Recurrent processing during object recognition

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Introduction

Cortical areas along the ventral stream are almost universally bidirectionally connected (2,7). One theory of the ubiquitous feedback connections is that they support top-down processes such as stimulus-based attention that operate after the initial feedforward object recognition process (7). An alternate theory is that bidirectional connectivity promotes rapid recurrent processing dynamics that extend across the full-time course of vision (1,6). How might this affect object recognition?

Backward masking experiment

To test our hypothesis, we conducted a behavioral experiment using backward masking, which has been suggested to selectively change recurrent processing while leaving any feedforward response intact (4).

- 8-category tasking
- 6 categories x 5 exemplars x 20 views
- Normalized for luminance
- Manipulated occlusion and contrast

100 ms SOA pattern mask

Example stimuli. Stimuli were taken from the ventral face category (8). The face category was contained in the category space.

The effect of the mask was compared between the control condition and the moderate occlusion condition as well as between the control condition and the low contrast condition.

Both the Mask x Occlusion and Mask x Contrast interactions were significant, indicating that the mask incurred with recognition memory under degraded viewing conditions compared to the relatively clear control viewing condition.

Simulating the effects of backward masking

The Leads Vision model (5), which contains bidirectional connectivity between hierarchically adjacent processing areas, was used to quantitatively account for the Mask x Occlusion interaction found in the experiment.

We simulated an isotropic version of the experiment with identical stimuli and task parameters. Importantly, it was not necessary to augment the model with any masking-specific mechanisms in account for the interaction. Instead, the processing cycle during which the mask appeared was simply varied as a free parameter to fit the behavioral data.

Recurrent processing during degraded object recognition

Recurrent compartment modeling work has shown that bidirectional connectivity between hierarchically adjacent processing areas supports robust recognition in the face of an occlusion degradation that makes stimuli highly ambiguous such as occlusion (5).

Recurrent processing necessary to resolve the occlusion can be recovered when the observation is made weak and stimuli highly ambiguous such as occlusion (5).

The identity of degraded stimuli.

In addition to providing a close quantitative fit of the behavioral data, our model was able to explain how the model incorporates the identity of degraded stimuli.

Conclusions

We have provided an account of how the extensive bidirectional connectivity throughout the ventral stream supports recurrent processing during object recognition. Specifically, when objects are degraded, they evoke weak, ambiguous responses via feedforward connections; however, recurrent processing can resolve this ambiguity by strengthening responses that are consistent with the bottom-up inputs while weakening those that are not.

Masking was shown to interfere selectively with the recurrent processing necessary to resolve the identity of degraded stimuli.

There was a clear relationship between the degradation of a stimulus and the amount of recurrent processing necessary to resolve its identity. Although relatively clear inputs could be identified with mostly feedforward processing, more degraded inputs required increasing amounts of recurrent processing to resolve.

Our results indicate at least one set of conditions under which the bidirectional connectivity of the ventral stream makes a measurable contribution to object recognition. Overall, this suggests a view of object recognition in which multiple brain areas interact bidirectionally across short time scales to contribute to recognition.

References


Further information

Please contact dy@colorado.edu. The CU3D dataset can be obtained at http://www.colorado.edu/CompCogNeuro/index.php/CU3D.

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