# The Contribution of Configural Shape to Object Recognition Is Processed by a Late-Onset Mechanism Likely Localized in Right Temporal Cortex

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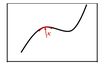
## Background




A large fraction of the visual cortex is devoted to object processing, and object shape information underlies our ability to detect, recognize and manipulate objects.

Object shape is comprised of both local and configural shapes.

Local shape refers to features confined to specific regions and can be interpreted independently. Configural shape arises from the spatial arrangement of local shapes.

Local and configural shape processing can be dissociated using synthetic maximum-entropy shape stimuli that progressively match the natural curvature statistics but lack global regularities[1,2].

Behavioural experiments reveal profound sensitivity to both higher-order statistics of local shape, as well as configural shape information[1,2].

Humans rely on configural shape to perceive objects[3], and perceive objects holistically, as revealed through inversion effects[4,5,6].

Here we use EEG to measure responses of the human visual system to shape silhouettes to investigate how the brain responds to manipulations of local and configural shape.

## Methods

### Stimuli

Experiments 1 and 2 used curvature matched controls: synthetic maximum-entropy shape stimuli made to match varying moments of natural shape curvature distributions, while lacking configural shape information.

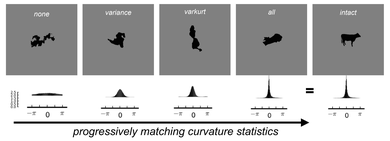
Stimuli progressed from minimal to full statistical matching of curvature distributions:

***none***: only the mean of the distribution is matched.

***variance***: both mean and variance of curvature is matched.

***varkurt***: mean, variance, and kurtosis are matched.

***all***: mean, variance, and higher order moments of the distribution are matched.

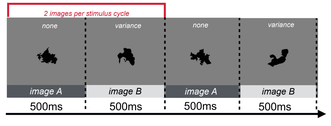



Experiment 3 used "Frankenstein" stimuli where the upper half of the object had been flipped relative to the lower half. This disrupts object recognition in human observers[3], while preserving local and configural shape information.

### Paradigm

We employed a Steady-State Visual Evoked Potentials (SSVEPs)[7] paradigm to investigate the cortical mechanisms that represent curvature statistics of objects silhouettes.

In each condition, participants passively viewed a sequence of cycles, each cycle consisting of 2 images, each presented for 500ms, resulting in a stimulation frequency of 1 Hz.




## Data Analysis

SSVEP data were collected using a 128-electrode Magstim EGI Geodesic Sensor Net.

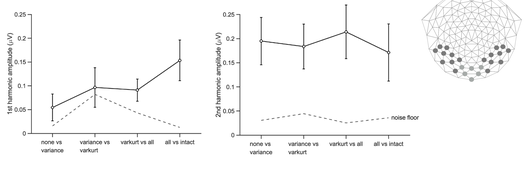
Our analysis focused on three electrode regions-of interest (ROI):
One over occipital cortex, and two over left and right temporal cortices.

Here we present coherent averaged amplitudes across all trials, electrodes, and participants.

The odd harmonics capture brain responses that differ between the two image classes[7] and therefore allows us to isolate responses driven by our shape manipulations.

The even harmonics capture brain responses that are the same for the two image classes shown, likely dominated by relatively low-level image-update responses. As expected, even harmonics were for the most part identical across all conditions in our two studies.

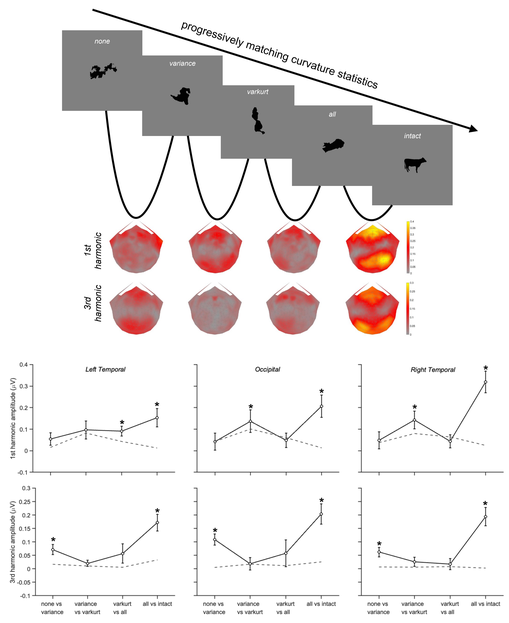
Below we present data from the left temporal cortex ROI as examples.




## Results

### Experiment 1a — n= 32

By comparing increasing levels of constraints, we investigated the sensitivity of the visual system to progressively matching the curvature distribution.




Group average amplitudes were computed by separately averaging the real and imaginary components across participants, and computing the magnitude of the group vector.

The magnitude of the projection of each participant's data onto the group vector was also computed. These projected amplitudes were used to compute standard error of the mean (used for error bars), and to run repeated measures ANOVAs.

Hotelling's $T^2$ tests were used to compare each response to the noise floor, using the real and imaginary components from each participant, and takes into account both the phase and the amplitude of the response. Significant $T^2$ tests are indicated with *****.

A repeated measures 2-way ANOVA with ROI (3 levels) and Condition (4 levels) was conducted for the 1st and 3rd harmonic separately.

***1st harmonic***

We found a significant main effect of Condition.

The main effect of ROI was not significant.

The interaction between ROI and Condition was significant.

***3rd harmonic***

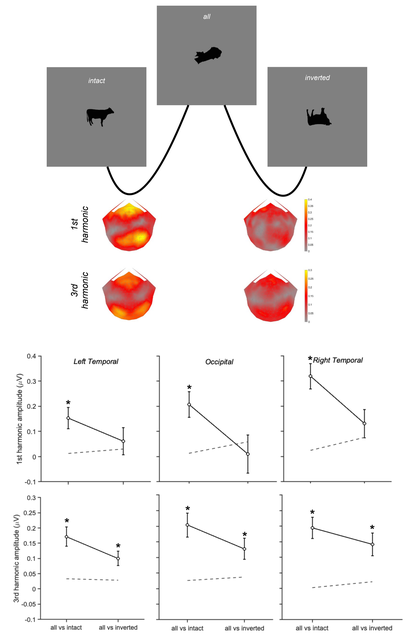
We found a significant main effect of Condition.

The main effect of ROI was not significant.

The interaction between ROI and Condition was not significant.

### Experiment 1b - Inversion Effect — n = 32

We compared the curvature-matched stimuli with both upright and inverted intact animal shapes, investigating the contribution of orientation-sensitive configural processing to object shape responses.




Data analysis was conducted as described in Experiment 1a.

A Repeated Measures 2 way ANOVA with ROI (3 levels) and Orientation (2 levels) was conducted for the 1st and 3rd harmonic separately.

***1st harmonic***

We found a significant main effect of ROI.

We found a significant main effect for Orientation.

The interaction between ROI and Orientation was significant.

***3rd harmonic***

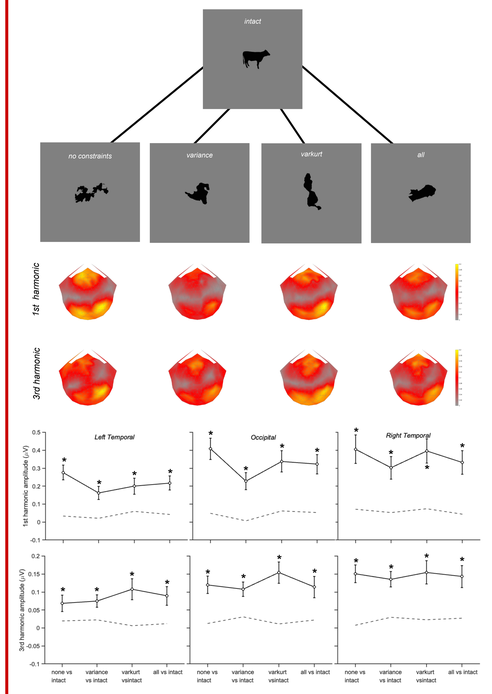
We found a significant main effect for Orientation.

The main effect for ROI was not significant.

The interaction between ROI and Orientation was not significant.

### Experiment 2 — n = 28

Experiment 2 compared each level of constraints with intact shapes to investigate the extent to which matching the curvature distribution produces responses similar to that of natural intact animal shapes.




Data analysis was conducted the same way as described in Experiment 1a.

A Repeated Measures 2 way ANOVA with ROI (3 levels) and Condition (4 levels) was conducted for the 1st and 3rd harmonic separately.

***1st harmonic***

We found a significant main effect of ROI.

We found a significant main effect of Condition.

The interaction between ROI and Condition was not significant.

***3rd harmonic***

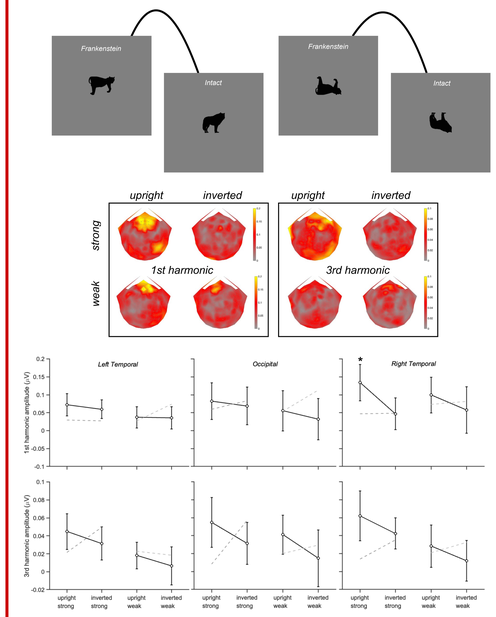
The main effect for ROI was not significant.

We found a significant main effect of condition.

The interaction between ROI and condition was not significant.

### Experiment 3 — n = 30

Experiment 3 compared upright and inverted versions of Frankenstein and intact objects, investigating the effects of manipulations to configural shape to object recognition.




Data analysis was conducted the same way as described in Experiment 1a.

A Repeated Measures 2 way ANOVA with ROI (3 levels) x Orientation (2 levels) x Strength (2 levels) was conducted for the 1st and 3rd harmonic separately.

***1st harmonic***

The main effect of ROI was not significant.

The main effect of Orientation was not significant

The main effect of Strength was not significant.

There were no significant interactions.

***3rd harmonic***

There main effect of ROI was not significant.

The main effect of Orientation was not significant.

The main effect of Strength was not significant.

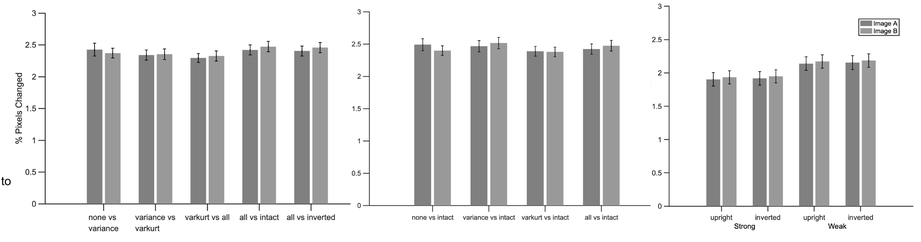
There were no significant interactions.

## Stimulus Analysis

We wanted to ensure that our responses are not driven by pixel-level differences between the A and B stimuli.

We calculated the percentage of pixels that changed when transitioning from image A to image B, and image B to image A.

We find no evidence of systematic differences at the image level between transitions to image A and B.




## Conclusions

The visual system is sensitive to manipulations in local and configural shape.

In Experiment 1, natural shapes produce highly robust, right-lateralized responses when compared to control stimuli with matched local curvature.

This effect is modulated by inversion, but not eliminated by it, suggesting that some aspects of configural processing survive inversion.

In both Experiment 1 and 2, responses to local shape (variance) are bilateral, consistent with early visual areas, and more transient.

Experiment 3 presents an intriguing pattern that does not reach significance. When comparing Frankensteined and intact patterns, a significant response is seen only in right temporal cortex, only when stimuli are upright and only when Frankensteining leads to a strong behavioural effect.

Follow-up analyses and new experiments are underway to probe these effects further.

## References

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