Experiment 1(Group 4)

Prototype formation in natural stimuli

Prototype effect refers to the advantage of prototypes in various concept learning tasks as compared to other stimuli. Since first demonstrated by Posner and Keele (1968), it has been shown to play a pivotal role in many theories of categorization and concept learning. In this experiment, we aim to demonstrate this effect in a more naturalistic bug-like stimuli in classification learning paradigm. We found better mean accuracy and lower mean reaction times for prototypes as compared to other stimuli.

1. Introduction

Concepts and categories are indispensable to cognition as they allow us to establish order to disorganized sensory experiences. Wittgenstein argued that people have a strong impulse to see something as 'X' rather than simply seeing it [1]. The way these mental categories are represented in the mind has been a topic of substantial research in cognitive science. In the classic dot-pattern experiment, Posner & Keele argued that people store average or summary-like representation of categories rather than storing all individual exemplars[2]. When a new object is encountered , it is compared to the existing prototypes in the memory. If it matches with the prototype of category A (say dogs), it is categorized and treated as a dog. Medin and Smith (1981) used an experimental procedure that is known as classification learning[3] to demonstrate this effect. In classification learning, the training stimuli were presented one by one and participants were asked to categorize each stimulus (which is the variation of an underlying prototype) into one of the two possible categories. Feedback was provided after each categorization response. In the testing phase, unseen exemplars and the prototype of the category are presented along with the old exemplars. The prototype effect, thus, occurs when the prototype of a category is classified faster and more accurately than the unseen examplars. This effect has been demonstrated in various types of stimuli set and categorical structures like abstract geometric shapes[4], faces[5], linguistic categories[6] etc.
In this experiment, we aim to show this effect in a more natural stimulus set in the classification learning paradigm.

2. Methods

2.1. Subjects

Seven university students volunteered for this experiment(3 females, mean age = 22.3). Since it is a within subject design, all the participants were allocated to a single experimental group. Each subject went through two phases - training and testing.

2.2. Materials

The bug-like stimulus set used in Experiment 1 (Fig. 1) was similar to the one used by Minda and Smith(2001)[6]. It has six feature dimensions — shape of body(d1), shape of head(d2), type of eye(d3), length of legs(d4), shape of antenna(d5) and type of feet(d6). Each feature can be of either of the two types (0 or 1). The prototypes of each category contain maximally distinct feature sets (i.e - 0 0 0 0 0 and 1 1 1 1 1). Six exemplars of each category were generated by changing one or two features from the prototype. All stimuli were regenerated using Adobe Photoshop software(https://www.adobe.com/in/products/photoshop.html) and scaled to 960 X 720 pixels. The category structure was similar to the one used by Smith and Minda(Experiment 1 - Set B, 1998)[6]. It has the property of being linearly separable(LS) i.e a simple, additive evidence rule could correctly classify all the evidence . The categories were fairly coherent with structural ratio of 1.83 and average feature diagnocity of 0.76. Table 1 shows the logical structure of the categories used.

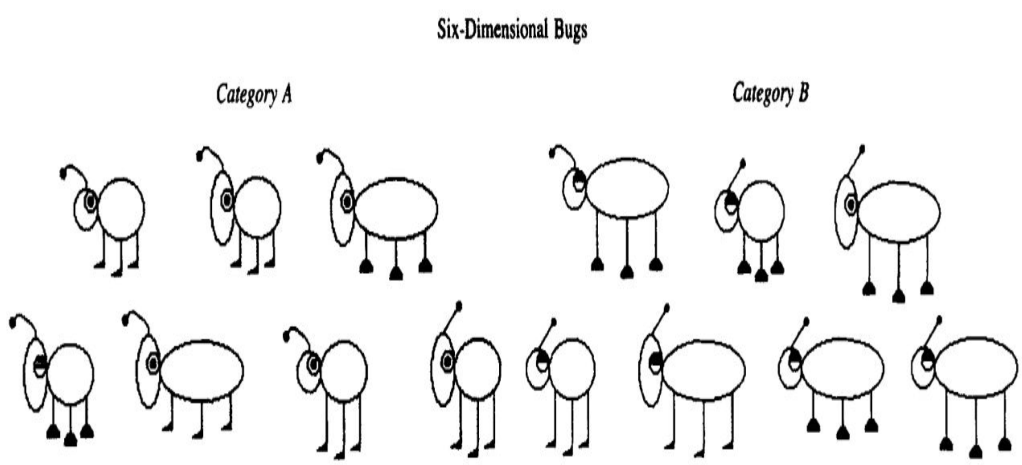

Figure 1 - Stimulus set used in the experiment. Adapted from Smith and Minda(1998)

Dimensions						
Stimulus	1	2	3	4	5	6
Category A						
A1(Prototype)	0	0	0	0	0	0
A2	0	1	0	0	0	0
A3	1	0	0	0	0	0
A4	0	0	0	1	0	1
A5	1	0	0	0	0	1
A6	0	0	1	0	1	0
A7	0	1	1	0	0	0
Category B						
B8(Prototype)	1	1	1	1	1	1
B9	1	1	1	1	0	1
B10	1	1	0	1	1	1
B11	1	0	1	1	1	0
B12	0	1	1	1	1	0
B13	1	0	1	0	1	1
B14	0	1	0	1	1	1

Table 1 - Logical category structure used in the experiment.

2.3. Procedure

It was assumed that the stimulus features had about equal salience since it was established in the previous study. The experiment consisted of two phases. In the training phase, 10 exemplars were randomly selected from the stimulus set (5 from each category) and were presented in a sequential fashion. The training stimuli did not consist of the prototype. The subject needed to respond by either pressing ‘a’ or ‘b’ (corresponding to category A or B) on the keyboard. Feedback was provided after each trial as either ‘Correct’(in green font) or ‘Incorrect’(in red font) along with the correct answer. The total number of trials in the training phase were 180(10 * 18) as all the stimulus were repeated 18 times.

In the testing phase, 2 of the previously seen exemplars(randomly selected) were presented along with 2 unseen exemplars and the prototype of each category. The total number of trials in the testing phase were 60(6 * 10) as each stimulus was presented 10 times in a randomized manner. No feedback was provided in the testing phase.
The total number of trials(training+testing) were reduced from the original experiment(560). It was done because the purpose of this experiment was to only observe the prototype effect and not to model the results.
The following instructions were displayed at the starting of the experiment :
“In this experiment, you will see a series of line drawings of bugs which can be classified either as "Category A" bugs or as "Category B" bugs. Your job is to look carefully at each bug and decide if it belongs to Category A or Category B. Press “a” on the keyboard if you think it is a Category A bug and “b” if you think it is a Category B bug. Appropriate feedback will be provided after each response. At first, the task will seem quite difficult, but with time and practice, you should be able to answer correctly. Press [space] to begin.”
The transition from training to testing phase was seamless and hence no separate instructions were required for testing phase. Categorization accuracy and Response time(RT) were recorded for each trial.
The experiment was conducted on cgs server(https://www.cgs.iitk.ac.in/wwwrw/srishabh20/prototype-experiment/experiment.html)

3. Results and Discussion

The accuracy and reaction times for each trial were recorded for all 7 participants. Accuracy and Reaction times for three different types of stimuli - Previously seen, Unseen and Prototypes are plotted for the testing phase in Figure 2 and Figure 3 respectively. The data has been averaged for all the participants as well as for each stimuli type. To ensure that participants' data reflected at least minimal mastery of the task, it was predetermined that participants who were below 60% correct in the training phase were excluded from the analysis.

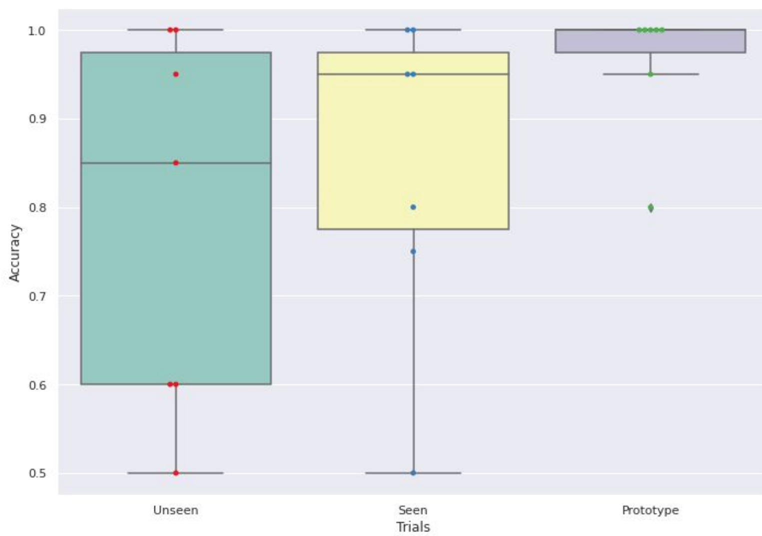

Figure 2 - Accuracy for different trial types(Unseen, seen and prototypes) in the testing phase

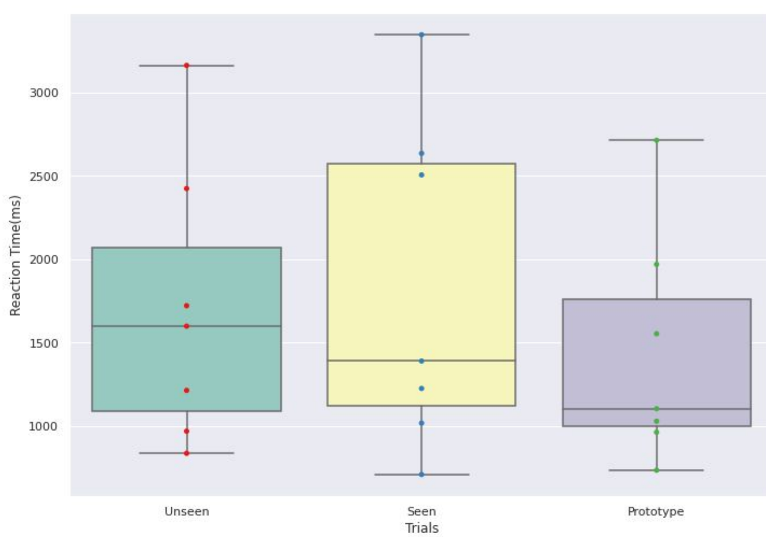

Figure 3 - Reaction Time(ms) for different trial types(Unseen, seen and prototypes) in the testing phase

Pairwise Kruskal-Wallis nonparametric analysis was performed for the three trial types.

	Unseen : Seen	Seen : Prototype	Unseen : Prototype
Accuracy	H-statistic : 0.1469(1,N=14) p-value : 0.70	H-statistic : 2.351(1,N=14) p-value : 0.13	H-statistic : 2.76(1,N=14) p-value : 0.09
Reaction Time	H-statistic : 0.102(1,N=14) p-value : 0.75	H-statistic : 0.3306(1,N=14) p-value : 0.57	H-statistic : 0.4939(1,N=14) p-value : 0.48

The results indicate that prototypes have better mean classification accuracy (mean = 0.96 and lesser reaction time(mean =1438 ms) as compared to the unseen stimuli. These results are interesting as both prototypes and unseen examples were not seen previously in the training phase. This is suggestive, but not conclusive, of the presence of prototype effect in natural stimuli as statistical significance was not reached.

References

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