Supplemental Data

This file contains Supplemental Discussion 1, 2, and 3.

Supplemental Discussion 1:

Could the instruction-induced response reflect motor preparation or spatial attention?

One might argue that the selective activity in response to the instruction signals may reflect a bias for motor preparation or spatial attention. In considering this possibility, it is important to note that our behavioral task was designed so that the probability to reach to the target T1 to T5 was equal regardless of the instructions given by the instruction cue. After training, monkeys knew that they would never reach to the cue position 0 or 6. Thus, the animals could not plan to reach leftward or rightward of the screen based on the instruction. Furthermore, by examining the time-dependent changes in the distribution of behavioral selectivity of individual neurons (Table 1, see also Figure 6) the following important findings emerged. First, during the early choice-cue period, neurons selective for both action plan and choice-cue location tended to be found more often among the group of neurons that had been selective for the action plan during the instructed delay period (61 vs. 29; Binomial test, $p = 0.001$). By contrast, neurons selective only for the motor plan were found more often among the group of neurons that had not been selective for the action plan (29 vs. 97; Binomial test, $p < 0.0001$). These results revealed that the interaction between the action plan and the incoming choice-cue location takes place mainly in the neuronal group selective for the action plan before the appearance of the choice cue, and that the motor plan was read out mainly by the group of neurons without selectivity for the action plan. Second, it was found that a majority of neurons selective for the action plan during the instructed delay period lost all selectivity by the end of the choice-cue period (n = 113 out of 193), suggesting that the action plan was transformed into other behavioral variables. Third, it was found that the motor-plan selectivity during the late choice-cue period occupied the largest group of neurons with significant selectivity and was similarly observed regardless of the instruction selectivity during the instructed delay period (41 vs. 68, Binomial test, p = 0.0124). The last finding suggested that the action-plan selectivity and the motor-plan selectivity became independent variables by the time when the movement was initiated. Taken together, it seems reasonable to rule out the possibility that the instruction-induced responses in the PMd reflected motor preparation or spatial attention.

Supplemental Discussion 2:

Could the instruction-induced response reflect motor preparation in object-centered frame of reference?

It seemed important to discuss about a possibility that the selective activity in response to the instruction cue may reflect motor preparation in the object-centered frame of reference, because oculomotor preparation in object-centered coordinates was reported in the supplementary eye field (Olson and Gettner, 1995). Under our behavioral condition, however, the following findings led us to judge that the instruction-induced activity is unlikely to represent motor preparation in the object-centered frame of reference.

(1) Among 193 neurons exhibiting right-left selectivity in response to instruction cues, a minority of neurons (n = 35) exhibited only right-left selectivity during the early phase of the choice-cue period, i.e., the period when motor targets appeared. During the late choice-cue period, the number of selective neurons further decreased to 18. This sharp decrease of selective neurons during the preparatory period is unreasonable if we assume that they represent motor preparation.

(2) If the right-left selectivity during the instructed delay period represents the object-centered target location, the activity would be greater when the target-cue appears (as did, indeed, in the report by Olson and Gettner (1999)). However, the magnitude of the right-left selectivity decreased in most neurons (172 out of the 193 neurons; -5.4±5.99, mean±s.d.) during the late choice-cue period compared with the instructed delay period. Further, examining the time course of the action selectivity revealed that it decreased throughout the choice-cue period (Figure 8A).

(3) The motor instruction selectivity (during the late choice-cue period) was not differently observed, regardless of whether neurons had exhibited motor-instruction selectivity or not during

the instructed delay period (n = 18 vs. 36; Binomial test, p = 0.0198).

We, therefore, interpreted the findings as showing that the instruction-induced activity is unlikely to represent the object-centered target location. Our interpretation is that the instruction-induced activity represents whether to select right or left of targets that are not physically present, hence the representation of the virtual action plan.

Supplemental Discussion 3:

Hypothetical involvement of the PMd in the network to achieve transformation of information. What we propose as a hypothesis as to the workings of the PMd in transforming information to generate a motor plan is conceptualized in a diagram shown in Figure 11. Two sets of inputs provide information to be processed in the PMd. First, instructions calling for the selection of future action (virtual action plan) are fed into an input layer representing either right or left of action selection at a conceptual level. Activity in this layer can be fed into the next, intermediate layer to set up a gradient of activity that then influences the later activity, biasing or "preshaping" the population activity in this layer (*cf.* Bastian et al. 2003). Subsequently, the choice-cue information is fed into the second input layer. At the next stage, integration of information coming through the two input layers takes place in the intermediate layer, where the biasing effect of the first input (for action selection) could serve to convert the choice-cue information into target-position information for planning the subsequent movement to reach to a target. It can be conjectured that left-selective cells in the (action-plan selective) input layer activates cells that represent the left of the choice-cue location and inhibits cells representing the right in the intermediate layer, while cells selective for selecting right could do the opposite. As a result, the output from the intermediate layer to be fed into the output layer in the PMd could specify a target position to constitute a motor plan.

References

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