

Ventral premotor cortex single-unit activity related to choices of target and hand, and to head position



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Abstract

We trained monkeys designed to examine interactions between lateralized choice of hand and target, and the influence of head direction on these choices. Two food wells are positioned to either side of the midline, and LEDs provided instructions on which hand to use and to which target to reach in order to get a reward. During these instruction cues, the monkeys were required to maintain both gaze and head fixed on a left, center, or right cyan LED (Figure 1). Four types of trials were used: NO CHOICE trials in which both the hand and the target were specified, TARGET CHOICE trials which provided a choice of either target to be taken with a specified hand, HAND CHOICE trials which provided a choice of either hand to be used in reaching to a specified target, and DOUBLE CHOICE trials which provided choices of both hand and target.

1. Behavioral task and Methods

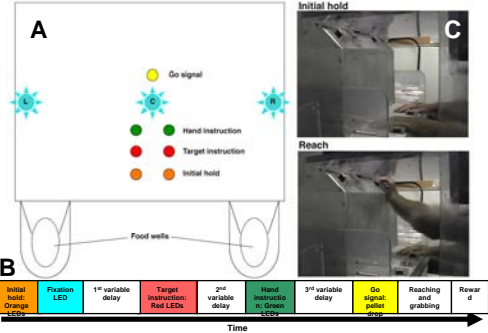


Figure 1. A. Cartoon of the panel with fixation and instruction LEDs. To initiate a trial the monkey placed both hands on home plates (initial hold; orange LEDs). Then, a blue fixation LED came on (L or C or R, cyan stars). The monkey had to direct both his head and eyes, monitored with magnetic search coils, to this fixation point. Then, a second set of LEDs (target instruction: red LEDs) informed the monkey into which food well (left and/or right) a food pellet would be dispensed. A food pellet could be dispensed on the left only (left LED), on the right only (right LED) or on both sides (choice of target, both LEDs). Following a second delay, a similar instruction would be provided concerning the hand to be used (hand instruction: green LEDs). Finally, a GO signal (yellow LED) informed the monkey that he could shift gaze and head ad lib, and reach for one food pellet (C, bottom). Infrared sensors at the home plates and food wells provided information on the monkey's movements. A single electrode drive (Trent Wells) was used to record single-units in both M1 and PMv. A total of 132 units were recorded from PMv, and 93 from M1 in two pig tail macaques (*Macaca nemestrina*; Monkey O and Monkey J).

2. Data from a PMv neuron



Fig. 2 Raster and histogram displays of data recorded in a single session from one PMv unit. This neuron discharged during the reach with either arm to either target, but showed anticipatory buildup for reaches with the left hand, particularly to the left target. This was much more prominent when fixation hand been directed to the right.

3. Types of task-related modulation

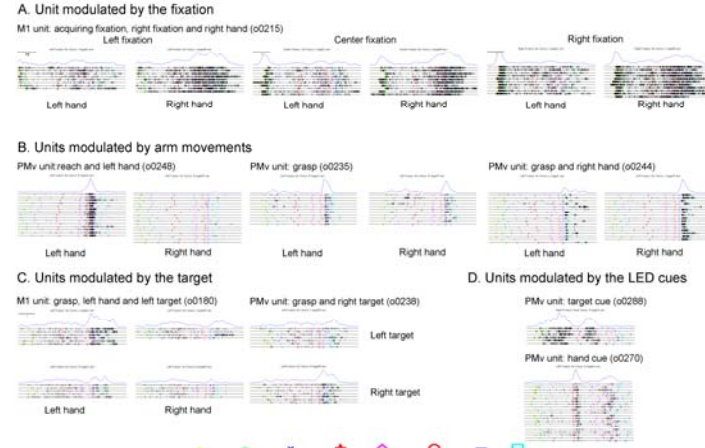


Fig. 3 Units with various types of task-related modulation. **A. Acquire fixation.** Unit o0215 discharged a burst as the monkey turned gaze and head toward the center or right (ipsilateral) fixation LED. This unit also discharged when the monkey used its right (ipsilateral) hand toward the center or right (ipsilateral) fixation LED. This unit also discharged when the monkey used its right (ipsilateral) hand toward the center or right (ipsilateral) fixation LED. This unit also discharged when the monkey used its right (ipsilateral) hand toward the center or right (ipsilateral) fixation LED. **B. Hand-related.** These PMv units discharged selectively during arm and hand movements: unit o0248 during the reach, and units o0235 and o0244 during the grasp epoch. Whereas unit o0235 showed a similar burst whether the monkey used its left or right hand, unit o0248 discharged selectively for the left (contralateral) hand, while unit o0244 discharged selectively for the right (ipsilateral) hand. **C. Target-related.** Units o0180 and o0238 showed their highest firing frequencies during the grasp epoch. Unit o0180 had its highest firing frequency when the monkey used its left hand (contralateral) and reached to the left target (contralateral). Unit o0238 was not modulated depending on the hand, but had its highest discharge when the monkey reached to the right target (ipsilateral). **D. Cue-related.** Finally, some units' highest firing frequencies occurred during the presentation of the LED cues. For example, unit o0288 highest firing frequency was during the target cue and unit o0270 was during the hand cue.

4. Summary of effects in recorded units

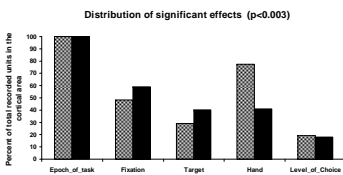
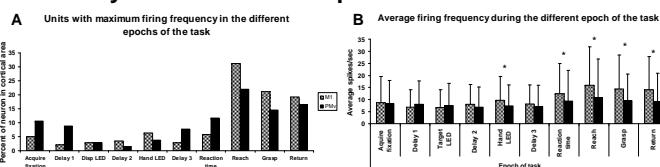


Fig. 4. Summary of the recorded units in our two monkeys. We used ANOVAN to evaluate whether each unit's firing frequency varied depending on the task epoch, the fixation direction, the target taken, the hand used, and/or the level of choice. For all units in both M1 and PMv firing frequency varied significantly across the different epochs of the task. A higher percentage of PMv than M1 units varied depending on fixation direction or target location. In contrast, a higher proportion of M1 units varied depending on the hand used. Finally, in both M1 and PMv, only a small percentage of varied their discharge depending on the level of choice.

5. Activity in relation to the epoch of the task



6. Activity in relation to fixation, target, hand and choice

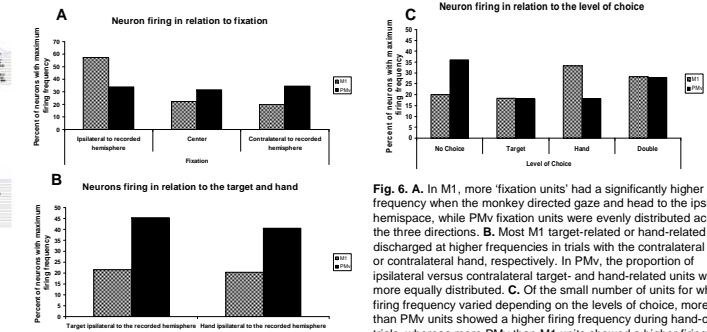


Fig. 6. A. In M1, more 'fixation units' had a significantly higher firing frequency when the monkey directed gaze and head to the ipsilateral hemisphere, while PMv fixation units were evenly distributed across the three directions. **B.** Most M1 target-related or hand-related units discharged at higher frequencies in trials with the contralateral target or contralateral hand, respectively. In PMv, the proportion of ipsilateral versus contralateral target- and hand-related units was more equally distributed. **C.** Of the small number of units for which firing frequency varied depending on the levels of choice, more M1 than PMv units showed a higher firing frequency during hand-choice trials, whereas more PMv than M1 units showed a higher firing frequency during the no-choice trials.

7. Cortical location of the different units

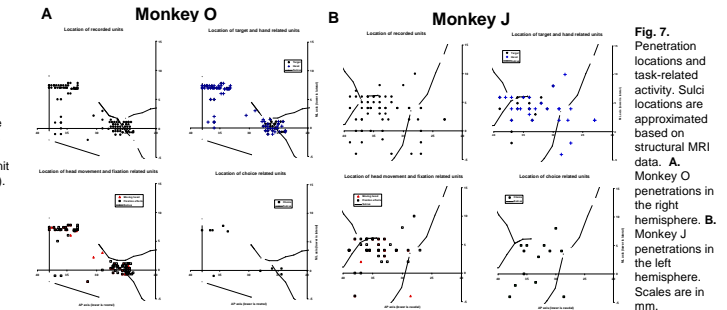


Fig. 7. Penetration locations and task-related activity. Sulci locations are approximated based on structural MRI data. **A.** Monkey O penetrations in the right hemisphere. **B.** Monkey J penetrations in the left hemisphere. Scales are in mm.

Conclusions

In both M1 and PMv, we found task-related units with discharge that varied depending on the fixation direction, the target location, the hand used and/or the level of choice. A higher proportion of PMv neurons had their peak firing frequency during the head movements used to acquire the fixation LED, and showed variation in discharge depending on fixation and/or target. In contrast, a higher proportion of M1 neurons showed variation depending on the hand used. Whereas M1 neurons that were modulated by fixation, target and/or hand showed a laterality bias, PMv neurons were more evenly distributed across fixation directions, targets and hands.

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