Behavioral evidence of predictive coding: Contrast sensitivity enhanced for stimuli matching the prediction from the preceding information

Seyoon Song, Minsun Park & Chai-Youn Kim

School of Psychology, Korea University, Seoul, Korea

Introduction

Predictive coding model has provided the viewpoint of studying the human brain as the organ of inference [1], with evidence from many findings that the top-down effect of predictive information can be reflected even in the earliest sensory cortices [2]. Although much neural evidence points to a sharpening direction [3], it remains as a question whether those predictive effects can indeed lead to enhancement in low-level perceptual performance in also the behavioral domain. Using a classical psychophysical method, this study examined the impact of predictive information on contrast sensitivity, which is one of the fundamental human visual abilities. In line with the neural findings, we expected to find enhancement in perceptual sensitivity due to existence of prediction.

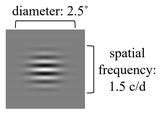
Methods

• Participants

- 34 participants (20-30 years of age, 12 males)

• Stimuli

- Gabor patches

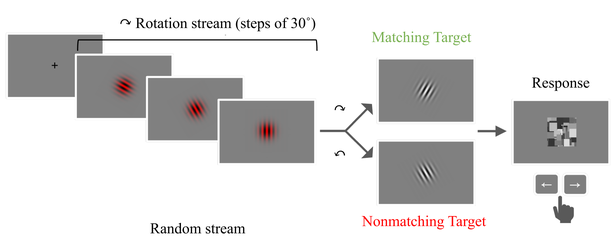


• Conditions

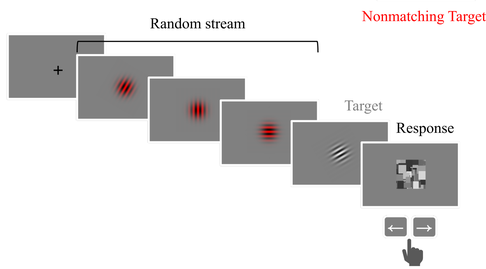
- a preceding stream of 3 sequential red Gabor patches (fixed contrast: 50%) was presented before the target

1) Prediction condition: preceding stream gave the impression of rotation by regular angles of 30°

- Matching: the target matched the orientation of the stream rotation
- Nonmatching: the target was in an orthogonal angle of the orientation of the stream rotation

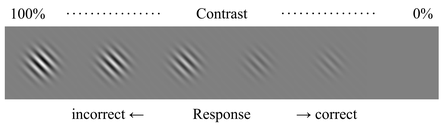


2) Control condition: the preceding stream was presented in random angles



• Procedures

- 2-AFC task of reporting the tilted orientation (left/right) of the achromatic target Gabor patch
- 1-up-1-down adaptive staircase method to measure the 50% contrast threshold for each condition



• Analyses

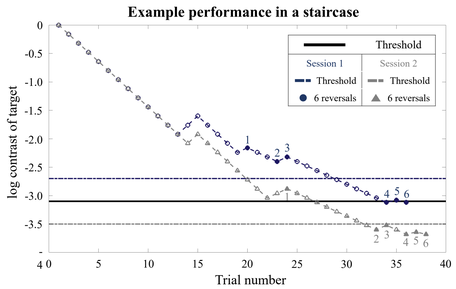
- averaged the threshold and sensitivity values from the 2 sessions of repetition

1) Threshold

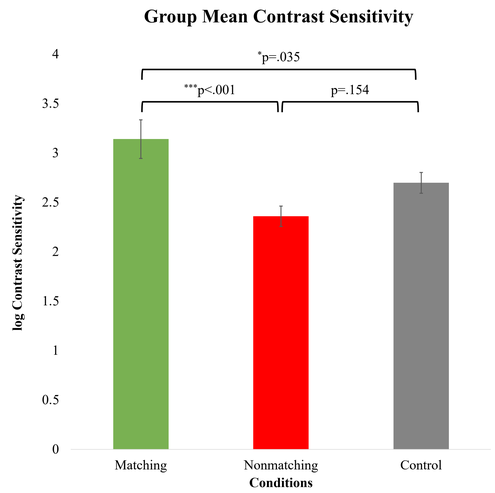
: averaged the contrast values from the last 6 reversal points out of 9 max reversals

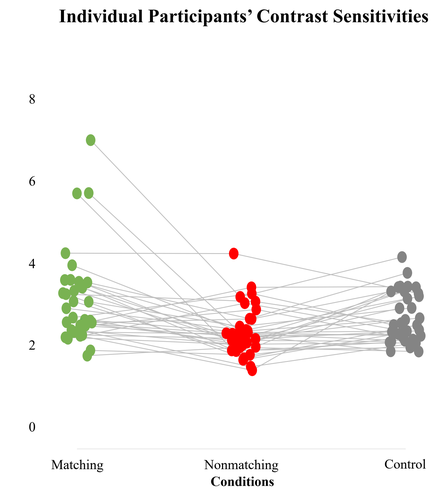
2) Sensitivity

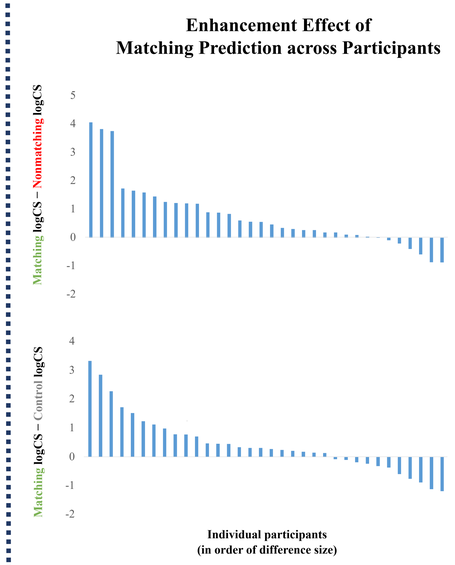
: 1/threshold



Results







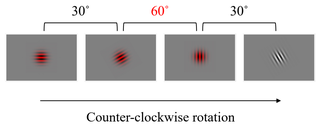
• Contrast sensitivity was better for the matching condition compared to the nonmatching and control conditions

- The results showed statistically significant main effect of condition ($F(1.547, 51.056) = 10.556$, $p<.001$). Post-hoc tests discovered that log contrast sensitivity for the matching condition was significantly higher compared to the nonmatching ($t=4.581$, $p<.001$) and control ($t=2.595$, $p=.035$) conditions.
- This implies that when prediction existed, the detection performance for its matching target was enhanced.
- Although insignificant, lower contrast sensitivity in the nonmatching condition compared to the control condition was observed ($t=-1.985$, $p=.154$). This tendency can reflect simple response biases, or suppression of perceptual performance for unpredicted (or tuned away) stimuli.

- In the viewpoint of individual data, most participants showed higher log contrast sensitivity for the matching condition than the nonmatching or the control conditions.
- This implies that the enhancement effect in contrast sensitivity is a consistently observed pattern among participants.

Next step

Is it truly prediction? If so, can the degree of prediction manipulate the degree of enhancement?



Among a regular rotating stream, an irregular angle step is introduced to weaken the predictability of the preceding stream. If the enhancement of behavioral performance was truly due to prediction, we expect to find out lower contrast sensitivity for these weaker predictability conditions, due to weaker enhancement effect of prediction.

Discussions & Conclusions

Contrast, a basic visual feature reflected in cortices even earlier than V1, was effectively processed with predictive information. This finding implies that human low-level visual performance can be affected by predictive coding, particularly in an enhancing way of matching the prediction. This result can add some insights towards the neural sharpening hypothesis of prediction. Although the problem of response bias and the specifics of the predictive effects are yet to be tackled, we provide behavioral evidence to the previous neural findings of predictive coding.

References

[1] Friston, K. (2018). Does predictive coding have a future?. *Nature neuroscience*, *21*(8), 1019-1021.

[2] Rao, R. P., & Ballard, D. H. (1999). Predictive coding in the visual cortex: a functional interpretation of some extra-classical receptive-field effects. *Nature neuroscience*, *2*(1), 79-87.

[3] De Lange, F. P., Heilbron, M., & Kok, P. (2018). How do expectations shape perception?. *Trends in cognitive sciences, 22*(9), 764-779.