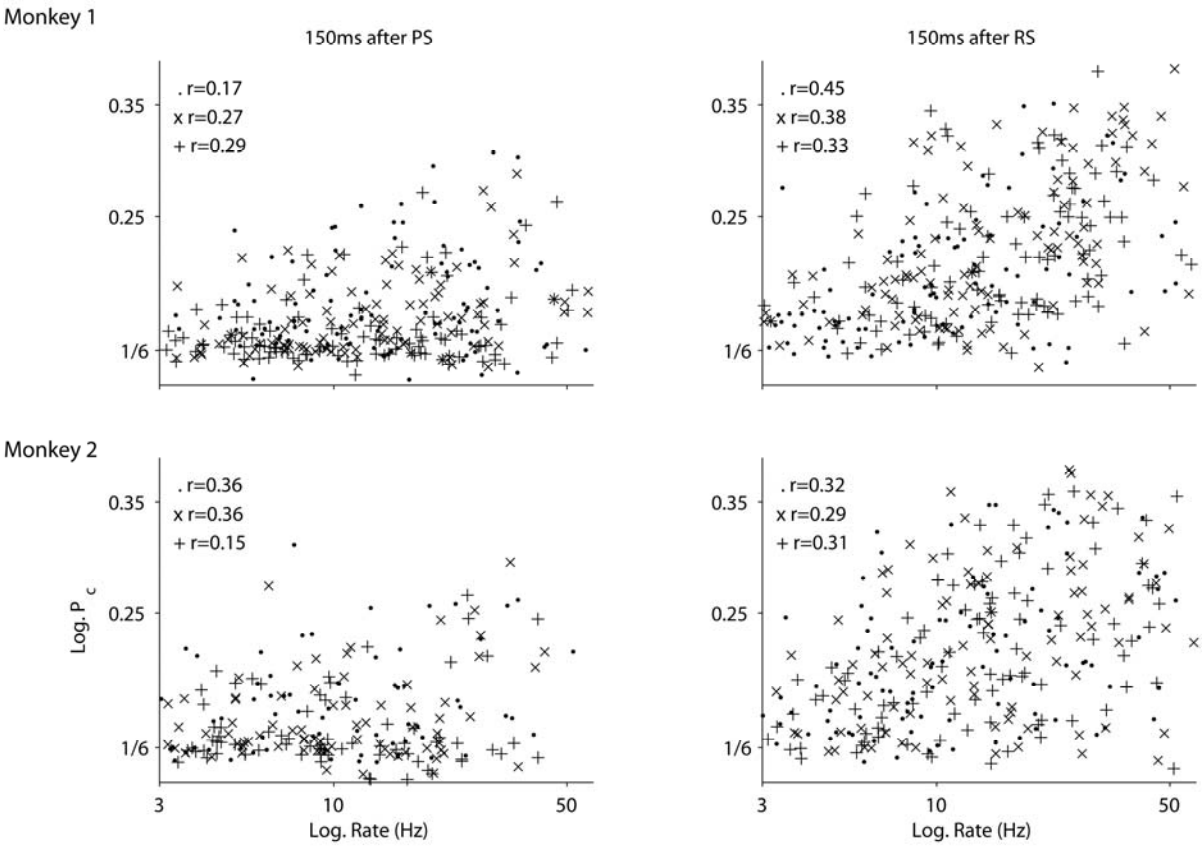
Supplemental Material

Correlation of firing rate and decoding probability

Supplement figure 1 gives the results for the estimation of the linear correlation between mean firing rates and decoding probability P_C at two instances in time: (1) in the early period of the preparatory phase 150ms after the preparatory stimulus (PS) was presented, and (2) 150ms after the reaction signal (RS) was presented. Both time points correspond to the maxima of the average firing rates (cf. Fig. 4).



Supplemental Figure 1: Correlation of firing rate and decoding probability. Each panel shows the average firing rate scattered against the decoding probability of individual neurons, both plotted on log-scale. Each dot represents one neuron. The distribution of dots depicts rates and decoding probabilities for all neurons of monkey 1 (top) and monkey 2 (bottom), either during movement preparation (left) or movement execution (right). Different symbols represent neurons recorded during the complete information condition (•), the 2-target (x), and the 3-target condition (+).

Stimulus coding

In the main text, throughout the whole trial, we decoded the direction of the executed movement. Here, we take a different perspective and, during the preparatory period, decode the preparatory stimulus PS (see Materials and Methods for details). As we considered only correctly executed trials, this analysis made no difference for the 1-target condition. In the 2-, and 3-target conditions we have 3 or 2 preparatory stimuli (PS) and thus the decoding reduces to a 3- or 2-class problem, respectively.

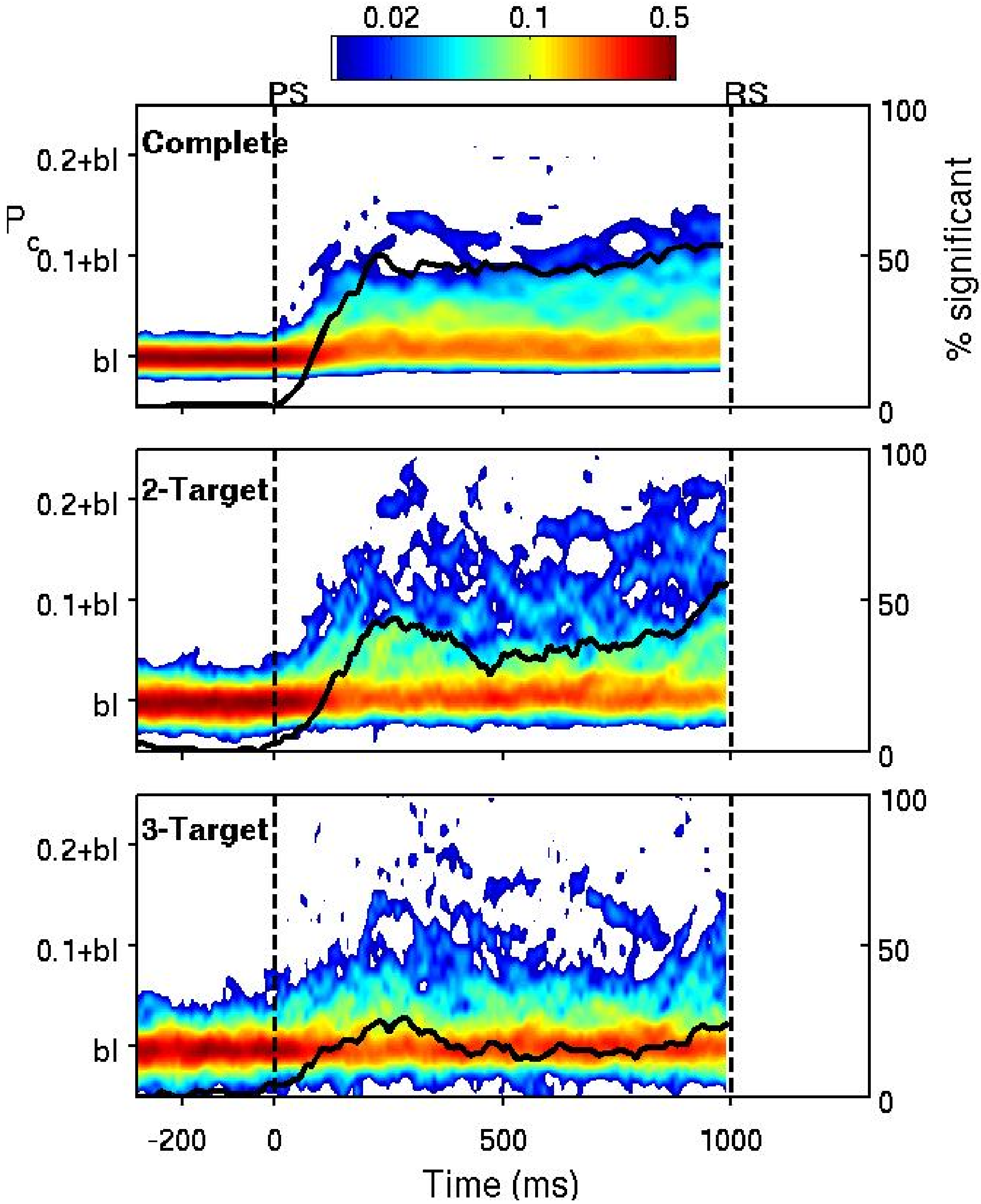
First, we repeated our analyses of single neuron tuning strength. The results are summarized in supplementary table 1. One can see, that tuning strengths as computed by Z_A and S_A decrease from 1-target to 2-target to 3-target – as they do when tuning strength was computed with respect to the executed movement. Pc is difficult to compare across conditions here, because its baseline increases from 1/6 to 1/3 to ½.

Measure	1-target	2-target	3-target
Z_A	1.13 0.92	0.76 0.64	0.50 0.51
S_A	53 57	61 63	67 64
Pc	0.199 0.188	0.377 0.364	0.532 0.530

Supplementary table 1: Different measures for tuning to the preparatory stimulus, averaged across all neurons during the preparatory period from PS+150ms to RS-150ms, Results given separately for each behavioral condition. First number in each entry is for monkey 1, second number is for monkey 2.

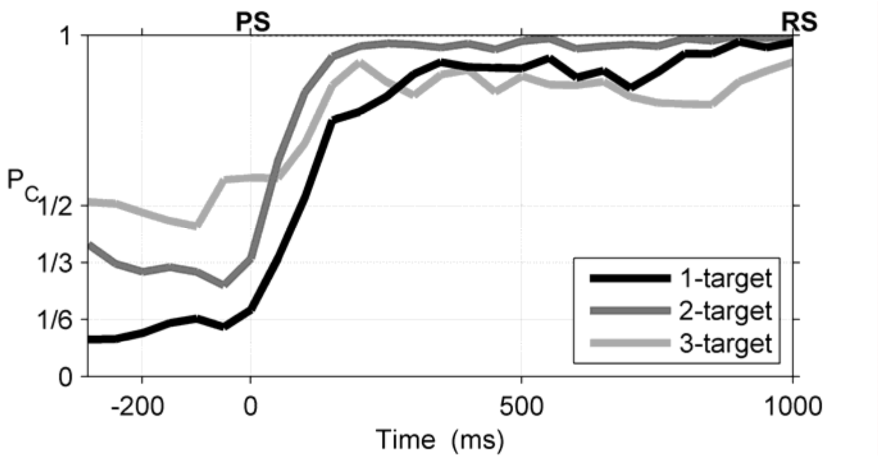
If we look at the number of significantly tuned neurons computed from those neurons with significant Pc ($P<0.001$, see Materials & Methods), we find a decrease from 1-target to 2-target to 3-target though (cf. supplementary figure 2) – as we found on the basis of Pc for decoding the executed movement (Figure 5). For monkey 1, the average number of significantly tuned neurons from PS+150ms until RS drops from 50% in the 1-target condition to 37% in the 2-target condition to 18% in the 3-target condition. For monkey 2 this number drops from 30% to 27% to 16% likewise.

Supplementary figure 2 also shows that the distribution of Pc values looks similar to their distribution when Pc was computed for decoding the executed movement shown in Figure 5. At any point in time, most neurons, indicated by red and yellow colors, are not or only weak encoders of the stimulus. Few neurons, indicated by blue colors, at any point in time are strong encoders of the stimulus.



Supplemental Figure 2: Time-resolved distribution and proportion of significant Pc values for decoding the preparatory stimulus (population of 112 neurons in monkey 1). Otherwise as in Figure 5 of the main text.

Second, we decoded the PS during the preparatory period from a population of 100 neurons. The Bayesian probability P_C for decoding the correct stimulus from a population of 100 neurons in monkey 1 reaches values close to unity (>0.85) shortly after PS in all three conditions (supplementary figure 3). Monkey 2 yields somewhat weaker values (>0.6, not shown). As to be expected, the stimulus type (1 target LED, 2 target LEDs, or 3 target LEDs) does not influence the quality of stimulus decoding. These results are consistent with and could be expected from our results on the population decoding of movement direction in Fig. 7. There, we also found decoding probabilities for the final movement direction that were close to the upper bound with P=1, P=1/2 and P=1/3 for 1, 2, and 3 targets presented with PS (see also Materials and Methods). Together with the result in Fig. 7 we can conclude that a population of 50-100 neurons carries information about the stimulus/direction of movement that comes close to the maximal information.

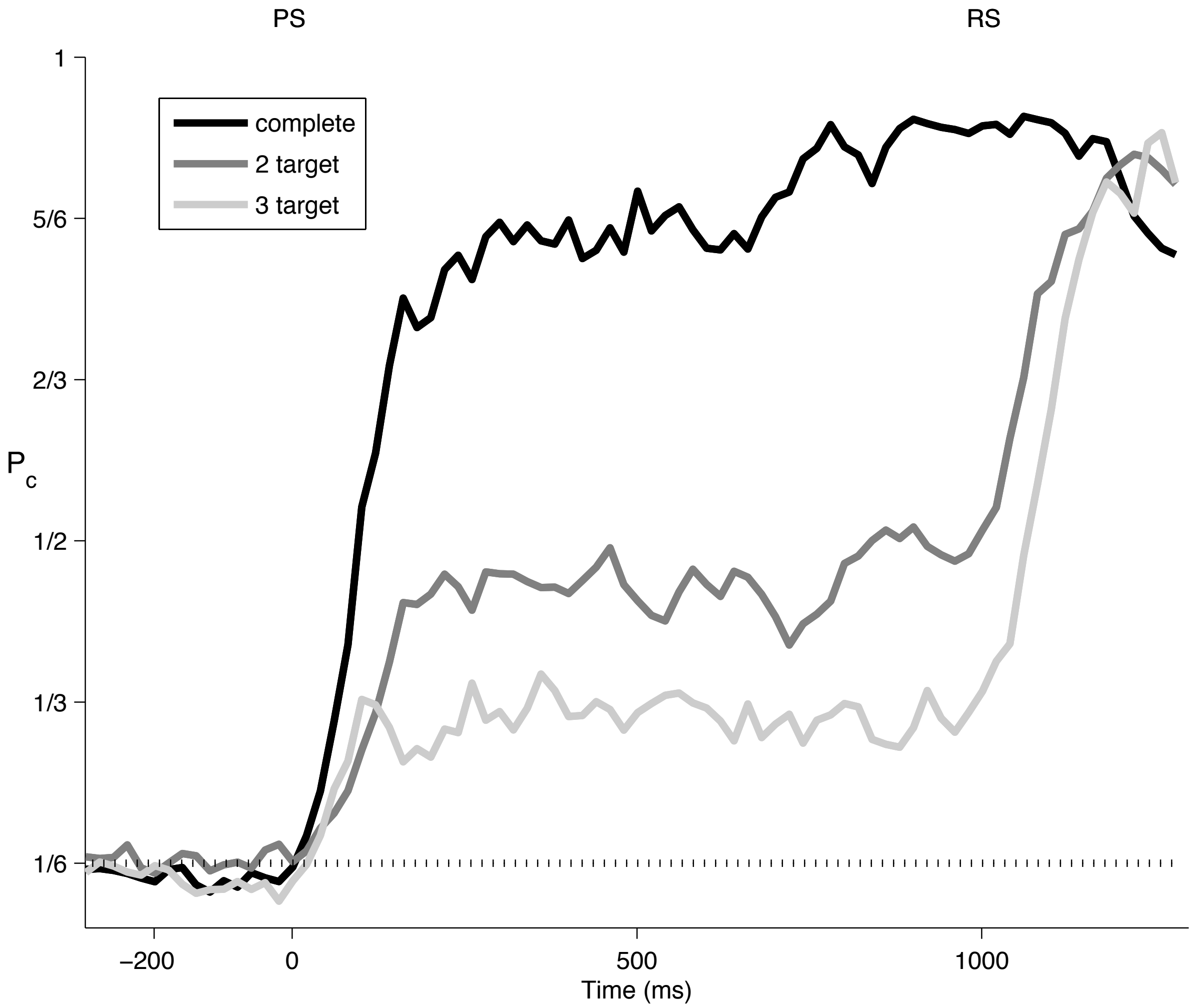


Supplemental Figure 3: Population decoding of stimulus. Bayesian probabilities for decoding the correct preparatory stimulus (PS) from a population of 100 neurons. In the single target condition there were 6 possible instruction stimuli with chance level 1/6. In the 2- and 3-target condition there were 3 and 2 possible stimuli, respectively (see Materials and Methods). Decoding statistics as in Fig. 7.

Note, that with the additional analyses on stimulus coding presented here, we do not intend to suggest that cells in M1 or PMd encode visual stimuli per se. The presentation of the visual stimuli alone without the association of any behavioral relevance should lead to no or diminished motor cortical responses. ,

Population decoding from a selected set of neurons

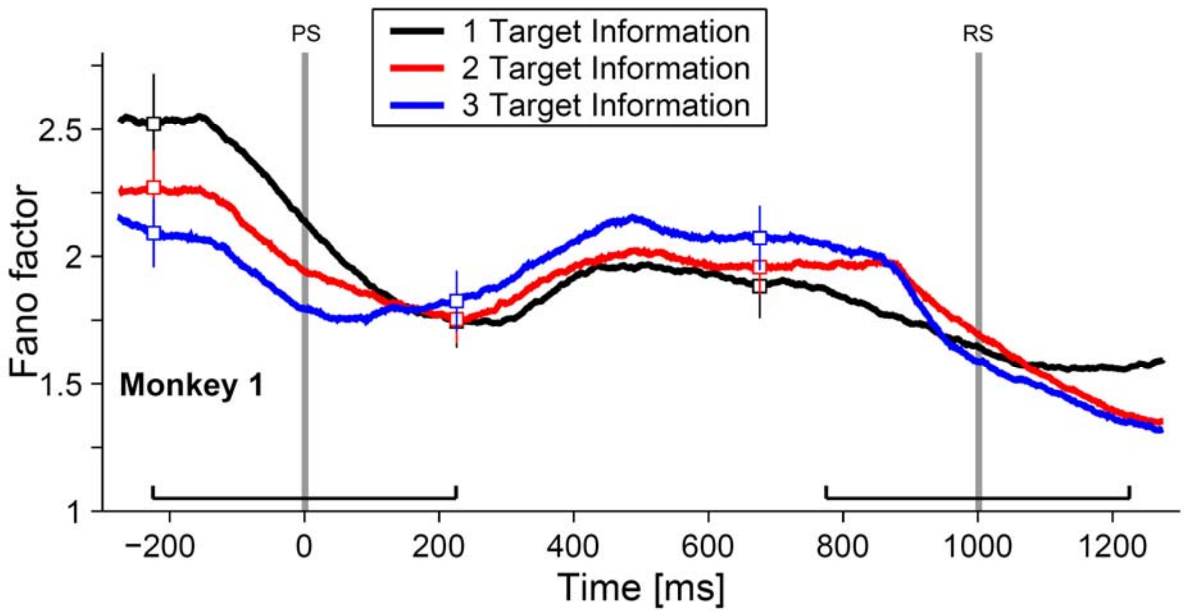
The distributions in Fig. 5 or suppl. Fig. 2 show that at any point in time only a subset of neurons are significantly tuned and of those only few neurons show strong tuning. Moreover, individual neurons are significantly tuned mostly during short periods of time (Fig.6). Consequently, at any point in time a different subpopulation of all neurons contributes to the population decoding. Here, we selected 10 neurons that showed the highest time-averaged decoding probabilities and repeated the time-resolved decoding from their single-trial activities. As shown in the supplemental Fig. 4, this subset of 10 selected neurons reached decoding probabilities similar to a set of 50 randomly chosen neurons (cf. Fig. 7).



Supplemental Figure 4: Decoding probability for the 10 ‘average best’ neurons (monkey 1). Computation performed as in Fig. 7, except that here the 10 neurons with highest time-averaged Pc as computed during preparatory and execution period were used. Results for complete information condition (black), 2-target condition (dark gray), and 3-target condition (light gray). Dotted line depicts chance level.

Dynamic changes of trial-by-trial variability

We performed a time-resolved analysis of trial-by-trial spike count variability. To this end we measured for each neuron the Fano factor, i.e. the count variance normalized by the mean count across trials, in a sliding window as described elsewhere (Nawrot et al., 2008; Nawrot, 2009). Supplemental Fig. 5 shows the average Fano factor across all neurons of monkey 1 in all three conditions. We found that before PS the variability was highest in the 3-target condition and lowest in the 1-target condition. Note, that the monkey performed the tasks associated with the 3 different conditions in separate blocks. The order of blocks was randomized across different recording sessions. During the preparatory period trial-by-trial variability reached the lowest value in the condition where prior target information was complete, and it was higher in the conditions with incomplete prior information.



Supplemental Figure 5: Temporal modulation of trial-by-trial variability depends on prior information. Time resolved Fano factor calculated in a moving window of 450ms width (indicated by black intervals) for the three different conditions of prior target information and averaged across all 112 neurons recorded in monkey 1. Error bars indicate standard error of the mean. Black: 1-target condition, red: 2-target condition; blue: 3-target condition.