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The Possible Role of Piriform Cortex in Association with Orbitofrontal Cortex in Human Learning

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Abstract: **Presently, there is a knowledge gap concerning the human orbitofrontal cortex and its link to the learning process. Through conducting research on the changes in the learning process after physiological increases of orbitofrontal cortex activity by nasal obstruction using odourless Vaseline, the study validates the hypothesis that the sensory properties of the orbitofrontal cortex facilitate the learning process in humans. The experiment conducted involves a control trial experiment with 40 participants. The results indicated that at the first 50 trials, the nasal obstructed participants outperformed the control group. Contrarily, there was a gradual increase in the performance of the control group. The study suggests that increased orbitofrontal cortex does facilitate learning. However, increasing its activity disrupts long-term memory as it affects encoding and consolidation of the declarative knowledge in hippocampus and related structure in the late trials.**

Keywords: **Orbitofrontal Cortex, Gradual Increase, Physiological Increases.**

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1. INTRODUCTION

The piriform cortex is one of the key structures participating in a neural network for sustaining elements such as fear, odour and learning. As one of the largest olfactory organs, the system is involved in the processing of olfactory input from the pyramidal cells in the anterior piriform cortex and the posterior piriform cortex (Haberly 2001). Furthermore, the correlative system functions similarly to those in association areas of neocortex, aside from the typical primary sensory functions that have been traditionally used to classify the system (Johnson and others 2000).

For a long time, the piriform cortex has been identified as the ‘primary’ olfactory cortex, which also encompasses other systems such as the olfactory tubercle and the peri amygdaloid cortex amongst others. This is because the system receives the largest neurotransmission from the mitral cells in the OB (Olfactory Bulb), which is the structure that transmits input from olfactory receptor neurons. However, studies from psychology and anatomy indicate that the cortical area is a complex and unique structure, designed differently from the primary cortical areas (Haberly, 1998). There is a circuit structure of neurons of the piriform cortex that receive input from the downstream brain regions such as the neocortical and subcortical regions. These regions receive odour-evoked signals and other multi-modal sensory input that it relays to the piriform cortex. In turn, the OFC provides direct feedback projections between the two structures (Johnson and others 2000).

Although the function of the piriform cortex is well documented in primates, there has been little research on the functioning of the system in human beings. In primates, the orbitofrontal cortex developed to a prominent structure that sends input back to the olfactory bulb. Thanks to recent advancements in neuroimaging, neurophysiology, and neuropsychology, the functions of the system have been identified. The studies indicate that the piriform cortex plays an integral role in the neural network as it sustains sensory integration, facilitates the learning process and is linked to emotional and reward-related behavioural responses (Cardinal et al., 2002 and Holland & Gallagher 2004).

The prefrontal cortex plays a role in memory and learning. Although studies on the nature of this role are unclear, the structure appears to mediate learning, memory and response control. However, the system does not contribute to the incremental acquisition of information (Hay, Moscovitch & Levine, 2002).

Studies indicate that a decrease in the functioning of the piriform cortex enhanced OFC activity (KengNei Wu 2012). The area involved in memory encoding (Mortimer Mishkin 1999). To understand the connections between the two structures, this study seeks to measure the extent of OFC involvement and the resultant change in learning psychological enhancement of orbitofrontal performance due to nasal obstruction(KengNei Wu 2012). To validate the hypothesis, the study utilises a learning set scenario that focuses on "Probabilistic category learning" (Medin and Schaeffer 1978, Nosofsky 1984, Estes 1986; Gluck and Bower 1988a, b). In a typical 'probalistic learning task,' stimuli are linked to responses with fixed probabilities. An indication that the learning process has taken place will be based on the "probability match". The subjects will exhibit a particular response that has been reinforced'' (Gluck and Bower1990). The outcome of the results will be evaluated between control subjects and nasal obstructed subjects

2. MATERIALS AND METHODS

Subjects:

The experimental design involved a control group and a trail group. Participants involved in the study were 40 individuals with a mean age of 18-22. The participants were recruited from King Faisal University. After explaining the nature and purpose of the study, the volunteers gave us the informed consent required when conducting research on human subjects. Furthermore, the Ethics Committee and Administration of the University consented to the study. Although the subjects were unaware of the learning task, they were provided with instructions concerning their role in the task. The cross-sectional study involved the division of the 40 volunteers into two groups, each consisting of 20 subjects, with one group consisting of the control group whereas the other consists of the trial group. None of the participants exhibited histories of previous neurological disorders. The trial group had their nasal obstructed by a swap of Vaseline in inner nostril for the purpose of obstructing the olfactory nerve.

Materials:

The learning task involving probabilistic classification learning was administered on a computer screen. Participants were required to determine which of the two outcomes presented in the cue is predicted over the different set of classes, as indicated in Fig.1. Each cue was independently linked to an outcome with a fixed probability. The frequency of the two outcomes was high. Table 1 illustrates the likelihood of outcome 1 depending on the probable combination of cues and likelihood of each pattern presented. Ideally, one, two, three, or four cues are likely to appear in all trials (14 possible patterns).

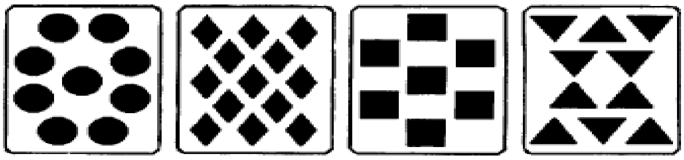
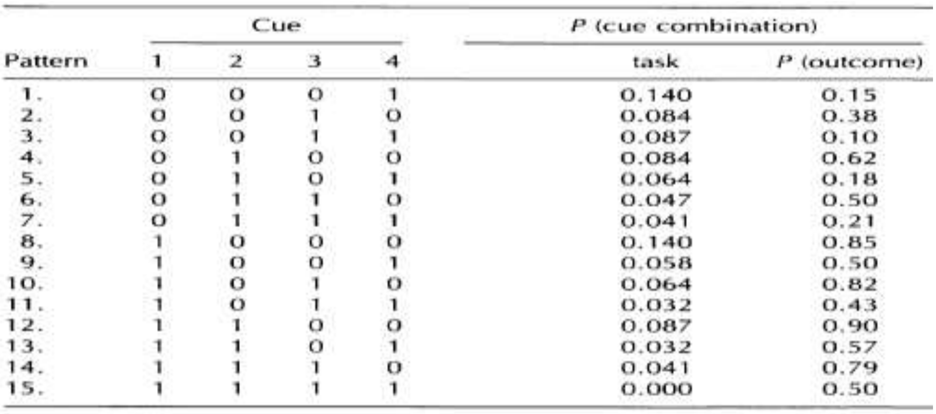


Figure 1: The four patterns presented on the computer screen

The different geometrical shapes were randomly presented in each trial for each subject.

Table 1 illustrates how the cue patterns were depicted, with each pattern only occurring once



	Cue				P (cue combination)	
Pattern	1	2	3	4	task	P (outcome)
1.	0	0	0	1	0.140	0.15
2.	0	0	1	0	0.084	0.38
3.	0	0	1	1	0.087	0.10
4.	0	1	0	0	0.084	0.62
5.	0	1	0	1	0.064	0.18
6.	0	1	1	0	0.047	0.50
7.	0	1	1	1	0.041	0.21
8.	1	0	0	0	0.140	0.85
9.	1	0	0	1	0.058	0.50
10.	1	0	1	0	0.064	0.82
11.	1	0	1	1	0.032	0.43
12.	1	1	0	0	0.087	0.90
13.	1	1	0	1	0.032	0.57
14.	1	1	1	0	0.041	0.79
15.	1	1	1	1	0.000	0.50

Table 1: In each trial, the likelihood appearance of 1 of 14 combinations is indicated as [P (cue combination)]. Each determined cue predicted outcome 1 with the probability P (outcome) as indicated in the table and predicted outcome 2 with a probability of 1 - P (outcome).

In a given trial, subjects were asked to determine whether a certain pattern indicated sunny or rainy weather. Out of the four possible cues, each cue could be associated with a possible outcome with varying ranges, that is, either at 75%, 57%, 43%, or 25%. These probabilities were determined by calculating the probability of obtaining outcome 1 based on a particular cue. Conditional probabilities were determined by calculating the likelihood that outcome 1 and a particular cue would occur at the same time and then divide the total probability that would occur in spite of the outcome. For example, from Table 1, the probability of cue 1 occurring can be calculated based on the formula [the P (cue combination) ×P (outcome 1)]. This is determined through summation across patterns 8-14(.337); the total probability of cue 1 can occur regardless of the outcome equals the sum of the P (cue combination) for patterns 8-14 (.445). Based on the calculations, the association of strength with outcome 1 was.337/.445 (75.7%). Whereas, the association of strength for cue 2 based on the P(cue combination) × P(outcome 1) is 225/.389, or 57.8%. There were about 4 to 24 different ways in which the association of strength could be assigned to each cue.

Procedure:

Subjects were informed that each trial consisted of different geometric shapes and that their role was to determine whether a given combination of shapes meant rainy or sunny weather. The inter-trial interval was 0.5 seconds. Participants were informed that, at first, they would feel as if their selections were based on guesswork. However, they would gradually improve over time. On each trial, there were two keys, with one indicating outcome 1(sunshine), whereas, the other indicated outcome 2(rain). At the start of the trial, a list of 1 to 3 cues is presented on the computer screen for 5 seconds, in which the client is expected to respond. The names of outcome 1 and 2 were on the screen throughout the training session. If the subjects' response was inaccurate, then the phrase "wrong answer" appeared on the screen. The feedback would last for 2 seconds on the screen, after which, a one-second inter-trial interval ensued. Each subject undertook 200 trial runs with a 1-minute pause after a block of 50 trials. Also, if the subject wished to continue, then the break was terminated (in most cases after ten secs).

Data Analysis:

The tasks seek to activate the process of explicit knowledge among its subjects. Resultantly, a participant made a correct response if they selected an outcome that was closely linked to the cue pattern. Subjects were scored if they identified a most likely outcome regardless of the fact that the feedback told them that their selection was wrong. Based on this approach, the correct score was an indication of how well subjects learned the probabilistic associations between cues and the two outcomes. Since the two outcomes occurred often, there was a 50% chance performance. Cue patterns with a likelihood of occurring (such as patterns 6,9 and 15 in Table 3) were not considered in the analysis because the selection of the patterns failed to provide information concerning classification learning. ANOVA was performed, in which the scores of 50 block trials for the 200 trials as well as groups of 10 trials of the first 50 trials were analysed.

3. RESULTS

Upon analysis of the controlled group and the trial group, the subjects with nasal obstruction achieved an optimal response of 77.8% and 77%, respectively that is both the control group and the trial group. The performance of the subjects is presented in figure 2 across the categorised 4 training groups. In block 1, the control subjects recorded 70% in terms of performance, similar to the nasal obstructed subjects. Then, the control subjects achieved a near 90% response by the fourth block, whereas the nasal obstructed group's response was a near 81%. ANOVA scores across the trials indicated no group effects (F< 1) [F=0.030, P = 0.9882], and the absence of interaction of group and trim block (F< 1, P>0.2).

Figure 3 Indicates performance across the first 50 trials. The response of the control subjects and the nasal obstructed subjects was nearly equal and was recorded at 70.6% and 71% respectively. ANOVA, measures indicate a lack of group effect (F< 1) [F=0.0064 , P = 0.9975], and absence of interaction between group and trim block (F< 1, P>0.2).

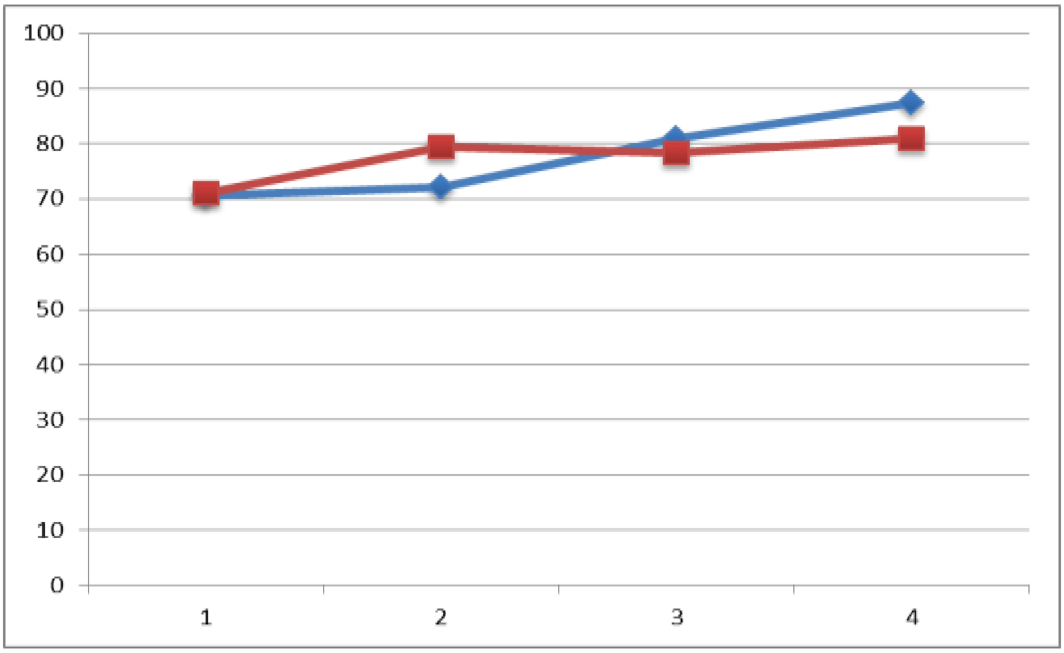


Figure 2: Percent optimal responses over all 200 trials for the control subjects (■) and nasal obstructed subjects (◆)

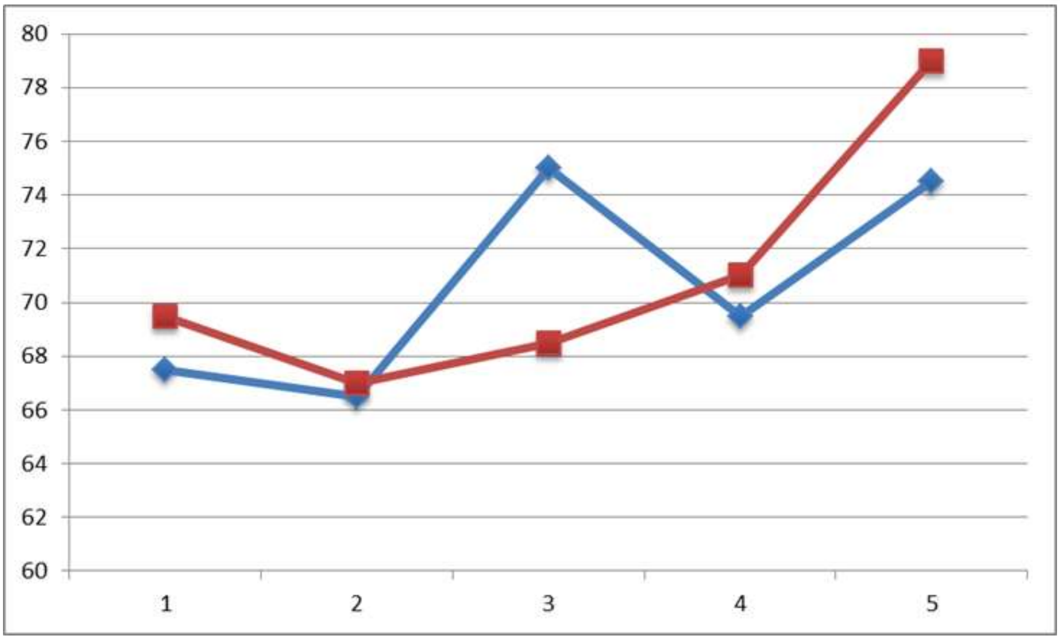


Figure 3: Percent optimal responses over the first 50 trials for the control subjects (■) and nasal obstructed subjects (◆)

4. DISCUSSION

The probabilistic classification task utilised the study indicates that Implicit learning process takes place due to the stimulation of the orbitofrontal cortex. In the first 50 trials, the performance of both groups, that is the control group and the subjects with the nasal obstruction significantly improved from 69.5% to 79%. The recorded improvement in the control subject was from 67.5% correct to 74.5%. In trial 51-200, the performance of the control group surpassed that of the nasal obstructed subjects. The initial findings in the first 50 trials suggest that the cortex is involved in the learning process, primarily in the motor domain. As the orbitofrontal cortex increased its activity, it facilitated the learning process (Schoenbaum, Takahashi, Liu & McDannald M 2011). This mechanism reflects how the brain distinguishes between right/wrong stimulations with the actual right/wrong stimulations, thus making the orbitofrontal cortex detrimental for adaptive learning particularly its role in signalling rewards and punishments (Cardinal et al. 2002 and Holland & Gallagher 2004). This explains the recorded outperformance of the nasal obstructed subjects at the beginning of the trial. In successive trials, the control group outperforms the nasal obstructed subjects. This is because the control group was able to develop declarative knowledge of the task due to the hippocampus and other structures (Knowlton, Squire & Gluck 1994). Contrarily, increased activity of the orbitofrontal cortex of the nasal obstructed subjects made it difficult for participants to establish long-term memory due to the inhibition of the development of the declarative knowledge (Ami, Bradley & Lesley).

5. CONCLUSION

The results depicted in the study indicate that the participants with nasal obstructions exhibited increased orbitofrontal cortex performance. The increased activity facilitated learning particularly at the initial stages of the probabilistic classification learning task. Contrarily, increased activity of the structure over time appeared to obstruct long-term memory.

6. SUMMARY

The purpose of the study is to determine the possible role of the piriform cortex in association with the orbitofrontal cortex in the learning process in human beings. The past several decades have resulted in advancements in cognitive and neuropsychological research in olfaction structures. However, a knowledge gap still exists concerning the role of the two structures in the learning process, including the structure of odour memory and the connections between these structures and the brain. The process of learning involves a network of neuron systems communicating between the brain and other structures. In this study, a control trial experiment with 40 participants is conducted to determine the learning experience at play in the human olfactory perception. The results presented in the study indicate that in the first 50 trials, subjects with nasal obstruction outperformed the control group. However, in the latter 51-200 trials, the control group outperforms the group with nasal obstruction.

The piriform cortex is a key structure involved in learning and recall of associations. The structure facilitates first learning experience in primates. For example, in dogs, the pups learn from their mother's odour concerning the unique environment. In humans, the actual function of the structure remains underexplored. However, the structure seems to endorse a privilege status in learning as it is involved in the processing of olfactory input from the pyramidal cells in the anterior piriform cortex and the posterior piriform cortex (Haberly 2001). In this task, subjects are required to determine a specific pattern from various cues and to link them to two main outcomes that are weather patterns. The results of the study indicate that a decrease in the functioning of the piriform cortex enhanced OFC activity (KengNei Wu 2012). However, increased activity of the orbitofrontal cortex performance over time limited long-term memory.

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