Changes in visual evoked potentials as a function of long-term familiarity in monkeys and humans

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1. How is familiarity represented in the brain?

In previous studies comparing novel and familiar objects over a short time scale (e.g., a single trial), researchers have reported more neural activity for novel objects than for familiar objects. A recent study by Holscher, Rolls, and Xiang (2003), however, explored long-term familiarity (over several testing sessions) using single unit recording in monkeys in the perirhinal cortex. They found more neural activity for familiar objects than for novel. In addition, in humans there is some evidence of a familiarity effect for faces. Previous results indicate that at approximately 250ms post-stimulus onset, a greater negative ongoing wave was generated in response to the subject's own face stimulus compared to other familiar and unfamiliar faces (Tanaka & Porterfield, 2001).

Experimental Questions

Can we detect changes in physiological response as a result of familiarity in monkeys and humans?

Are these familiarity effects robust?

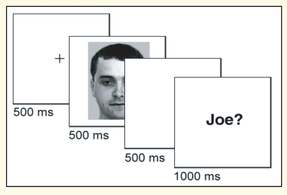
Could the familiarity effect found for humans and monkeys be the result of similar underlying processes?

2. Visual ERPs were recorded in humans during a discrimination task

Recordings

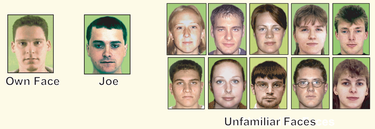
ERPs: A 128 channel geodesic sensor net was used to record ERPs from 24 people (12 males, 12 females).
Signals were filtered between 0.1Hz and 100Hz, sampled at 250Hz
The EEG was digitally filtered with a low pass of 40Hz prior to analysis
Reference was frontal

Behavioral Task



At the beginning of each trial, participants viewed a fixation cross for 500 ms, followed by a 500 ms presentation of either their own face, the "Joe" target or an unfamiliar face. After the face stimulus was presented, the "Joe?" prompt appeared and participants indicated whether the face image was "Joe" via a key press. Each face was shown 72 times.

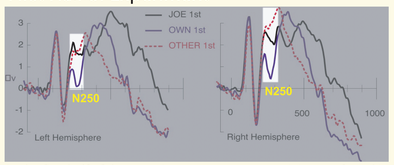
Stimulus Conditions



Face stimuli included an image of the participant's face, the target face and 10 unfamiliar faces. A male "Joe" target was used for the male participants and a female "Jane" target for the female participants. Stimuli were counterbalanced across conditions such that each face appeared once in each condition.

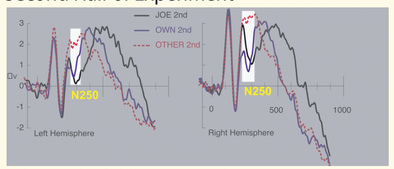
3. We found a significant familiarity effect at 250 ms in the Joe/not Joe task in humans

First Half of Experiment

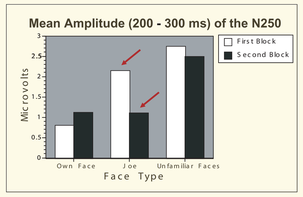


In the first half of the experiment, a greater negativity was found in response to the own face stimulus relative to Joe and the other unfamiliar faces at approximately 250 ms after stimulus onset. Given that the N250 distinguishes one's own face from other faces suggests that it is sensitive to pre-experimental familiarity.

Second Half of Experiment



In the second half of the experiment, the N250 response to Joe became more negative and approximated the level found for the own face.



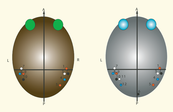
These results suggests that the magnitude of the N250 can be altered through repeated exposure when stimuli are attended or task relevant (e.g.,Joe), but not when repetitions are ignored (e.g., others).

4. Visual ERPs and Local Field Potentials were recorded in monkeys during discrimination

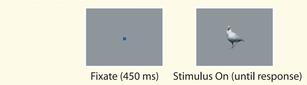
Recordings

ERPs: Titanium skull screws were implanted in two monkeys
Signals were filtered between 0.1Hz and 300Hz, sampled at 2.5kHz

LFPs: A single electrode was lowered into the inferotemporal cortex of the monkey
Signals were filtered between 0.1Hz and 300Hz, sampled at 2.5kHz



Discrimination Task



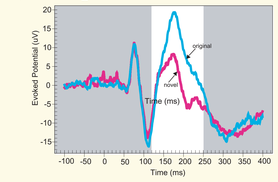
Stimuli were randomly assigned to left and right responses

Stimulus Conditions for Discrimination Task

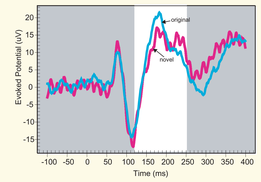
The monkeys were initially trained with 8 original birds and later given 8 novel birds. They each received 400 repetitions of each stimulus prior to the introduction of the novel birds (13 days, monkey S; 17 days, monkey T).

5. Novel category exemplars revealed clear differences in event-related potentials in two monkeys

A) Average ERPs across all channels

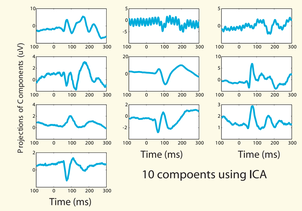


Day 1 with Novel Exemplars



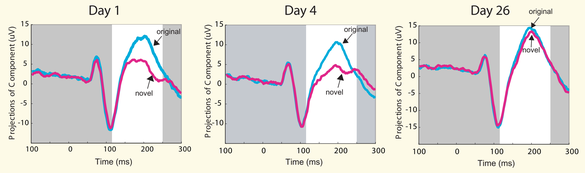
Day 26 with Novel Exemplars

B) Independent Components Analysis

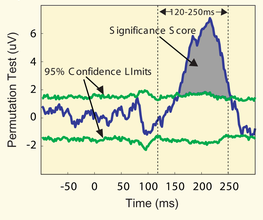


10 components using ICA

We used Independent Component Analysis (Comon 1994, Bell & Sejnowski 1995) to isolate that part of the EEG signal pertaining to the novelty of the visual stimuli. The ICA was used on a data set containing the first day, a middle day, and the last day. We then looked at the novel and original stimuli for each day.

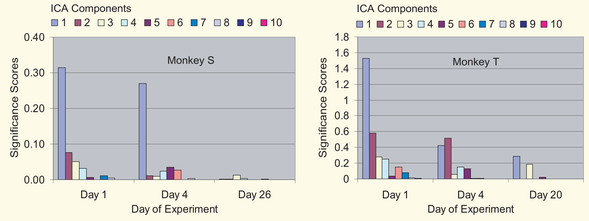


C) Permutation Tests



For each component, the difference curve between the average projection on novel trials and the average projection on original trials was calculated (blue line). A difference curve was created for 2400 random reassignments of the trials to the two categories. We used the area inside the actual difference curve but outside the 95% confidence limits derived from the permutations (green lines; two-tailed, Bonferroni corrected) as a "significance score".

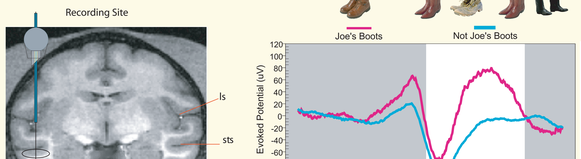
Significance scores for two monkeys show a significant familiarity effect on the first day that is absent by the last day.



6. Using the Joe/not Joe task, we find a familiarity effect in local field potentials (LFPs)

Behavioral Task

Boot stimuli included Joe's boots (the target image) and 8 unfamiliar pairs of boots. Thus, Joe's boots were task relevant and should be attended, but repetitions of the remaining boots should be largely ignored by the monkey. Of the 8 unfamiliar boots, 4 (probes) were changed in each block help the monkey learn the task. We only compared those boots that were shown for an equal number of repetitions by the time of LFP recording (125 times each).



Even when stimulus repetitions are identical, we still find a larger neural signal for a stimulus which was task relevant. These data suggest that the neural signal for long-term familiarity may be enhanced by attention.

7. Conclusions

- We found a greater neural signal for highly familiar stimuli in both humans and monkeys. This difference developed over the course of training and 72-400 repetitions of each stimulus.
- Differences attributable to image familiarity were found at 230-320ms after stimulus onset in humans and 120-250ms in monkeys. Although the timing for these familiarity effects overlap, the signal appears to occur earlier in monkeys than in humans.
- Changes in LFP signals were found in monkeys using task relevance to produce familiarity (similar to the task used in humans).
- In monkeys, the familiarity effect has been reported for numerous object categories and individual objects. In humans, however, it is unclear whether this familiarity effect will be found for categories other than faces.

Repeated visual experience and task relevance induce widespread and automatic changes in neural processing of complex visual forms in humans and monkeys

Supported by the James S McDonnell Foundation, NIH 1R01 EY014681, and the Burroughs Wellcome Fund.