EXPLORING PERIPHERAL MEMORY STORAGE IN THE OCTOPUS ARM

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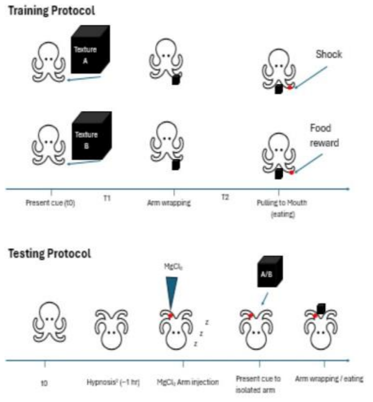
Introduction:

The peripheral nervous system (PNS) of the East Pacific red octopus (*Octopus* rubescent) is a remarkable example of decentralized control. Differing from our centralized nervous system, the octopus boasts semi-independent neural centers distributed throughout its body, particularly in its eight arms. Each arm possesses an intricate network housing 500 million neurons, enabling remarkable adaptability and intricate motor control[1]. The organization in each octopus arm reflects sensory inputs, motor neurons, and central neuropils processing vast amounts of information[2].

Method:

Method 1:This method involved three octopuses, where their responses were measured based on two key metrics: "T1," the time spent retrieving the dice, and "T2," the time to put the dice to their mouths. Each octopus was presented with smooth and fuzzy dice, with positive and negative stimuli assigned randomly. Following the training period, each octopus was put in a hypnotic condition and given an injection of magnesium chloride into one arm to cut off the link between the brain and that arm. This was done for eight trials every day. They were then retested so that it was possible to determine whether they had accepted or rejected the textured dice.

Method 2:This method involved five octopuses where their responses were measured by the total time they could hold the dice to a maximum of 30 seconds. In each interaction, octopuses received reinforcement based on their choices: a squid reward for selecting the smooth die and a mild shock for choosing the fuzzy die. Eight trials daily were conducted and after the training phase, each octopus was placed in a hypnotic-like state where magnesium chloride was injected into one of the arms to block the connection between the brain and one arm. Then they were retested enabling evaluation of their acceptance or rejection of the textured dice.



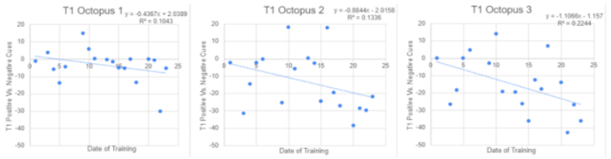


Figure 1(method 1) The difference in grabbing time for positive versus negative cues over training. Individual points represent averages of T1 over 144 trials. There is no preference on day 1 of training, but over the next 18 days the octopus reacts faster to the positive cue, demonstrating training. Day-to-day variation in mean reaction times among individuals underlines large differences in learning and adaptation between octopuses.

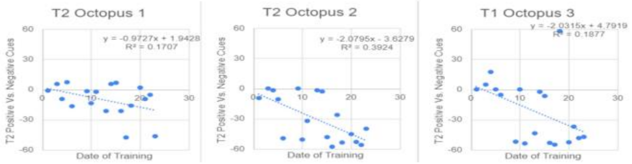


Figure 2(method 1) Overall increasing trend in eating time lag to the negative cue across the training sessions. This behavior reflects associative learning by differentiating between positive and negative cues while also learning from the negative feedback; hence, the gradually increasing T2 emphatically underlines cognitive and emotional involvement and calls for an emphasis on negative reinforcement driving behavior.

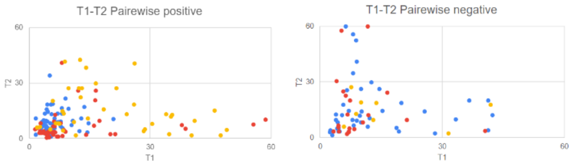


Figure 3(method 1) Pairwise comparison of Grabbing time (T1) versus Eating time (T2) for three animals. T1-T2 relationship reflects decision-making processes following object interaction, where T1 measure's reaction time and T2 measures the time taken to accept and taste the object.

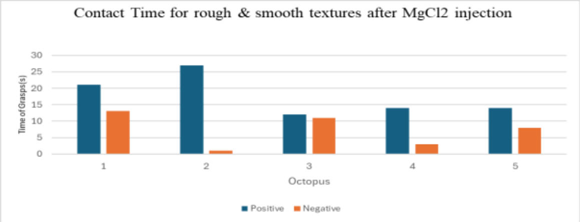


Figure 4 (method 2): After 80 trials each octopus was put into "octopus hypnosis". The data shows after anesthesia the total time that each of the five octopuses held onto the dice after injection. This information reveals a strong correlation: octopuses spent significantly more time with the positive dice, suggesting a clear preference for positive stimuli. This behavior indicates that they have learned to associate the positive dice with a favorable outcome.

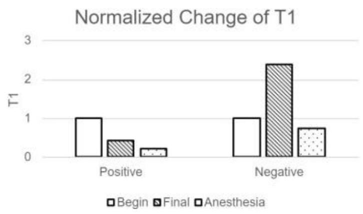


Figure 5(method 1)**:** Grabbing time change for positive and negative cues at the beginning and end of training, and post anesthesia. The arm grasped both cues faster after anesthesia than baseline measurements.

Conclusion:

A study into the peripheral storage of memory in octopus arms expressed various theories on their cognitive processes regarding disparate learning curves; individuals showed inherited differences in cognitive adaptation.

In method 1: The average reaction times for Octopus 1 were quite consistent, those in Octopus 2 and 3 showed greater variation throughout, indicating different learning mechanisms across different individuals based on motivational factors and risk evaluation.

In method 2: There was a clear and consistent indication of a stronger preference for the positive stimuli over the negative stimuli across all octopuses. Importantly, persistence of the learned preference beyond the magnesium block trials would indicate that the periphery has a degree of autonomy and memory recall, thus encouraging further research into the molecular basis of memory storage in decentralized neural networks.

References:

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Acknowledgments:

All experiments were carried out in accordance with protocol #23015 approved by the University of Illinois Urbana-Champaign (UIUC) Institutional Animal Care and Use Committee (IACUC).