Measuring the flexibility of orientation selectivity in face processing by varying task demands

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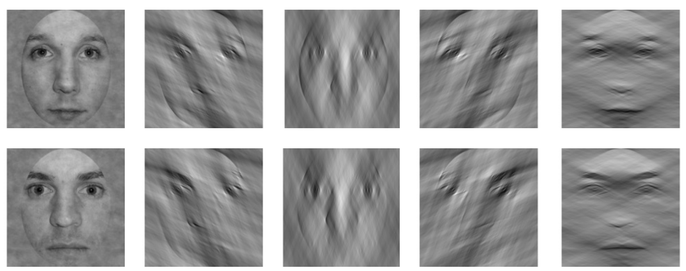
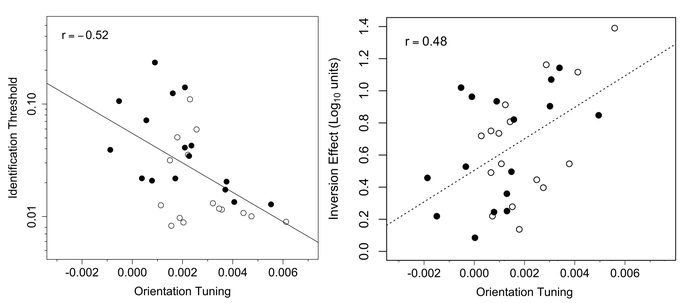
Face identification tasks

The information conveyed by horizontal structure in the Fourier domain is a highly diagnostic cue for face identification, because this information differs significantly between face identities.[1,2]



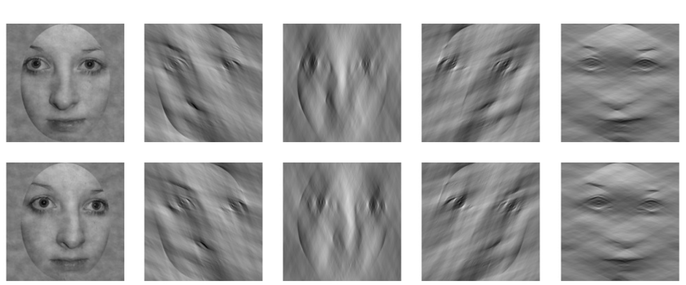
Two target faces filtered to retain frequency components at different orientations (bandwidth = 60°). Note that the images retaining horizontal structure appear more distinct than any other orientation.

The degree to which individuals selectively process horizontal structure in upright faces predicts face identification performance and the magnitude of the face inversion effect.[3]



Data from Pachai et al.[3] demonstrating the relationship between orientation tuning (i.e., the extent to which observers preferentially process horizontal facial structure) and **left:** upright face identification (lower values are better) **right:** the face inversion effect (higher values indicate a larger inversion effect). Open and closed circles indicate two threshold accuracy levels (50% and 67%), measured between-subjects, that had no effect on the relationship in question and therefore represent an internal replication.

Viewpoint discrimination tasks



One target face, with a viewpoint to the left or the right, filtered to retain different orientation structure (bandwidth = 60°). We hypothesized that the vertical band contains more information diagnostic for left/right viewpoint discrimination. However, this hypothesis is difficult to confirm with visual inspection if human sensitivity to the relative orientation content in the face does not match the diagnostic structure for this task. Therefore, we assessed our hypothesis by modelling the performance of an ideal observer.

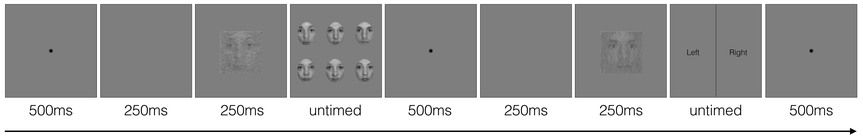
Research questions

Does horizontal selectivity reflect the output of a flexible system tuned to the most diagnostic available information, or a default mode of processing in face-related tasks?

To explore this question, we utilized tasks for which the diagnostic orientation band was either horizontal (identification) or vertical (viewpoint discrimination), as confirmed using an ideal observer analysis.

To quantify the extent to which horizontal and vertical structure convey diagnostic information in the two tasks, we modelled also the performance of an ideal observer.

Methods



Time course of the experiment in the intermixed condition, with representative noise. Stimulus contrast increased for visibility.

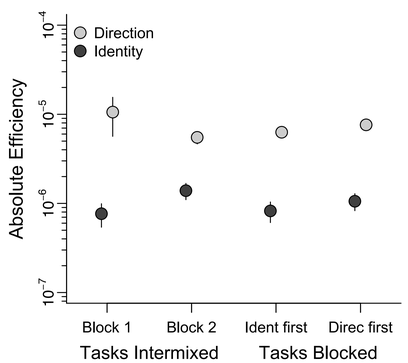
Tasks blocked or intermixed (between subjects).

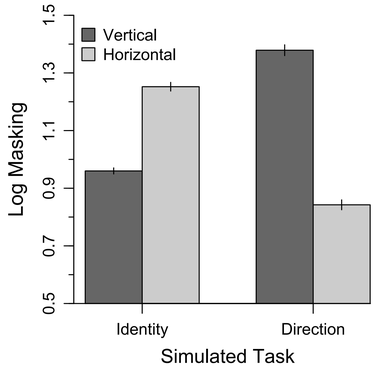
Targets masked with horizontal noise, vertical noise, or a low-noise baseline. Measured d'=1 RMS contrast thresholds.

Change in contrast threshold relative to baseline quantifies the observer's reliance on the masked orientation band.

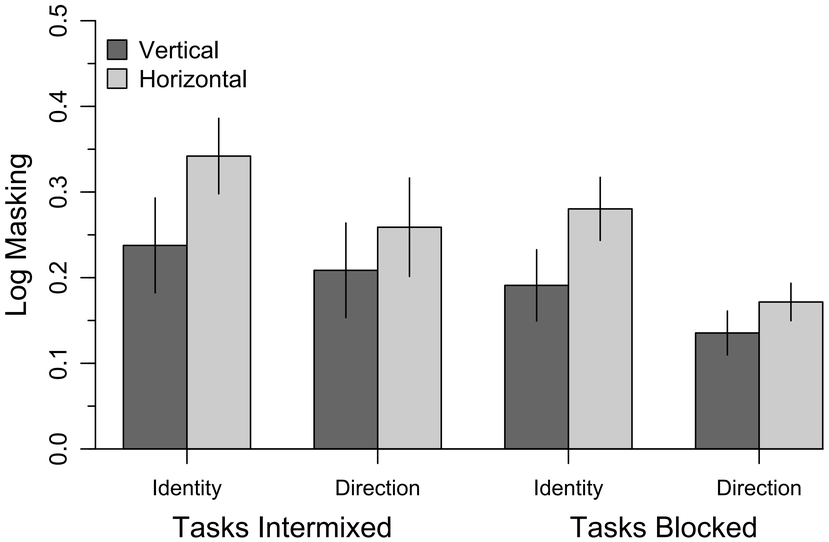
Results

Ideal Observer





Human Observers



Left: Absolute efficiency, defined as the ratio of ideal to human threshold energy. A value of 1 indicates optimal performance. Observers are inefficient (common in face-related tasks[4,5]), and slightly more efficient in the direction task. Error bars are +/- SEM.

Middle: Masking for the ideal observer, defined as the difference (in log units) between RMS contrast thresholds obtained in each masked condition and the unmasked baseline. More masking indicates that the ideal observer was more hindered by selective disruption of the orientation band in question, and therefore quantifies the diagnosticity of each orientation band for the two tasks.

Right: Masking for the human observers. A significant main effect of orientation ($p < 0.001$) indicates a greater reliance on horizontal structure. However, the orientation x task interaction was not significant ($p = 0.13$) demonstrating that observers did *not* change their orientation selectivity toward selective use of the more optimal vertical band in the direction discrimination task.

References

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For more information, contact Matt Pachai at pachaim@mcmaster.ca. ***Matt is on the post-doc market now!***

Conclusions

Observers did *not* switch to vertical selectivity for direction discrimination, despite being the optimal strategy for this task.

Observers seem to inflexibly rely on horizontal structure to perform many face discrimination tasks (see also ref. 6).

Horizontal selectivity may be the 'default mode' of processing that underlies human performance in face-related tasks.