Université
franco-allemande
Deutsch-Französische
Hochschule

PhD project of Ellen Joos: "EEG correlates of normal and altered processing strategies to solve the perceptual inference problem"

The information available through our senses is noisy, incomplete, and to varying degrees ambiguous. The perceptual system has to reconstruct the exogenous world by integrating the limited sensory information with endogenous factors such as memory [1]. This construction process causes the perceptual inference problem, i.e. one single sensory information can be interpreted in multiple ways. In a probabilistic manner, the brain decides for one of those interpretations in order to provide a stable and reliable percept. The present dissertation investigates different aspects of this probabilistic decision in neurotypical participants but also in patients with Schizophrenia Spectrum Disorder (SSD) by comparing visual processing of ambiguous/low-visibility with disambiguated/high-visibility stimuli.

Ambiguous figures are paradigmatic when studying the perceptual inference problem, because in those figures one sensory information allows for two possible interpretations. Using electroencephalography (EEG), previous studies already found large event-related potential (ERP) differences 200 ms and 400 ms after stimulus onset between ambiguous stimuli and disambiguated variants thereof [2,3], i.e. the ERP Ambiguity Effects. In the first part of this dissertation [see also my publication 4], I replicated one experiment using ambiguous stimuli [from 2,3] and studied whether these ERP Ambiguity Effects also occur with low-/high-visibility stimuli. I found that not only different levels of stimulus ambiguity, but also different degrees of stimulus visibility evoke those ERP effects. The stimuli used were smiley faces with two different emotional expressions that were either clearly or less visible. Ambiguous figures impose different demands on the perceptual system compared to low-visibility stimuli. Common to both types of stimuli is, however, that they evoke uncertainty. The ERP effects identified by Kornmeier et al. [2,3] and replicated in the current work might thus reflect a certainty rating of perceptual constructs at a higher cognitive level, beyond sensory details. The effects are accordingly re-labelled to ERP Uncertainty Effects.

Patients with SSD show fundamental differences in the process of perception [5], in the integration of sensory with endogenous information [6], and reveal diculties in processing of ambiguous emotional expressions [7] compared to controls. Thus, the experimental paradigm and stimuli from the first part of this dissertation were investigated in patients with SSD in the second part of this dissertation. Due to the Corona pandemic, I was not able to finish data acquisition during the time of my PhD. Therefore, the following results are preliminary. The ERP Uncertainty Effects were replicated in both groups. An observable tendency for smaller ERP effects in patients compared to controls did not reach statistical significance. Additional exploratory analyses indicated significant differences in the processing of perceptual (un)certainty in patients with SSD compared to controls. These results are interpreted within the predictive coding theory [8], which postulates that the brain

continuously forms models about the external world and continuously updates these models with new sensory information. Patients with SSD show alterations in those updating mechanisms [e.g. 9]. The current results particularly indicate altered reliability attribution to the sensory information, which ultimately might result in altered (un)certainty ratings as found in this study.

Helmholtz' inferential approach on perception postulates that the brain uses information from previous experiences in order to appropriately reconstruct the exogenous world despite the limited sensory information. Currently discussed predictive coding theories are based on this idea and further assume that the brain (1) always forms a prediction about the to-be-created perceptual interpretation, (2) integrates these predictions with the current sensory information, and (3) concurrently creates new predictions for an upcoming moment. The ERP Uncertainty Effects show unusually large effect sizes and individual statistical significance, which makes the understanding of their functional roles even more interesting. Previous experimental evidence suggested the involvement of the ERP effects in the above mentioned processes, but their exact role could not be systematically investigated due to the experimental paradigm. In the third part of this dissertation [see also my publication 10], I modified the experimental paradigm in order to investigate the functional role of the ERP Uncertainty Effects with a particular focus on predictive coding theories. The results of this third study confirm the involvement of the ERP Uncertainty Effects in predictive mechanisms. They further confirm the strong influence of temporal aspects on perceptual processing. Particularly, the perceptual system seems to automatically and unavoidably exploit regularities from past perceptual experiences in order to generate predictions about the immediate perceptual future. This seems to be the case even in situations where the perceptual past and the perceptual future are irrelevant for a current task related to a currently seen stimulus. The present results further indicate that our expectations about the immediate perceptual future influence how we perceive the present.

The findings of this dissertation should be considered when investigating physiological correlates of psychiatric diseases. Particularly, altered predictive processes in patients with SSD should be investigated by means of the experimental paradigm from the third part of the dissertation. Further, emotional expressions in smiley faces with different degrees of their visibility (as in the first and second part of this thesis) should be used as stimulus material. In future studies these modifications will allow to measure predictive processes in patients with psychiatric diseases and in neurotypical participants in a state of perceptual uncertainty, which closely resembles difficult situations within the patients and controls everyday life, i.e. dealing with uncertainty in social interactions.

Université
franco-allemande
Deutsch-Französische
Hochschule

Bibliography:

[1] von Helmholtz HLF. Handbuch der physiologischen Optik. Leipzig: Leopold Voss; 1867. https://doi.org/10.3931/e-rara-21259.

[2] Kornmeier J, Bach M. Object perception: when our brain is impressed but we do not notice it. J Vis 2009;9:7 1-10. https://doi.org/10.1167/9.1.7.

[3] Kornmeier J, Wörner R, Bach M. Can I trust in what I see? – EEG Evidence for a Cognitive Evaluation of Perceptual Constructs. Psychophysiology 2016;53:1507–23. https://doi.org/10.1111/psyp.12702.

[4] Joos E, Giersch A, Hecker L, Schipp J, Heinrich SP, Elst LT van, et al. Large EEG amplitude effects are highly similar across Necker cube, smiley, and abstract stimuli. PLOS ONE 2020;15:e0232928. https://doi.org/10.1371/journal.pone.0232928.

[5] Silverstein S, Keane BP, Blake R, Giersch A, Green M, Kéri S. Vision in schizophrenia: why it matters. Front Psychol 2015;6. https://doi.org/10.3389/fpsyg.2015.00041.

[6] van Assche M, Giersch A. Visual Organization Processes in Schizophrenia. Schizophr Bull 2011;37:394–404. https://doi.org/10.1093/schbul/sbp084.

[7] Kohler CG, Bilker W, Hagendoorn M, Gur RE, Gur RC. Emotion recognition deficit in schizophrenia: association with symptomatology and cognition. Biol Psychiatry 2000;48:127–36. https://doi.org/10.1016/S0006-3223(00)00847-7.

[8] Friston K. Prediction, perception and agency. Int J Psychophysiol 2012;83:248–52. https://doi.org/10.1016/j.ijpsycho.2011.11.014.

[9] Notredame C-E, Pins D, Deneve S, Jardri R. What visual illusions teach us about schizophrenia. Front Integr Neurosci 2014;8. https://doi.org/10.3389/fnint.2014.00063.

[10] Joos E, Giersch A, Bhatia K, Heinrich SP, Tebartz van Elst L, Kornmeier J. Using the perceptual past to predict the perceptual future influences the perceived present – A novel ERP paradigm. PLOS ONE 2020;15:e0237663. https://doi.org/10.1371/journal.pone.0237663.