



INTERACTIONS BETWEEN LATERALIZED CHOICES OF HAND AND TARGET

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1. Abstract

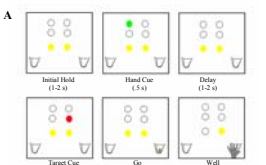
In monkeys performing a controlled reach and prehension task, we examined whether the choice between identical food pellets positioned to the left and right of midline was biased by which hand was required, and whether the choice of which hand to use was biased by presenting a food pellet only on the right or left. We also examined whether the choice of both hand and food pellet laterality resulted in a different pattern of responses.

Three monkeys were trained to retrieve food pellets in the following task. First, the monkey viewed an LED instruction to use its right hand, its left hand, or its choice of hand. After a variable delay a food pellet (target) was dispensed to the right of the midline, to the left, or bilaterally. Then the monkey reached for one pellet, using one hand. Different combinations of hand instruction and target delivery resulted in four different types of choice trials: no choice of hand or target, choice of hand, choice of target, choice of both hand and target.

In trials with choice of hand but not target, each monkey showed a preference for either the right or left hand independent of whether the target was on the right or left. In contrast, when the monkeys had a choice of target but no hand, they tended to choose the right target when required to use the right hand, and the left target when required to use the left hand. Comparing double choice to single choice trials revealed similar target laterality preference whether the hand was chosen or instructed, but hand laterality preference was stronger when the target was chosen than when only one target was delivered. These observations suggest that the monkeys made a choice of which hand to use before food pellets were delivered, and that when pellets appeared bilaterally the monkeys tended to choose the target ipsilateral to the hand already selected, introducing a cue about the target location before the hand instruction did not alter the laterality preferences.

2. Methods

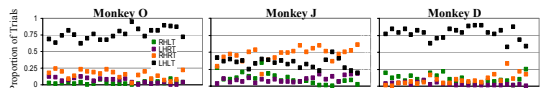
Three *Macaca nemestrina* monkeys were trained to retrieve food pellets under four different behavioral conditions: no choice of hand or target, choice of hand but not target, choice of target but not hand, and choice of hand and target. A schematic representation of the trial sequence is shown in figure A below. To begin a trial the monkey placed each hand between sensors 2 cm on either side of the midline at approximately 13 cm below shoulder level (figure B below). After a variable delay the left, right or both top green LEDs were illuminated indicating that the monkey must use its left hand, right hand or could choose either hand, respectively. The monkey was required to keep its hands in the initial position for another variable delay after which one or both of the middle red LEDs illuminated indicating whether a food pellet would be dispensed in the right, left or both food wells. An instant later, the food pellet(s) dropped into the well(s), which served as the GO signal. The monkey could then lift one hand and retrieve one pellet.



Sensors by each food well detected when the monkey's hand entered the well. A sliding floor beneath each food well opened to let food pellets fall out of the monkey's reach if the monkey lifted the non-instructed hand or lifted both of the food wells. In trials where food pellets were dispensed in both wells, as the monkey's hand entered one well, the sliding floor beneath the opposite well opened, preventing the monkey from retrieving a second food pellet.

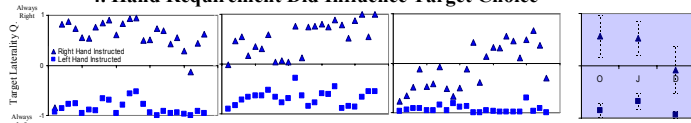
At each choice level, a combination of hand and target were possible: left hand left target (LHLL), left hand right target (LHRT), right hand right target (RHRT), right hand left target (RHLL). Trials occurred in blocks each consisting of 1 trial of each no choice combination, 2 trials of hand choice with left dispenser required, 2 trials of hand choice with right dispenser required, 2 trials of target choice with right hand required, and 4 trials of hand and target choice. These 16 trials were presented randomly within each block.

3. Given Double Choices Monkeys Display Both Hand And Target Preferences



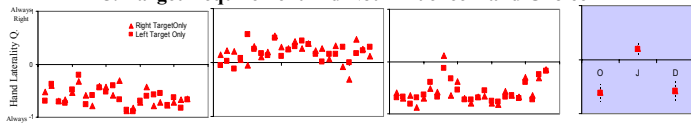
The figures above show the proportion of double choice (hand and target) trials in which the monkey chose each type of hand-target combination.

4. Hand Requirement Did Influence Target Choice



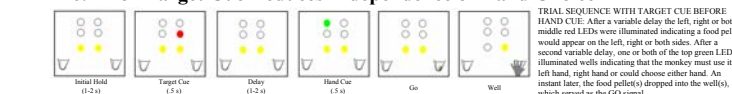
ABOVE: When required to use the left hand the monkeys tended to choose the left target more often than the right. They tended to choose the right target more when required to use the right hand.

5. Target Requirement Did Not Influence Hand Choice



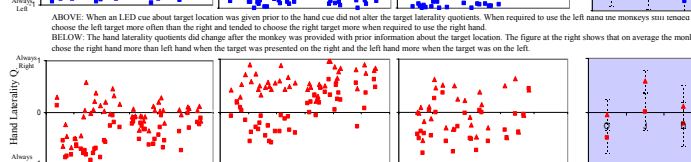
ABOVE: HAND LATERALITY QUOTIENTS WHEN EITHER THE RIGHT OR LEFT TARGET WAS REQUIRED. In trials where there was choice of hand but not choice of target, monkeys' preference for the right versus left hand was independent of the side on which the target was delivered. Since the trial sequence consisted of the hand instruction cue prior to the target location cue it is likely that hand choice was determined before the target cue was given.

6. Prior Target Cue Reduces Independence of Hand Choice



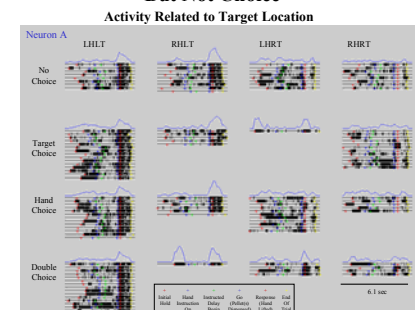
ABOVE: When an LED cue about target location was given prior to the hand cue did not alter the target laterality quotients. When required to use the left hand the monkeys still tended to choose the left target more often than the right and tended to choose the right target more when required to use the right hand.

BELOW: The hand laterality quotients did change after the monkey was provided with prior information about the target location. The figure at the right shows that on average the monkeys chose the right hand more than left hand when the target was presented on the right and the left hand more when the target was on the left.



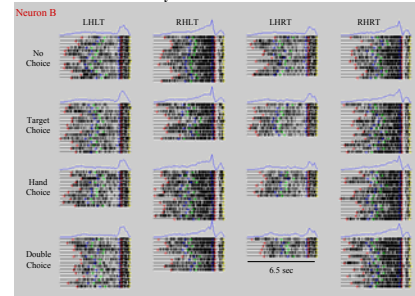
Task Conditions	Food Reward	
	right required (R, RT)	left required (L, LT)
right required (R, RT)	right hand used to take right food reward (R, RT)	right hand used to take left food reward (L, RT)
left required (L, LT)	right hand used to take right food reward (R, LT)	right hand used to take left food reward (L, LT)
choice of right or left (R, RL)	choice of hands used to take right food reward (R, RL)	choice of hands used to take left food reward (L, RL)
choice of both hand and target (R, RL)	choice of hands used to take right food reward (R, RL)	choice of hands used to take left food reward (L, RL)

7. Neurons Modulate With Hand And Target But Not Choice

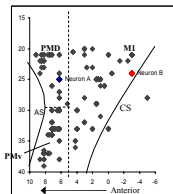


186 out of 202 recorded left hemisphere neurons were significantly modulated in relation to the task. 129 of the neurons that were modulated during a trial also discharged in relation to the hand-target combination. The neuron in the raster display above had a different pattern of activity during the reach period for left target reaches than for right target reaches. The raster display below shows a neuron that had a different pattern of activity during the reach period when using the left hand versus using the right hand. We did not find neurons with different patterns of activity based on the level of choice, but in many recordings there were too few trials for particular hand-target and choice combinations to evaluate the neuron discharge (for example, the above neuron only has one trial of RHLL Target Choice).

Activity Related to Hand Used

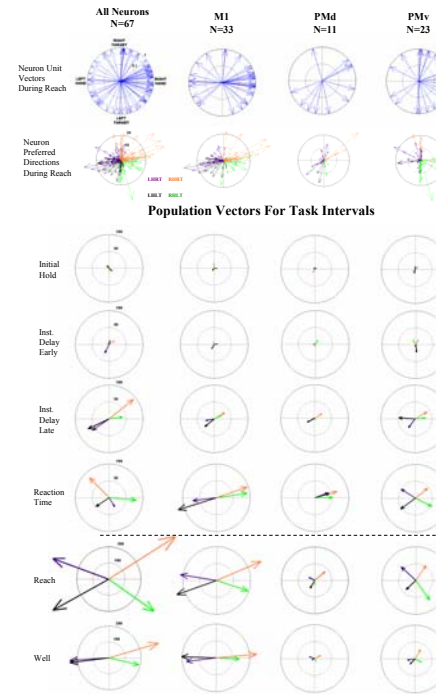


LATERALITY QUOTIENTS:
 Laterality index for hand choice when right target only (+)
 $Q_{RH} = \frac{H_{RH} - H_{RH}}{H_{RH} + H_{RH}}$
 Laterality index for hand choice when left target only (-)
 $Q_{LH} = \frac{H_{LH} - H_{LH}}{H_{LH} + H_{LH}}$
 Laterality index for target choice when left hand required (R)
 $Q_{RH} = \frac{H_{RH} - H_{RH}}{H_{RH} + H_{RH}}$
 Laterality index for target choice when right hand required (L)
 $Q_{LH} = \frac{H_{LH} - H_{LH}}{H_{LH} + H_{LH}}$
 If H denotes hand and T denotes target. Subscript C denotes right choice, R right choice, L left choice, and RL is left or right.



LEFT: Schematic of recorded neuron locations. Dotted lines indicate arbitrary boundaries of dorsal and ventral pre-motor areas and primary motor area. Locations of Neuron A and Neuron B in the raster displays above are indicated AS - arcuate sulcus CS - central sulcus

8. Population Analysis – No Choice Trials Hand Cue Only



7. Conclusions

- When given a hand instruction prior to target cue, the monkeys' choice of hand was independent of the side on which the target was presented. In contrast, when required to use the left or the right hand, the monkeys more often chose the ipsilateral target indicating that the monkeys made the hand choice first.
- Presentation of the target cue before the hand instruction changed the monkeys behavior so they began choosing the hand on the side of the target more often.
- Neuron activity can indicate target location or hand used but does not indicate type of choice.
- The neuronal population in one hemisphere encodes information about right and left hand and right and left target
- The M1 neuronal population encodes more hand information than target and the PMv neuronal population encodes more target than hand.