Supporting Information

Navalpakkam et al. 10.1073/pnas.0911972107

Decision Models

Here, we explain the derivation of the global likelihood terms in Eqs. **3–5**. Let $P(T_x = H|\vec{a})$ denote the posterior probability of target H's presence at location x given the vector of sensory observations at all locations in the display, $\vec{a} = \{a_1 \ldots a_n\}$. Each display consists of target H, V, and $n - 2$ distractors. Thus, the posterior probability of H's presence at location x can be expressed as the joint probability of H's presence at x, target V's presence at any other location $y \neq x$, and distractor D's presence at the remaining locations $z \neq x, y$, marginalized over all choices of y. The posterior probabilities can then be expressed as a product of the likelihood and prior terms. We assume that target V can occur at any location $y \neq x$ with equal probability, $P(T_y = V|T_x = H) = \frac{1}{n-1}$. Thus, we get the following:

$$P(T_x = H|\vec{a}) = \sum_{y \neq x} P(T_x = H, T_y = V, T_{z \neq x,y} = D|\vec{a}) \quad \textbf{[S1]}$$

$$P(\vec{a}|T_x = H)P(T_x = H) = \sum_{y \neq x} P(\vec{a}|T_x = H, T_y = V, T_{z \neq x,y} = D) \times P(T_y = V|T_x = H)P(T_x = H) \quad \textbf{[S2]}$$

$$P(\vec{a}|T_x = H) = \frac{1}{n-1} \sum_{y \neq x} P(\vec{a}|T_x = H, T_y = V, T_{z \neq x,y} = D) \quad \textbf{[S3]}$$

In Eq. **S3**, $P(\vec{a}|T_x = H)$ denotes the global likelihood of target H's presence at location x, based on the sensory observations at all locations in the display, $\vec{a} = \{a_1 \ldots a_n\}$. Let $P(a_x|T_x = H)$ denote the local likelihood of H's presence at location x based on the sensory observation at that single location, a_x.

The global likelihood term on the right-hand side in Eq. **S3** can be expressed as a product of local likelihoods, as shown in Eq. **S4**. This completes the derivation of Eq. **3**. Eqs. **4** and **5** are derived similarly.

$$P\left(\vec{a} = \{a_1 \ldots a_n\} \middle| T_x = H\right) = \frac{1}{n-1} \sum_{y \neq x} P(a_x|T_x = H) \times P(a_y|T_y = V) \Pi_{z \neq x,y} P(a_z|T_z = D) \quad \textbf{[S4]}$$

Experiment 1: Orientation

Individual Subjects' Data Compared with Model Predictions. Fig. 2 *A–D* shows data from subject S1. Here, we show the data from the remaining subjects S2 through S6. As seen in Figs. S1–S5, behavior of all subjects is consistent with the predictions of M3. Thus, subjects in experiment 1 behave as reward maximizers that saccade to the location of the maximum expected reward.

In experiment 1 (and others), fixations could land on either target H, target V, or distractor D. Fig. S9 shows the distribution of fixations of subject 1 on target H, target V, and distractor D in different value and feature-contrast conditions. Note that the average probability of fixating a distractor is 8.1% (SD = 5.6%) and that it is not affected by the relative value or feature-contrast of the targets [no effect of value using paired t tests at a significance level of 0.05; no effect of feature-contrast using paired t tests at a significance level of 0.05; no correlations between % fixations on the distractor and target's relative value ($R^2 = 0.01$) or feature-contrast ($R^2 = 0.04$)]. For this reason, all subsequent analyses focus on fixations to one of the targets (e.g., H). Fig. S9 also shows that in many conditions, subjects chose flexibly between targets H and V (e.g., Fig. S9, *Upper Left*, when target H is twice as salient but V is twice as valuable; *Upper Right*, when both targets are equally salient and valuable; *Lower Left*, when target H is twice as valuable but V is twice as salient). This shows that subjects used a dynamic strategy of choosing flexibly different targets between trials rather than a static strategy that they may have acquired through ample practice or training in a condition.

Saccade Latency. How do value and feature-contrast affect latency to the first saccade? Fig. S8 shows the data pooled over all six subjects. The data show two main trends: (*i*) saccade latency decreases as the target's feature-contrast increases (two-way ANOVA shows a significant effect of feature-contrast: $F(6, 18) = 898$, $P < 0.01$) until it reaches a mean latency of ≈330 ms (the highest latency of 500 ms occurs when the target's feature-contrast is very low and indicates that it is never fixated within 500 ms), and (*ii*) saccade latency decreases as the target's relative value increases (two-way ANOVA shows a significant effect of value: $F(3, 18) = 28$, $P < 0.01$). Thus, value and feature-contrast affect the initial gaze and its latency. The shortest latency of around 330 ms followed by a fixation duration of at least 100 ms (required to earn the reward) indicates that subjects mostly made one saccade during the 500 ms of presentation in experiment 1.

Individual Subjects' Data for Experiment 2: Intensity

The reward maximization behavior observed in experiment 1 on oriented stimuli extends to experiment 2 on luminance stimuli. Fig. 3 and Figs. S6 and S7 show the data from three individual subjects.

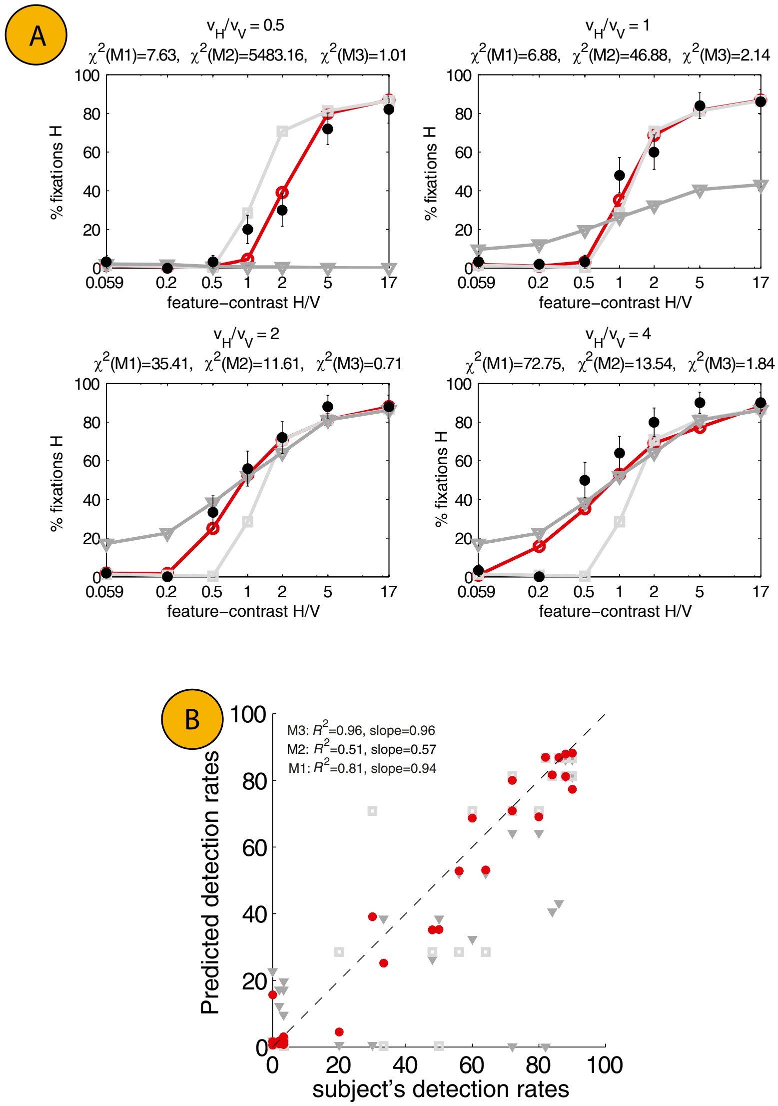

Fig. S1. Experiment 1, subject S2 (author). (*A*) Subject's data (black dots with error bars denoting SEM) and the psychometric functions predicted by the three models (M1: light gray, M2: dark gray, M3: red). Each panel denotes a different ratio of values of targets H vs. V. The χ^2 goodness-of-fit statistic (comparing how well each model fits the data) is shown in the title. Across all conditions tested, M3 (the ideal observer) fits the subject's data better than M1 and M2. (*B*) Predictions of model M3 correlate well with the subject's data (pooled across all value conditions).

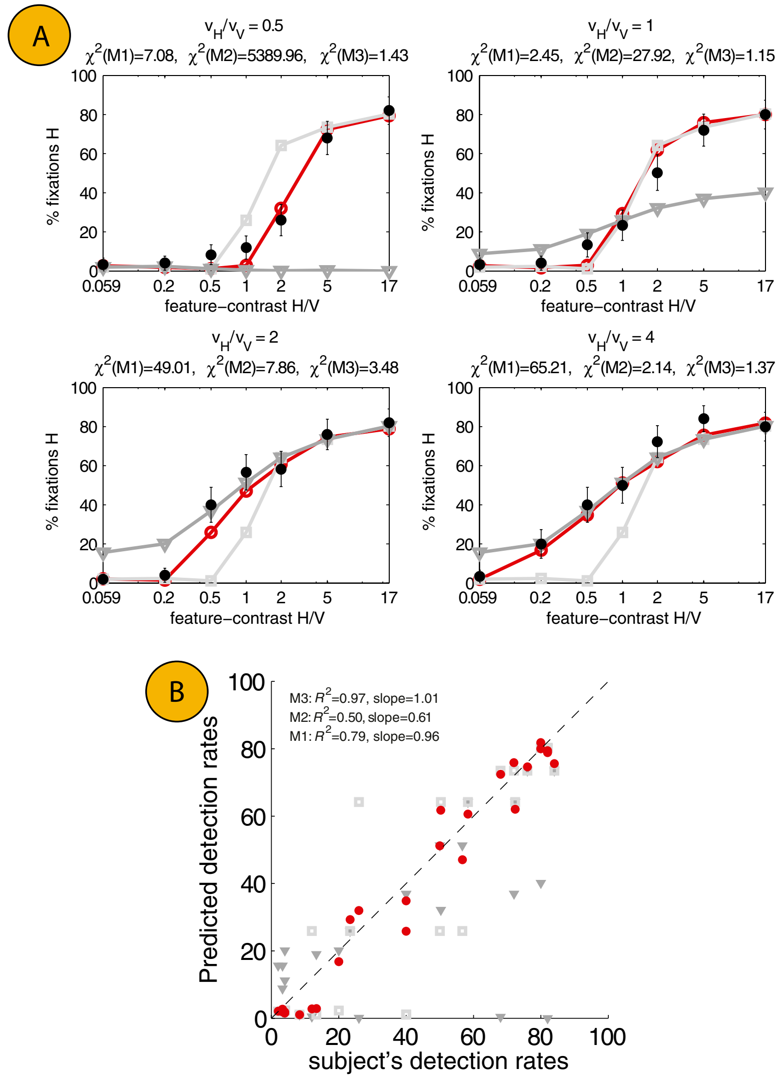

Fig. S2. Experiment 1, subject S3; similar to Fig. S1.

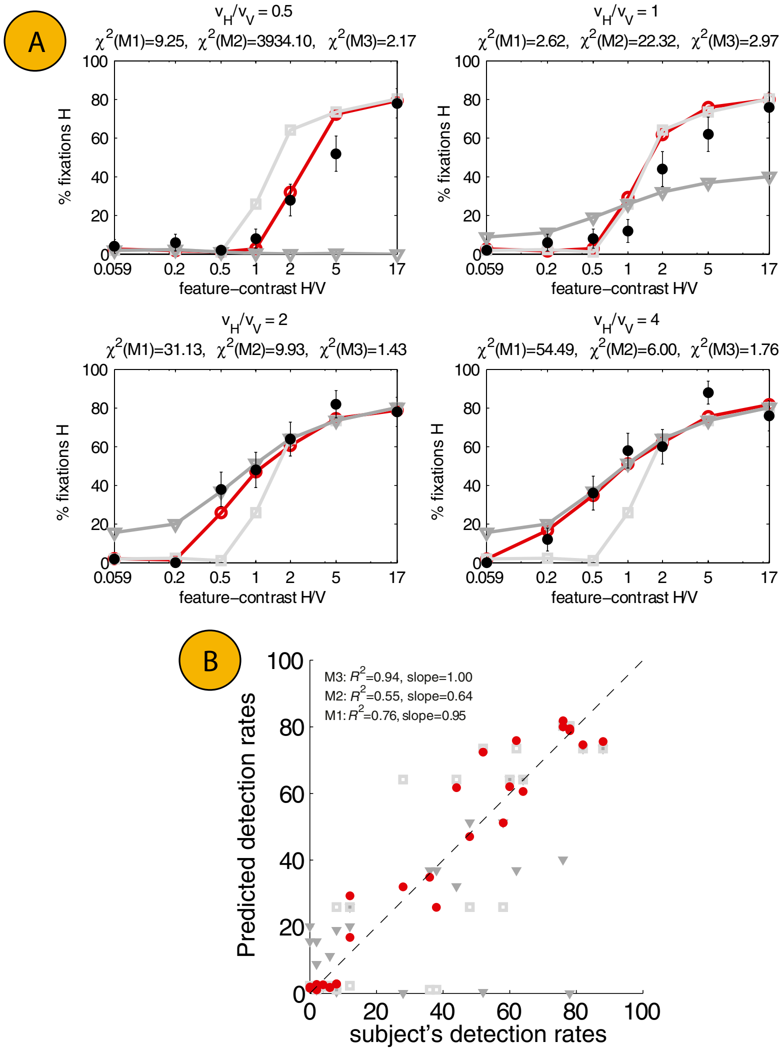

Fig. S3. Experiment 1, subject S4; similar to Fig. S1.

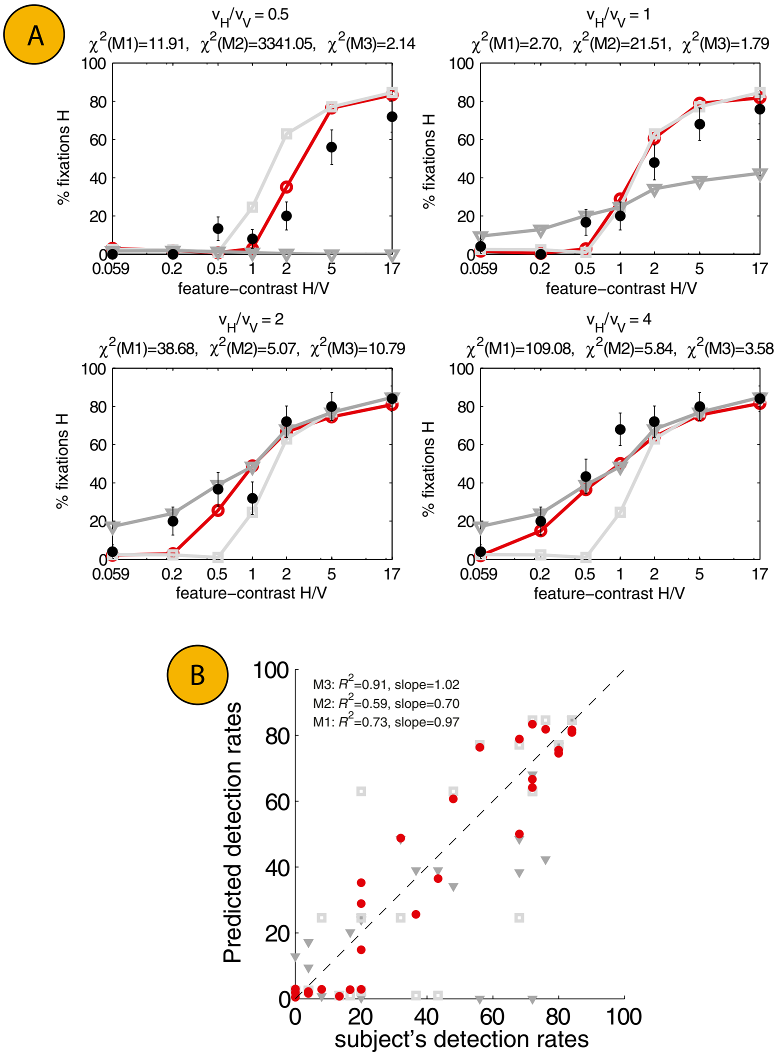

Fig. S4. Experiment 1, subject S5; similar to Fig. S1.

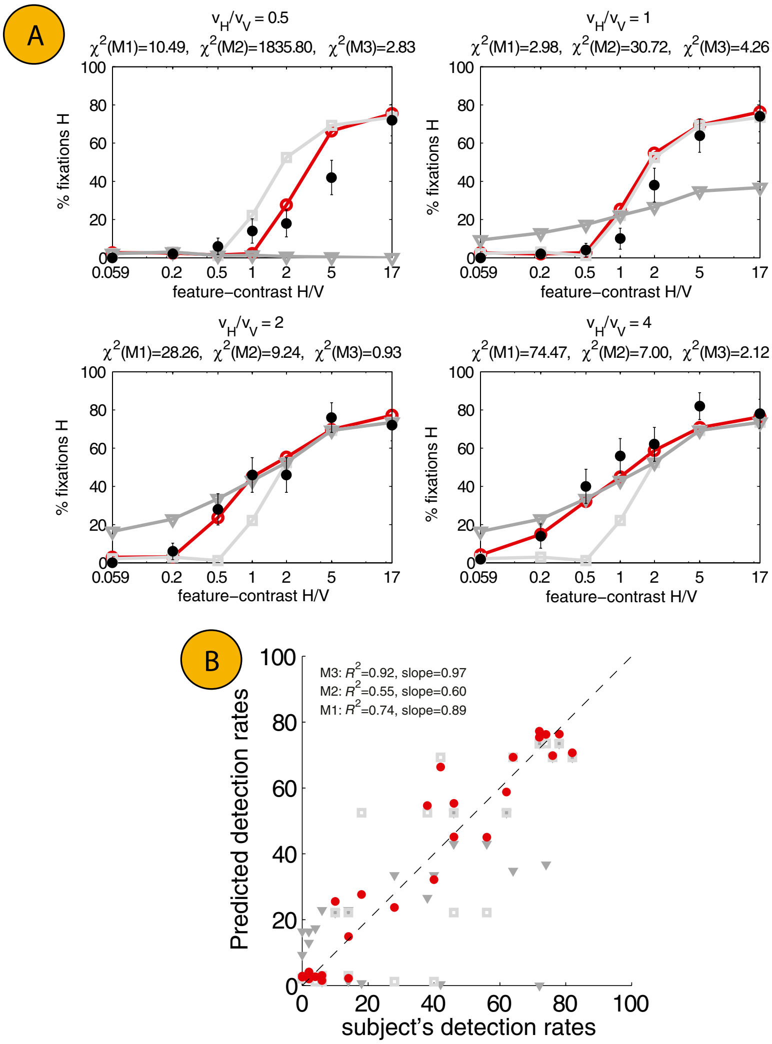

Fig. S5. Experiment 1, subject S6; similar to Fig. S1.

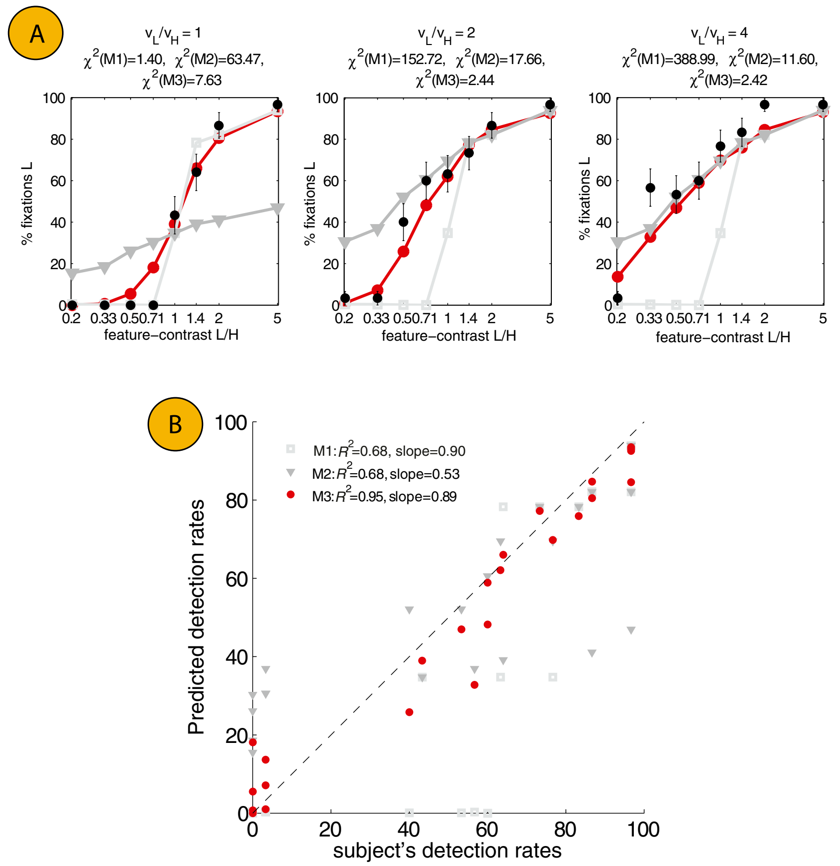

Fig. S6. Experiment 2, subject S2; similar to Fig. S1 but using brightness intensity as the feature.

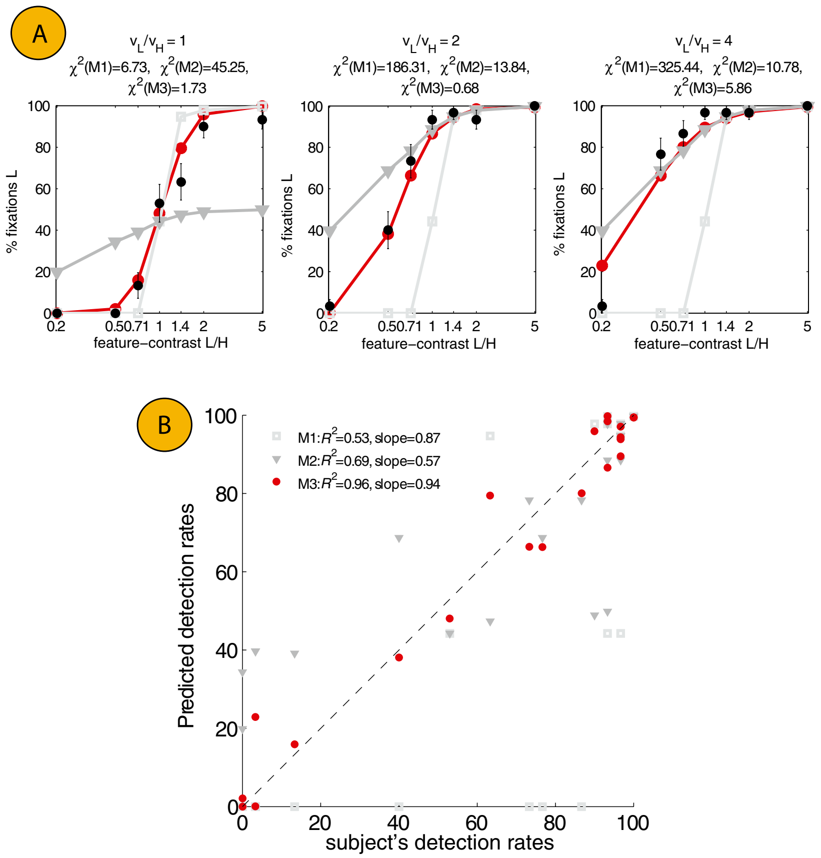

Fig. S7. Experiment 2, subject S3; similar to Fig. S1 but using brightness intensity as the feature.

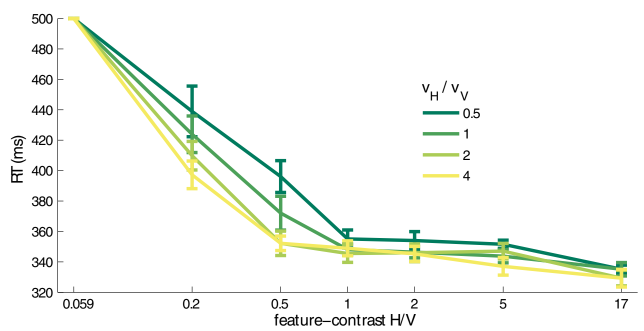

Fig. S8. Saccadic latency for experiment 1. This figure shows the time to saccade to the horizontal target as a function of its relative value and feature-contrast. Saccades become faster as the target's value and feature-contrast increase. RT, reaction time.

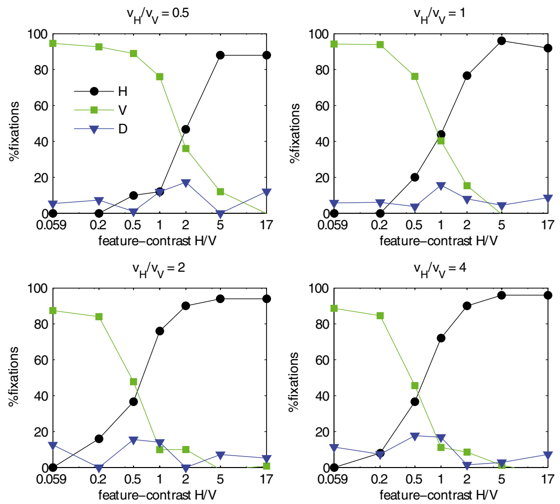

Fig. S9. Experiment 1, subject S1. Fixations to the distractor (blue), target H (black), and target V (green) for different value and feature-contrast conditions in experiment 1. Although the fixations to the targets vary systematically with value and feature-contrast, the fixations to the distractor appear to be unaffected (details provided in *SI Text*).