Eye movements as predictors of visual detection

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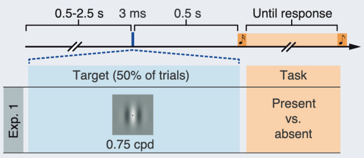
1. BACKGROUND

Microsaccades are briefly inhibited when we detect a visual stimulus. Indeed, their occurrence can be used to predict visual detection on a single trial [1]. As microsaccades are rare events, we assessed whether other features of fixational eye movements and pupil size [2] provide additional information about an observer's report of stimulus detection.

We compared three well-known algorithms used in binary classification:

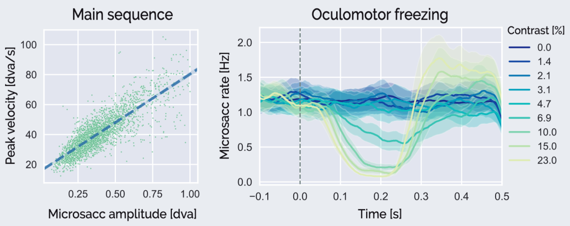
- Linear Support Vector Machine (SVM) [3, 4]
- Linear Discriminant Analysis (LDA)
- Random Forest Ensemble (RFE).

2. "EXPLICIT VISUAL DETECTION" TASK



We used data from a simple detection task [1]. Observers fixated the center of the screen. In stimulus present trials (50%), a Gabor was flashed briefly (contrast ranging from 0 to 23%). 500 ms later, a tone cued observers to judge stimulus presence. We recorded fixational eye movements after stimulus onset.

3. DATA PROCESSING



We extracted the following features from gaze positions after stimulus onset:

- Horizontal and vertical velocity
- Microsaccade occurrence
- Microsaccade peak velocity
- Microsaccade amplitude

Microsaccades were detected when the median velocity in 2D velocity space was exceeded by 5 SD for 6 ms in both eyes [5]. Pupil size was filtered and processed following the procedure described in [2].

4. BUILDING THE MODELS

Dataset

- 12 observers | 4,200 trials | 8 interleaved contrasts | 28% of yes-response
- Maintain class balance in train and test sets.

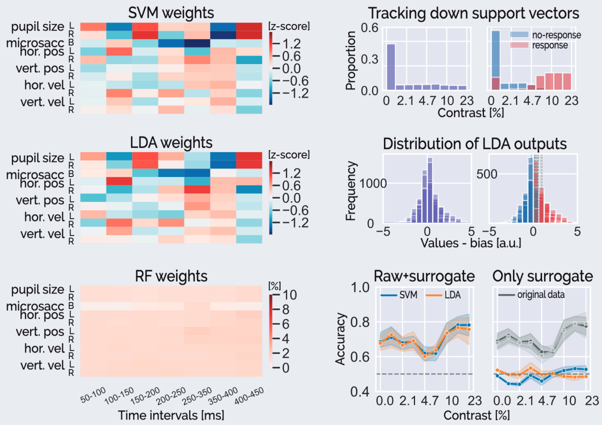
Procedure

1. z-transformation of each feature, except microsaccades
2. Averaging each time feature in 50 ms intervals from 50 ms - 500 ms
3. Determine feature vectors using ***signed-r^2*** separability measurement
4. Create input matrix: X = *[trials, eye features · time features]*
5. Obtain binary output: $y = w^T \cdot X - b$
6. 5-fold cross-validation to prevent overfitting and extend sample size
7. Averaged results for each subject for comparison.

5. MODEL PERFORMANCE

Both SVM and LDA show similar performance across validation folds as well as train/test sets. RFE overfits the most frequent class (no-response).
For SVM and LDA, accuracy of classification depends on stimulus intensity: better results at higher contrasts, worst at threshold contrast.
F1 score indicates the performance regarding response class only. It is consistent with the observer's response.

6. HOW DO THE MODELS DECIDE?



The most decisive features for predicting detection are microsaccades and pupil size. These features show their largest impact in different time windows:

- Microsaccades are informative from 150 to 350 ms
- Pupil size is most informative from 150 to 200 ms and from 400 to 450 ms

A sanity check shows that linear classifiers can extract the information of eye movements from a surrogated dataset only if the raw data is included.

7. CONCLUSIONS

Fixational eye movements and pupil size can be used to classify an observers' perceptual report in a simple visual detection task. Linear classifiers reveal that both microsaccades and pupil size are most informative for classification. Prediction accuracy depends on stimulus intensity and exceeds that of a simple Bayesian classifier based only on microsaccades [1].

REFERENCES

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