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CCS2 Project Proposal:

Predictive Processing (PP) theory of brain function is one of the most debated theories in cognitive science. It posits that the brain is constantly generating predictions about the environment based on the mental model of the world. The predictions are being continously updated through incoming sensory information. They guide our behavior, interactions with the world and shape our subjective experiences. Key to PP view is the assumption that our brains minimize the prediction error - the difference between the generated predictions and the perceived sensory data. While facing new sensory input which yields big prediction error, a person can either update their beliefs or take action to change the world in order for it to match the mental model. Beliefs are represented as *prior knowledge* about the world. The view of the brain as a predictive machine follows closely the concept of Bayesian Inference, which is a statistical method which leverages Bayes' Theorem for updating the probability of a given hypothesis. By calculating Bayesian probabilities, we can model the brain via PP theory.

A body of recent work has focused on the relationship between PP and how humans process data from different modalities (Sidhu & Vigliocco, 2023; Hohwy, 2020). In particular, the central role of integrating multisensory data has been explored. This is due to the role of *crossmodal correspondences* - the mutual dependence of processes underlying perception of data from different modalities. The Predictive Processing view of the brain allows to easily account for the correspondences through *multimodal priors,* representing some prior knowledge about the relationships between multimodal data in our environment. As an example, it has been shown that humans consider audio and visual data as coming from the same source even if their actual emission locations differ, if they believe that there is a causal link between the data (the effect commonly known through example of Ventriloquist Illusion, Stawicki et al., 2019). This belief can be represented as (multimodal) prior knowledge about the co-occurrence of stimuli of different modalities in perceived scene.

In our study we would like to prepare a Bayesian model, which would predict the likelihood of occurrence of Ventriloquist Illusion given the spatial mismatch between the audio and visual stimulus, as typically measured in the ventriloquist effect paradigm. As an important factor, we would like to experimentally introduce a *multimodal prior*, representing the prior knowledge about the co-occurrence of the multimodal data. To build and test the model, we would like to reuse the publicly available data from an experimental study, exploring the effect of the ventriloquist illusion, conducted by Kayser et al. (2022).

What does the data consist of?

Data contains experiment information for 20 participants. Each trial consists of stimuli - response series. The first stimuli is always audiovisual (AV), where both audio (A) and visual (V) stimuli are presented. Participant's goal is to locate the source of the sound. This measures the Ventriloquist Illusion. The AV stimuli is followed by auditory stimuli, which the participant is supposed to locate. This measures the after effect. Some trials also consist of purely visual stimuli which are supposed to balance out the modal load. For all of the participants, each row of the dataset represents a trial, and the columns correspond to various trial-specific variables (visual stimuli position, auditory stimuli position, difference between visual and auditory stimuli positions, modality: AV, A and V, perceived location of stimuli coordinates and additional information which we will not be taking into account).

How do you plan to introduce the multimodal prior?

We want to model the perception of the Ventriloquist Effect and recalibration considering previous trials' influence. We would like to create a Bayesian model which predicts participant's response given the location of the audio and visual stimuli. The multimodal prior will be introduced as a variable which models each participant's receptivity to the illusion. We would like to initialize it as a normal distribution, which makes no assumptions about the individual beliefs other than the mean and standard deviation. Then, we would like to check how the distribution changes as we update the model in each trial for each participant, representing individual beliefs. The likelihood distribution will be based on observed data from the given dataset. We plan to use the PyMC python library for Bayesian modeling.

How will you evaluate the results?

We would like to evaluate the results by introducing a Bayesian baseline model (which would predict participant's response based only on the location of perceived stimuli) and comparing it with our Multimodal Prior Bayesian model. As evaluation metric we will use Widely Applicable Information Criterion (WAIC), which is a Bayesian model comparison criterion that estimates the expected log pointwise predictive density. We are hoping that the Bayesian framework will accurately model the way human perception works in case of multimodal sensory data integration, in line with the postulates of the Predictive Processing view of the brain.

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