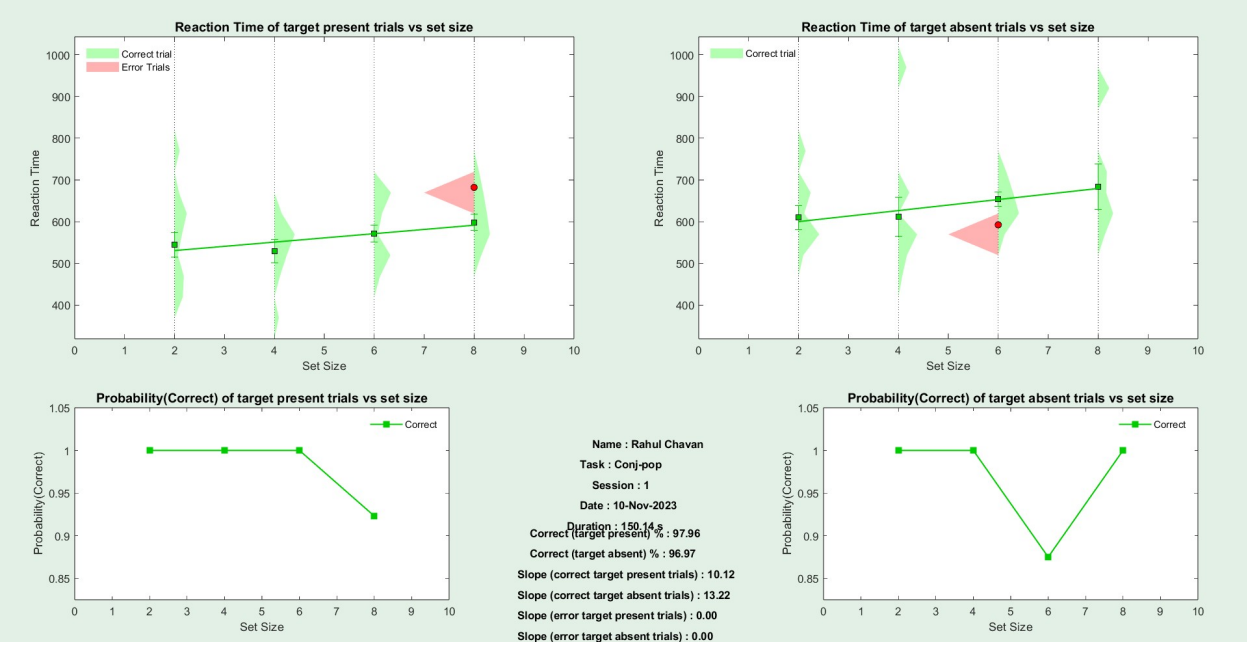

Figure 3: Plots for color-orientation conjunction task

We observe that on increasing the set size, the reaction time increases. This is serial search where we search for individual objects and try to match with the target until we exhaust all possibilities to conclude that the target is not present in the display.

We also observe that errors occur at large set sizes in both target present and target absent conditions. Also, the accuracy takes a dip in both the conditions at large set sizes. Clearly, the number of distractors does matter here. This is concluded by the fact that the reaction time is not constant and is gradually increasing with an increase in set sizes.

4. Color-Color Conjunction Task

The color-color conjunction effect is a phenomenon in which a single feature, such as color, is not sufficient to guide attention to a target item, but a combination of two colors is required to guide attention to a target item. Here we are looking for a particular color-color combination where red top - green bottom rectangle is the target whilst the opposite are the distractors.

We observe that this task in general has a higher reaction time. Also, the reaction time increases rapidly with an increase in set size in both target present and target absent conditions, which concludes that the number of distractors do matter here. The accuracy, however, is not affected much by the set size in both conditions. This is another example for serial search. Searching for an opposite orientation of the two colors in a pool of distractors with same colors is a difficult task, accounting for the higher reaction time.

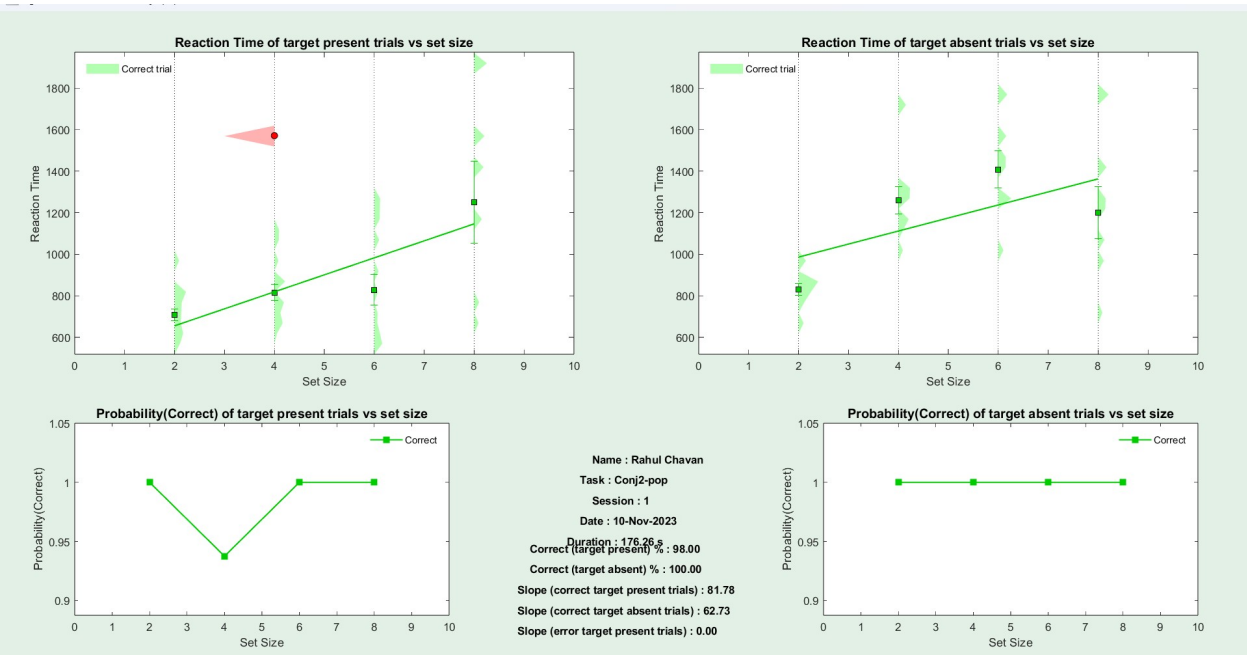

Figure 4: Plots for color-color conjunction task

We can in general also conclude that the reaction time is higher in conjunction search tasks than in feature search (pop-out) tasks. This is because in feature search tasks, the target pops out and is easy to detect and the visual field can be scanned in parallel, whereas in conjunction search tasks, the target does not pop out and the visual field has to be scanned serially to detect the target, causing a higher reaction time, and making the task difficult. The accuracy should also ideally decrease in conjunction search tasks as the distractors are more similar to the target than in feature search tasks, but this is not observed in our experiment and can be explained by the subject's strategy (like compensating with a higher reaction time) and attentiveness.

5. Working Memory Task

Working memory is a cognitive system with a limited capacity that is responsible for temporarily holding information available for processing.

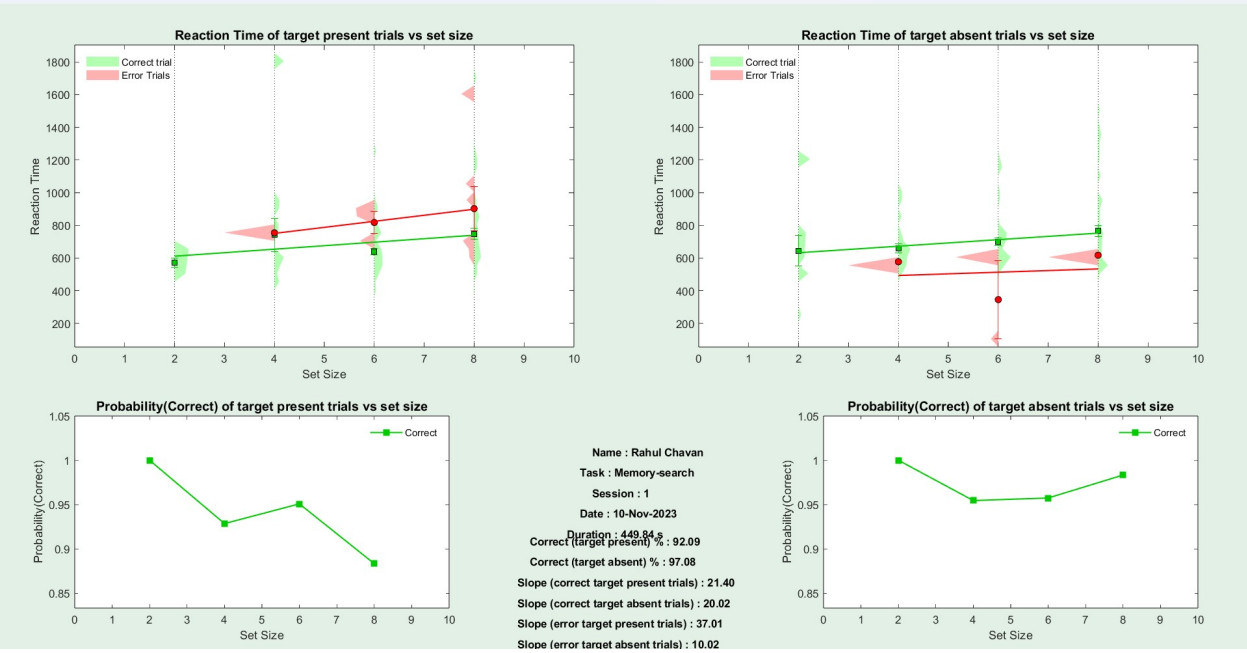

Figure 5: Plots for working memory task

In our task, we were asked to remember the letters presented on the screen and then search for their presence or absence on the next screen. We observe that the reaction time increases with an increase in set size in both target present and target absent conditions. The number of errors and the reaction time for those errors also increases with an increase in set size. We can also see that accuracy takes a dip with the increase in set size in both target present and target absent conditions. This is because the working memory has a limited capacity and the more the number of items to be remembered, the more difficult it is to remember them.

6. Priming Task

Priming is a phenomenon whereby exposure to one stimulus influences a response to a subsequent stimulus, without conscious guidance or intention. For example, the word NURSE is recognized more quickly following the word DOCTOR than following the word BREAD. Priming can be perceptual, semantic, or conceptual. It can also be positive, negative, or affective in nature.

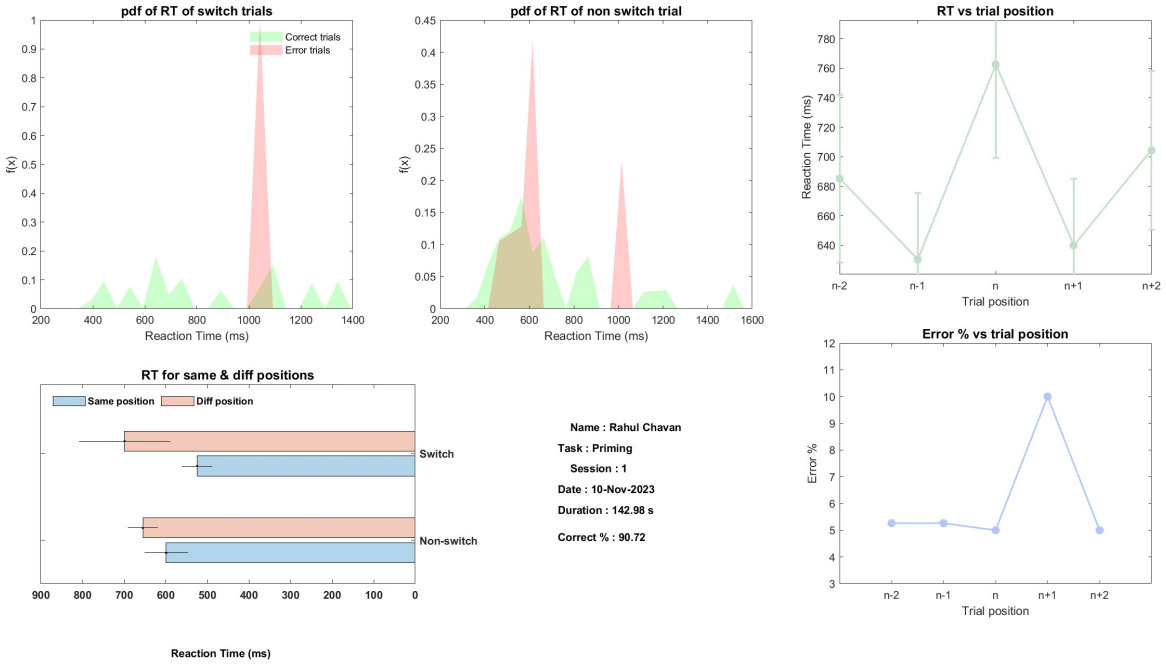

Figure 6: Plots for priming task

In our task, we were supposed to identify the presence of red squares among green squares and green squares among red squares.

If there is a sequence of red squares among green squares followed by a green square among red squares or vice versa, such trials are called switch trials. Here, the targets may or may not appear in the same position.

What is interesting to note is that the reaction time for switch trials is higher than that for non-switch trials. This is because the subject is primed to look for a particular color and the reaction time is less when the target appears at the same position. The reaction time is more when the target appears at a different position as the subject has to search for the target at all the positions. The accuracy is also less for switch trials than for non-switch trials. These can also vary with the subject's strategy and attentiveness.