Current Biology, Volume *28*

Supplemental Information

Accuracy of Rats in Discriminating Visual Objects Is Explained by the Complexity of Their Perceptual Strategy

Vladimir Djurdjevic, Alessio Ansuini, Daniele Bertolini, Jakob H. Macke, and Davide Zoccolan

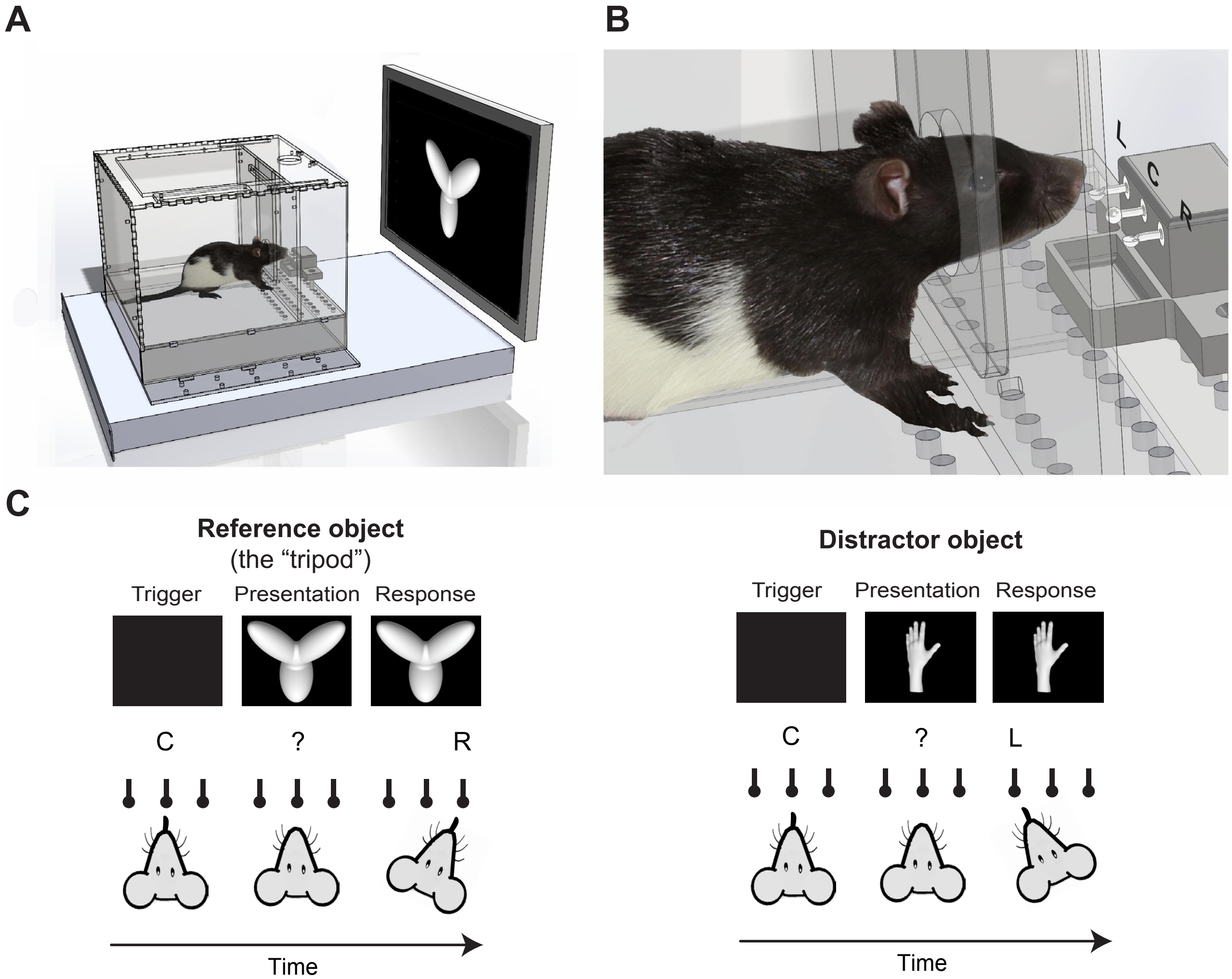

Figure S1. Experimental rig and behavioral task, Related to Figure 1 and STAR Methods.

(A-B) The drawings illustrate the operant box in which rats were trained to perform the visual discrimination task described in our study. In the pictures, several elements of the rig are visible: 1) the box (whose walls were actually black, but are rendered here as transparent to allow viewing the inside of the box); 2) the block holding the three feeding needles, which served both as touch sensors, to record rat responses, and reward ports, to deliver liquid reward in case of correct choices; 3) the viewing hole, where a rat had to insert its head to face the stimulus display and interact with the touch sensors; and 4) the computer monitor, where the visual stimuli were shown. Note that six of such boxes were simultaneously active during the experiment, so as to train in parallel all the rats tested in our study.

(C) Schematic of the object discrimination task. The animals learned to trigger stimulus presentation by licking the central sensor and to associate each object identity to a specific reward port/sensor – the right-side port was associated to the reference tripod object, while the left-side port was associated to all the distractor objects (distractor #10 is shown here as an example).

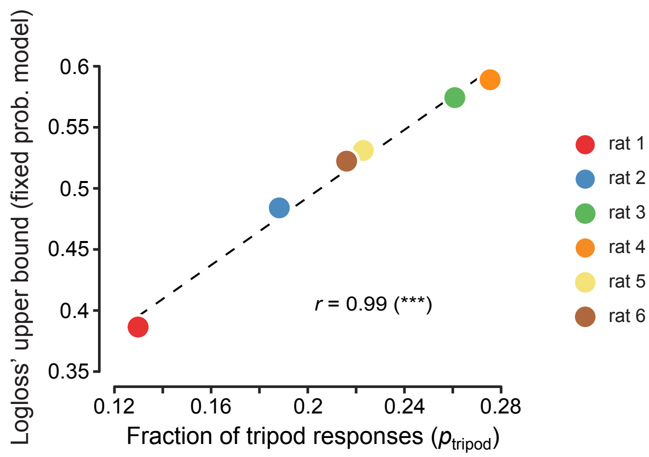

Figure S2. The logloss' upper bound depends on the predictability of rat responses, Related to Figure 4.

Relationship between the logloss of the constant-probability response model (used to estimate the loss' upper bound) and the fraction of tripod responses that each rat gave to the random tripods. The two quantities were strongly and significantly correlated (two-tailed t-test; $p < 0.001$).

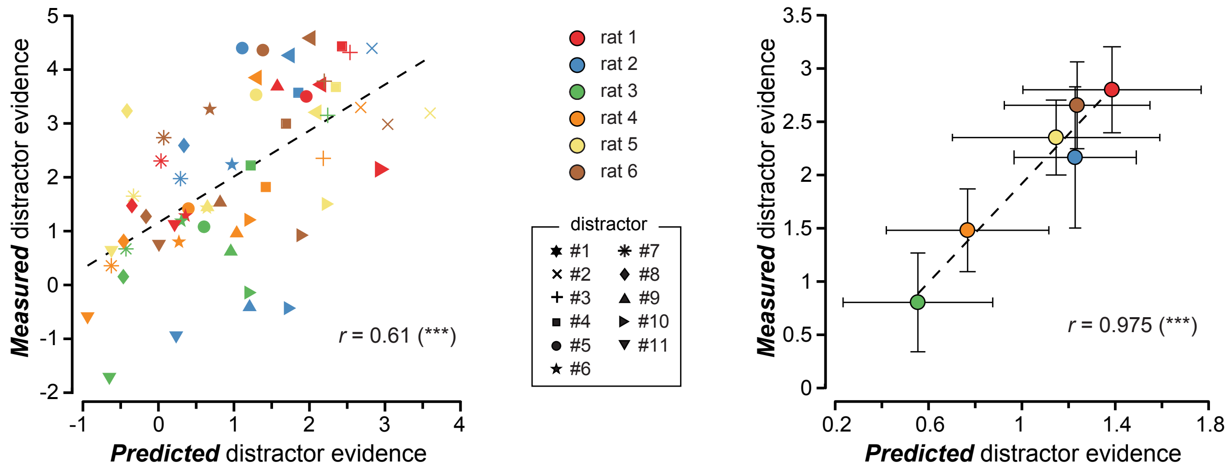

Figure S3. Predicting rat perceptual choices to the distractor objects, Related to Figure 4 and STAR Methods.

Relationship between measured and predicted distractor evidence, as obtained: 1) by considering all rats and distractor conditions together (left); and 2) after averaging, separately for each animal, the measured and predicted evidences across the 11 distractors (right; dots show means ± SEM). Both correlations were significant according to a two-tailed t-test ($p < 0.001$).

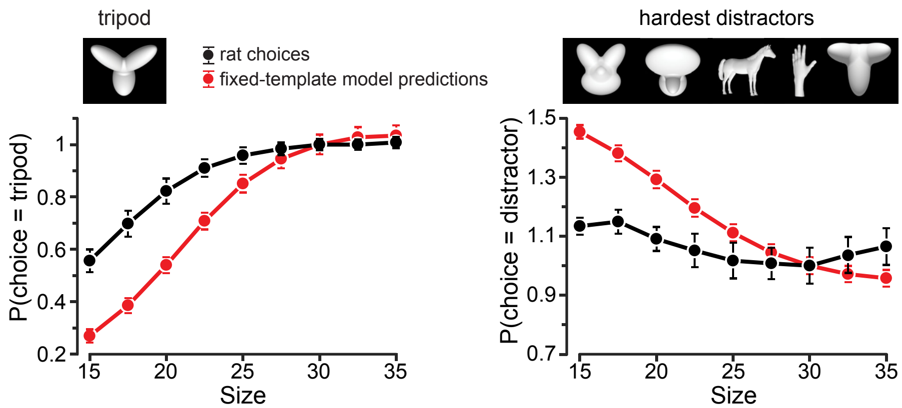

Figure S4. A fixed-size, template-matching strategy does not explain rat discrimination performance with the reference and distractor objects across size changes, Related to Figure 5.

Rat group average accuracy (black) with the tripod (left) and the five hardest distractors (right) as a function of size is compared to the average accuracy yielded by the logistic regression models (red), based on the classification images obtained from the regular-size (30º) random tripods (dots show means over the six rats ± SEM). The curves (that were normalized to their values at 30º for a better comparison) all displayed some degree of modulation over the size axis, but this was much sharper for the model predictions than for rat performances. Such different modulation was statistically assessed by a two-way ANOVA with size and observer (i.e., either rat or model) as factors. For both the left and right plots, the main effect of size was significant ($p < 0.001$; $F_{8,40} = 175.474$ and $F_{8,40} = 46.565$ respectively), as well as its interaction with observer ($p < 0.001$; $F_{8,40} = 22.387$ and $F_{8,40} = 14.993$ respectively), thus showing that the two performances dropped at a different pace along the size axis. This, in turn, confirmed the failure of the fixed-size template-matching model to account for rat size-tolerant behavior.

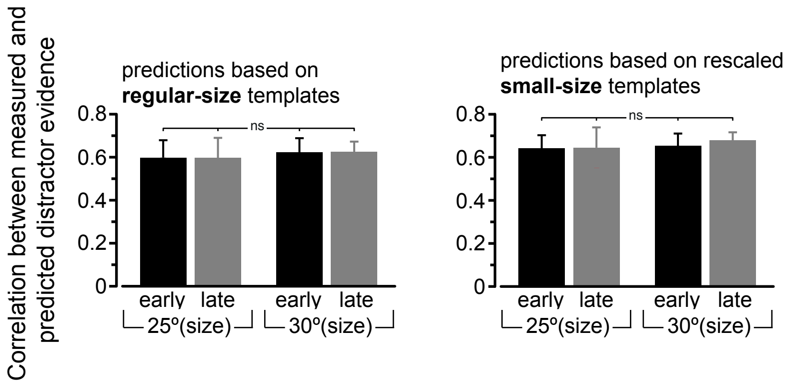

Figure S5. Transformation-tolerance of rat perceptual strategy with the distractor objects, Related to Figure 4 and Figure 6.

The correlation between measured and predicted distractor evidence across the 11 distractors was computed, for each rat, using the logistic regression model (eq. 1). The resulting correlation coefficients were averaged to yield the bars shown here (mean over 6 rats ± SEM). The predictions were derived from models based either on the classification images obtained at the regular size (i.e., those shown in Figure 6A) or on the rescaled versions of the classification images obtained at the small size (i.e., those shown in Figure 6C) – left and right panels, respectively. Correlations were obtained for the distractors shown both at size 25º and 30º, in both the early (black) and late (gray) sessions, i.e., when the random tripods were shown, respectively, either at the regular or small size (see STAR Methods). No pairwise comparisons were significant according to a two-tailed, paired t-test. This indicates that the perceptual template obtained at a given size (e.g., 30º) was equally good at accounting for rat choices at that size and at a different one (e.g., 25º), once properly rescaled, thus confirming the tolerance of the object processing strategy to size changes.

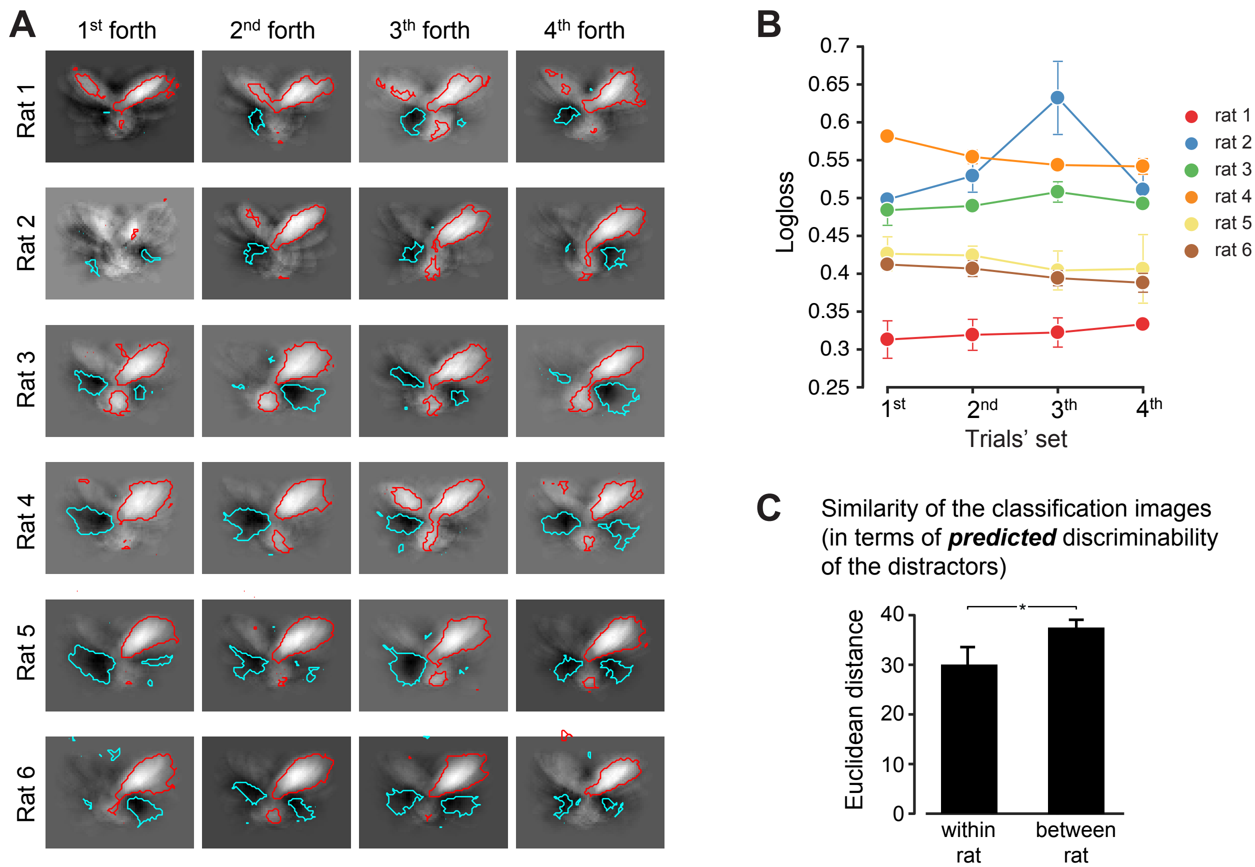

Figure S6. Stability of rat perceptual strategies over time, Related to Figure 6 and STAR Methods.

(A) The figure shows, for each rat, the classification images obtained in four consecutive, equally sized sets of trials (see STAR Methods for details). This allows appreciating how, for most animals, the pattern of salient and anti-salient features was largely preserved over the duration of the experiment. The notable exception is rat #2, whose classification image was initially poorly defined. This can be taken as an indication that, at the onset of the test with the random tripods, the animal did not consistently apply a unique strategy to process these stimuli. The strategy, however, stabilized later, as indicated by the cleaner classification images obtained from the second set of trials onward.

(B) To quantify the stability of a rat's perceptual strategy over time, we measured how well each of the classification images computed over the four consecutive sets of trials (i.e., the classification images shown in A) predicted rat responses to a test set of held-out stimuli (once plugged into the logistic regression model of eq. 1; see STAR Methods for details). As in Figure 4B, the goodness of the prediction was assessed by computing the logloss cost function, which was remarkably stable over time for all the rats, again with the exception of rat #2 (dots show means over 10 runs of the analysis ± SEM; see STAR Methods for details).

(C) As a final test for the stability of rat perceptual strategies, we computed the similarity between the predicted perceptual discriminabilities of the 11 distractors according to each of the classification images shown in A. That is, we obtained a matrix of Euclidean distances between pairs of predicted discriminability vectors, similar to the one shown in Figure 3B (left), only that now each rat contributed four classification images (one for each consecutive set of trials), thus resulting in a 24x24 matrix. We then averaged the elements of the matrix above the diagonal, after dividing them in two groups: one including only within-rat comparisons (i.e., 6 comparisons per rat, for a total of 36 values) and the other including only between-rat comparisons (240 values). The bar plot shows the resulting average Euclidean distances obtained for the two groups (means ± SEM). Critically, the within-rat distance was significantly lower than the between-rat distance ($p < 0.05$; one-tailed t-test), thus showing that, on average, the classification images obtained for the same rat across time were more similar to each other than to the classification images of the other animals. This further demonstrates the stability over time of rat perceptual strategies.

	Rat #1	Rat #2	Rat #3	Rat #4	Rat #5	Rat #6
Sessions in which the regular-size (30º), full-body random tripods were tested						
Regular Stimuli	14,477	13,901	12,482	15,919	14,431	15,257
Random Tripod Stimuli	1,809	1,354	1,571	2,112	1,999	2,433
Sessions in which the regular-size (30º), outline random tripods were tested						
Regular Stimuli	15,569	14,042	17,652	15,796	15,541	15,715
Random Tripod Stimuli	2,757	1,499	3,059	2,819	2,901	3,08
Sessions in which the small-size (25º), full-body random tripods were tested						
Regular Stimuli	22,175	20,579	14,516	21,418	19,425	21,189
Random Tripod Stimuli	2,705	1,867	2,076	2,878	2,823	3,138

Table S1. Number of trials collected in the three phase of the experiment where the random tripods were presented along with the regular stimuli (i.e., the reference and distractor objects), Related to Figure 2 and STAR Methods.