Neural measurements of sensitivity to contrast and texture naturalness in developing macaques

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trial duration ≤ 1.2 seconds


time (ms)

naturalness

- Neuronal responses in V2, but not V1, are sensitive to texture naturalness.
- Average neuronal traces (example V2) show that V2 but not V1 has a greater chance of having responses that are more natural.

behavioral naturalness sensitivity improves during early life – sensitivity (inverse of threshold) roughly doubles across the age range we measured. The data from the example photometric functions above are plotted with red dots. Each animal is represented by a different color and shape.

Methods – behavior

Behavioral task

We trained three macaques (all females including two from where we made physiological recordings) to perform a four-alternative naturalness discrimination task. Animals sat in a custom-designed primate chair designed for a just noticeable difference (JND) task (for our results: three noise textures, and one target of variable naturalness, right panel). Animals had to locate and fixate on the target texture for 0.4s, before the end of the 1.2 s trial.

Results – behavior

Naturalness sensitivity (a.u.)

- Neuronal responses to natural textures appear – three noise textures, and one target of variable naturalness (right panel). Animals had to locate and fixate on the target texture for 0.4s, before the end of the 1.2 s trial.

Results – physiology

Neural responses correlate with texture naturalness – Post-stimulus time histograms show that single unit responses rates increased as stimulus naturalness increased. The left plot depicts an example time series from V1/V2, the right shows V4.

Methods – physiology

Recordings

We implanted two juvenile female macaques each with two 96 channel "Utah arrays". As shown in the schematic in the bottom right, one array was placed as close as possible to the border between V1 and V2, and one was placed in V4. The visual receptive fields for all arrays were centered 1.5 deg from the center of gaze. We extracted multi-unit threshold crossings from our data. Because we do not have histological data for the V1/V2 arrays used here, we will refer to them as "V1/V2 area."

Comparing behavioral and neural performance with an adapted linear classifier

To facilitate comparison with behavioral performance, we used a modified linear discriminant analysis. First, we fit a linear discriminant to our data (left: shown as colored data). This provides the one-dimensional projection (solution line) that best separates the classes (in our case, naturalistic and noise). The data are then projected onto this line (middle panel). Finally, using held-out data, we draw one naturalistic example (the "target") and three noise examples ("distractors"). We project these four natural examples onto the discriminant (right panel). If the naturalistic-evoked response has the largest magnitude (right panel), the trial is correct. Otherwise, the trial is incorrect. We compile the results into neurometric functions.

Results – population analysis

Neural naturalness sensitivity does not change over the age range tested – Population naturalness sensitivity improves during development and remains relatively stable over the age range tested, as shown in the example neurometric data (left). Neural naturalness sensitivity is relatively stable across the statistics range age we tested.

Conclusions

Behavioral naturalness sensitivity roughly doubles from 6 to 24 months.

V4 is more sensitive to naturalness than V1, and is more similar to behavior.

Neural naturalness sensitivity is relatively stable across the statistics range age we tested.

References and acknowledgments


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