UNIVERSITÄT LEIPZIG

Institute of Psychology, Cognitive and Biological Psychology

DFG Deutsche Forschungsgemeinschaft

Predictions based on action intention facilitate the recognition of stochastic regularities

Betina Korka, Erich Schröger, Andreas Widmann

INTRODUCTION

- The predictive coding theories suggest that the brain is continuously building up and updating predictive models.
- Sources for predictions may be drawn from sensory regularities in a bottom-up manner based on feed-forward prediction error, as suggested when regularity violations lead to elicitation of the **mismatch negativity (MMN)** component.
- Recently, Schröger & Roeber (2020) showed that **stochastic regularities** are difficult to encode: their data indicate that rare deviants of medium pitch enclosed between frequent high and low pitch standards do not elicit the MMN, unless the standards are arranged **deterministically** (e.g., alternating high and low).

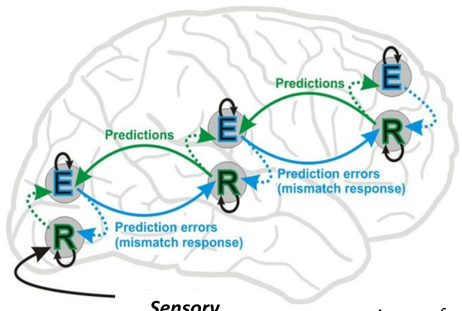


Image from Stefanics et al.,2014

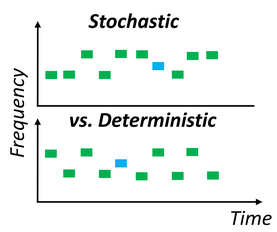


Image adapted from Schröger & Roeber (2020)

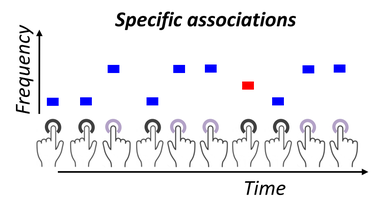
- Here, we wanted to test the implication of the predictive coding theory that predictions based on higher order generative models, for example based on action intention, are fed top-down in the hierarchy to sensory levels. We asked participants to produce random sequences of high and low pitch sounds by key presses in two conditions: In a condition with ***hand-specific associations***, one button produced high and the other low pitch sounds; In a condition with ***unspecific associations***, both buttons randomly produced high or low-pitch sounds.
- We expected that the rare medium pitch deviants elicited a larger MMN in the *specific* compared to the *unspecific* condition, despite the actual sound sequences being actually stochastic in both conditions.

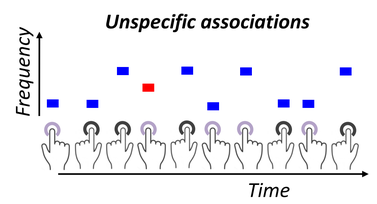
METHOD

✓ **Participants:** 14 (8 male, mean y.o. = 23,3).

✓ **Task instructions**: press a key about every second to generate tones, without producing fixed patterns.

✓ **Stimuli: 1000 Hz for the deviant (with 10% probability)** and **900 Hz and 1100 Hz for the standards (each with 45% probability).**





✓ **Conditions:** ***specific*** vs. ***unspecific*** *associations*, identical in terms of physical stimulation, but higher-order predictions based on intention are only possible in the first case.

Note that left and right keys are displayed in different colours only for visualization.

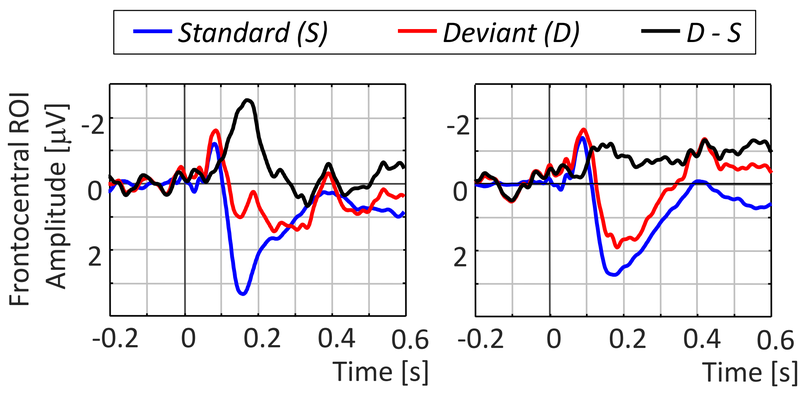
✓ **EEG recording:** BrainAmp system, actiCAP, 32 electrodes; Online reference: the tip of the nose; EOG activity: electrodes placed on the outer canthi and below the left eye.

✓ **EEG preprocessing:** data were filtered (0.1 to 45 Hz) and epoched relative to tone onset (-200, 600 ms). Artifacts were rejected using ICA; The MMN was identified using a temporal PCA (Geomin rotation, covariance relationship matrix, no weighting).

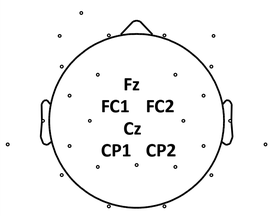
RESULTS

1: Grand – Average ERPs

SPECIFIC ASSOCIATIONS **UNSPECIFIC ASSOCIATIONS**



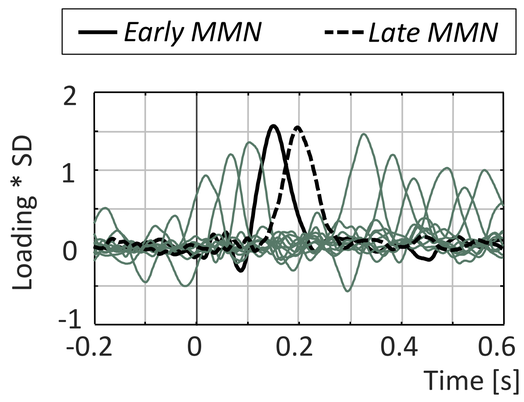
Frontocentral ROI:



- ERPs were calculated for every condition and stimulus type.
- The **MMN-specific activity** (deviant – standard wave) is displayed (black) for a region of interest (ROI) composed of frontocentral electrodes.

2: Principal Component Analysis

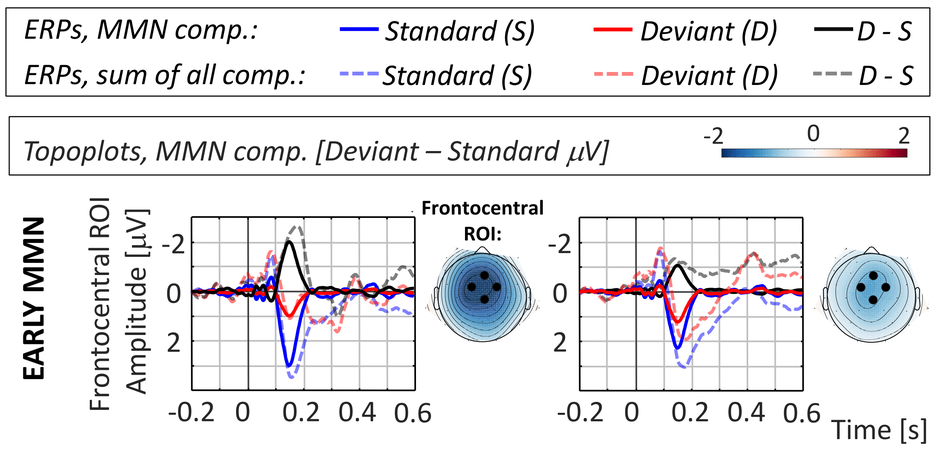
FOURTEEN PRINCIPAL COMPONENTS



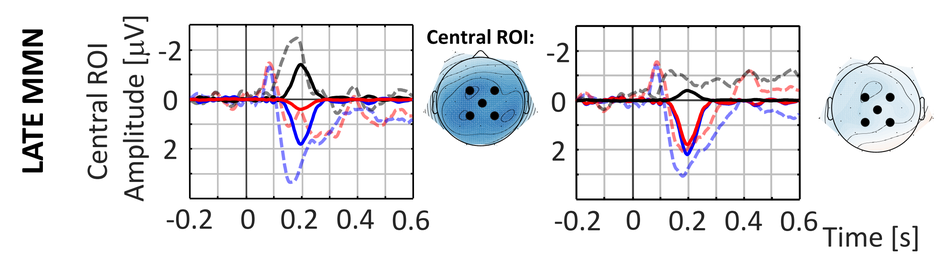
- Horn`s parallel test: 14 principal components explaining more than 95% of the epoch variability were retained.
- Two components peaking at **150 ms** and **196 ms** respectively, explain the **MMN latency range**; these (hereafter, **early and late MMN**) were further analyzed.

3: Early and Late MMN Components

SPECIFIC ASSOCIATIONS **UNSPECIFIC ASSOCIATIONS**



- Early MMN in both cases, but larger following specific associations.*



- Late MMN is reliably elicited only following specific associations.*

*** For details regarding the statistical analyses, see below.**

CONCLUSION

- The observed larger MMN responses in the *hand-specific* condition indicate that intention-based predictions can boost stochastic regularity-based predictions; this extends previous findings indicating that action intention alone (i.e. in the absence of auditory regularities) leads to predictions at sensory levels (Korka et al., 2019). Nevertheless, we also find a weak MMN when higher order predictions based on intention are not possible (in the *unspecific* condition) – it thus remains for future research to clarify the precise and necessary conditions for the encoding of stochastic regularities.
- Finally, these results demonstrate that under certain task conditions, active inference (i.e. predictions based on expected action effects) can enhance the sensory inference (i.e. predictions based on encoded environmental regularities).

Statistical analyses

Bayesian rANOVAs with factors *Condition* (specific vs. unspecific associations) x *Stimulus type* (Standard vs. Deviant) were calculated for each MMN. $BF_{Inclusion}$ calculated across matched models are reported here, while the BF_{10} refer to the pairwise follow-up comparisons. If **the BF >3 (or <0.33) ⟶ evidence for the alternative (or null) hypothesis**.

Early MMN: the main effect of *Stimulus type* explains the data best ($BF_{Inclusion}$ = 29125.42), suggesting MMN effects in both conditions. Follow-up Bayesian *t*-tests confirm that the **MMN was elicited in both conditions** (specific associations: BF_{10} = 92.41 ±≤0.001% ; unspecific associations: BF_{10} = 9.98 ±0.001). A further Bayesian *t*-test calculated on the difference scores (Deviant – Standard) brings evidence that the **MMN in the case of specific associations is larger** (BF_{10} = 11.11 ±≤0.001%).

Late MMN: similarly, the main effect of *Stimulus type* explains the data best ($BF_{Inclusion}$ = 47.7). Yet, the presence of the **MMN** is confirmed **for the specific associations** (BF_{10} = 23.94 ±≤0.001%), while the evidence regarding the unspecific condition is rather inconclusive (BF_{10} = 1.07 ± 0.004%).

betina-christiana.korka@uni-leipzig.de @BetinaKorka

Ref.: **Korka**, B., Schröger, E., & Widmann, A. (2019). Action Intention-based and Stimulus Regularity-based Predictions: Same or Different?. *J Cog Neurosci*, *31*(12), 1917-1932.; **Schröger**, E., & Roeber, U. (2020). Encoding of deterministic and stochastic auditory rules in the human brain: The mismatch negativity mechanism does not reflect basic probability. *Hearing Res*, 107907.; **Stefanics**, G., Kremláček, J., & Czigler, I. (2014). Visual mismatch negativity: a predictive coding view. *Frontiers in human neurosci*, *8*, 666.