Supplemental Figure Legends, Tables, and Methods

Supplemental Figure Legends

Figure S1 – Disparity and Vergence Angle Sampling for Coupled Reach Targets in Experiment 1. The disparity of coupled reach targets is shown on the x-axis and distance is shown on the y-axis (Reach Depth). The same reach target disparities were tested at each vergence angle. Coupled reach targets at 13° vergence angle are shown in magenta, for 9.7° in blue, and 6.5° in red. The +1.5° disparity target at 6.5° vergence angle was outside the reach span of both monkeys (not shown).

Figure S2 – Disparity and Vergence Angle Sampling for Decoupled Reach Targets in Experiment 2. The disparity of decoupled reach target is shown on the x-axis and distance is shown on the y-axis (Reach Depth). Different reach target disparities were tested at each vergence angle, however the absolute depth of reach targets was at 5 constant values (15 to 35cm in 5 cm increments). Decoupled reach targets at 13° vergence angle are shown in magenta, for 9.7° in blue, 6.5° in red, 1.9° in green.

Figure S3 – Target sampling for Index A, calculating modulation by reach target disparity and fixation depth. The modulation was calculated at 3 fixed absolute target depths, circled in the figure. Note that the modulation calculated for each circled group covers a different range of target disparity. The modulation for the 3 groups was then averaged to produce a single number for Index A.

Figure S4 – Target sampling for Index B, calculating modulation by vergence angle at constant reach target disparity. The modulation was calculated at 3 values of disparity, circled in the figure. The modulation was calculated for the 3 groups and then averaged for Index B.

Figure S5 – Disparity tuning responses during cue, planning and movement periods. Although fixation behavior is constant throughout these periods, other factors differ: 1) visual stimulation by the presentation of the reach target occurs only in the cue period, 2) the reach occurs in the movement period, and disparity tuning responses may also reflect motor related signals such as motor efference or proprioceptive feedback. The shape of disparity tuning from the cue period was reflected in the planning and movement period responses in PRR neurons (Figure S5 A & B). Cross correlating the disparity tuning curves for the cue, planning, and movement periods for each neuron yields correlation coefficients that measure the similarity of disparity tuning between different periods (see Supplemental Methods). These data suggest that a representation of target disparity formed during stimulus presentation carries into the formation of movement plans, and that spiking activity during the guidance of the hand to the target also reflects aspects of target disparity that were encoded in movement plans, in conjunction with other movement related signals. A: Neuron response at 13° vergence angle for different trial periods with significant correlation ($P<0.05$) for tuning between periods. The cross correlation at zero lag between the cue and planning period was 0.9273, and between the planning and movement period was 0.9897. B: Neuron response at 13° vergence angle for different trial periods with significant correlation ($P<0.05$) for tuning between periods. The cross correlation at zero lag between the cue and planning period for this neuron was 0.7732. The cross correlation at zero lag between the planning and movement period for this neuron was 0.7819. C: Histogram of significant cross correlation values at zero lag ($P<0.05$) between cue and planning periods (red, n = 88 total cross correlations from 65 neurons), and planning and movement periods (blue, n = 136 total cross correlations from 89 neurons). The average magnitude of significant correlations are very similar (μ = 0.84 for cue and planning, μ = 0.86 for planning and movement) and not significantly different (Kruskal-Wallis; $P>0.08$).

Figure S6 – Example of Complex disparity tuning from coupled reach targets viewed at 13° vergence angle. Significant modulation by disparity for this neuron occurred only at 13° vergence angle (ANOVA P=4e-4).

Figure S7 – Cue period DTI. The mean of the maximum cue period DTI from each neuron in the population (n=137) is 0.4976 (±0.2679) with a median DTI of 0.4324. A: Histograms of cue period disparity tuning index (DTI) at each vergence angle for all neurons from experiment 1 (n=137). The mean of the DTI at each vergence angle does not differ (Kruskal-Wallis; $P>0.52$), and the distributions of DTI at each vergence angle do not differ (Komolgorov-Smirnov test; $P>0.64$ for 13° and 9.7° vergence; $P>0.54$ for 13° and 6.5°; $P>0.36$ for 9.7° and 6.5°). B: Cue period DTI from different vergence angles are paired for each neuron, shown for the population. Different pairings of vergence angle are shown from left to right. Cue period DTI is correlated at different fixation depths across the population (r=0.75 for 13° and 9.7° vergence; r = 0.65 for 13° and 6.5° vergence; r = 0.79 for 9.7° and 6.5° vergence; $P<1e-5$ for all r). C: Cue and planning period DTI at each vergence angle for all neurons (n=137). Though there is a difference in magnitude between cue and planning period DTI (μ=0.0522, Kruskal-Wallis; P=0.0011), there is no effect of vergence angle in this difference (Kruskal-Wallis; P>0.50). Cue and planning period DTI are correlated at each level of vergence across the population (r=0.80 for 13°, 0.71 for 9.7°, 0.74 for 6.5°; P<1e-5 for all r).

FIGURE S8 – VTI from experiment 1. A: Histograms of planning period VTI for all neurons (n=137). The average VTI was similar across disparity, however there was a significant difference with a lower VTI for targets at 0° disparity (Kruskal-Wallis; P = 0.0277), which was found to be only between targets at 0° and -1.0° disparity (Kruskal-Wallis with Bonferroni correction for multiple comparisons, P<0.05). B: Histograms for cue period VTI for all neurons (n=137). There is no difference in VTI due to target disparity (Kruskal-Wallis; P>0.17). C: VTI is paired for planning and cue periods for all neurons (n=137). The VTI averaged across disparity is similar for cue and planning periods (μ_{cue}=0.3103±0.1896, $\mu_{planning}$=0.2678±0.1606; Kruskal-Wallis; P>0.07;), and no significant differences exist between cue and planning VTI at each level of disparity (Kruskal-Wallis, all P>0.06). The average difference between cue and planning VTI across neurons and disparity is -0.0425, which is a 13.69% reduction of the cue VTI during planning, and the difference does not vary with disparity (Kruskal-Wallis; P>0.90). The correlation of the VTI averaged across disparity between the cue period and planning period for all neurons (n=137) is r =0.84 (P<1e-5), and correlations between VTI during the cue and planning period at each level of disparity are shown for all neurons (P<1e-5 for all r; n=137). D: The planning period DTI and VTI, averaged across vergence angle and disparity respectively for each neuron, is paired and shown for all neurons (n=137), with a correlation of r = 0.92 (P<1e-5).

Figure S9 – Histogram of difference in tuning indices (Index A-Index B) from experiment 2 (n=137). Index A and B calculate firing rate modulation using the same vergence angles and reach targets grouped in different ways. Index A measures modulation strength by both disparity and vergence for targets at constant absolute depth. Index B measures modulation strength by vergence angle and absolute target depth for targets at constant disparity. A difference of zero indicates that disparity does not modulate a neuron's response more than vergence, a negative difference indicates a greater strength of modulation by vergence than disparity, and a positive difference indicates a greater modulation by disparity. The arrow indicates mean difference in population is > 0 (μ=0.05, σ=0.11; Wilcoxon signed rank test, P=5.8e-6).

Tables

Area	Mean DTI	Median DTI
PRR	**0.43**	**0.36**
V1	**0.38**	**NA**
V4	**0.45**	**0.41**
IT	**NA**	**0.36**

Table S10 – DTI from different cortical areas. DTIs from V1, V4, IT are during stimulus presentation for different types of stimuli, DTI from PRR is during movement planning. This data has been adapted from Figure 12 in (Hinkle and Connor 2005) in order to include the DTI from PRR for comparison. (NA = not available)

Supplemental Methods

Disparity Tuning Cross Correlation

Disparity tuning curves from experiment 1 at each vergence angle from the cue, planning, and movement periods were cross correlated. The disparity tuning curves from all vergence angles only included disparity values from -1.5° to +1.0° in 0.5° steps. The cross correlation value at zero lag is considered a correlation coefficient, ranging from $-1 \le \rho \le 1$.

$$\rho = \frac{\sum_i (X_i - \mu_x)(Y_i - \mu_y)}{\sqrt{\sum_i (X_i - \mu_x)^2 (Y_i - \mu_y)^2}}$$

The zero lag cross correlations were compiled for 1) cue and planning periods, and 2) planning and movement periods. A permutation test was employed to determine the significance of cross correlations. Trials were shuffled, and disparity tuning curves at each level of vergence and each period were calculated from the shuffled data (preserving the number of trials for each condition obtained in the experimental session) and cross correlated at zero lag. The cross correlations at zero lag between disparity tuning curves from different periods were considered significant if they exceeded the magnitude of 95% of shuffled cross correlation values at zero lag ($P<0.05$).

Vergence Tuning Index

Vergence Tuning Index (VTI) is a measure of modulation by vergence at a single level of target disparity:

$$\text{Vergence Tuning Index} = \frac{(\max - \min)}{(\max + \min)}$$

VTI was calculated for planning and cue period responses without subtracting baseline firing rates. The VTI was measured using coupled reach targets in experiment 1 and compared at different disparities across the population of neurons. VTI contains 3 samples at each level of target disparity (13°, 9.7°, and 6.5° vergence angle), and only target disparities commonly sampled at all vergence angles were considered (-1.5° to +1.0° in 0.5° steps).