Anticipating Movement through a Virtual Environment from activity in the Visual Cortex

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Introduction

The brain stores knowledge gained through experiences in internal models. It uses them to generate predictions and make sense of incoming sensory information. However, not all ongoing processes in the brain are driven by the immediate sensory environment. Pre-existing knowledge also allows us to initiate thought processes unrelated to the immediate sensory environment and simulate moments expected to happen in near or far future. We are investigating how automatic thoughts about the future coexist with immediate sensory information in the visual cortex.

Methods

We created a virtual environment which the participants explored prior to the fMRI experiment using a VR headset. We compiled four videos of navigation through the virtual apartment, following four different routes of navigation through the rooms (marked with arrows in the image below). Each video started in one room (either the bedroom or the games room) and ended in a second room (either the kitchen or the office). These videos served as main stimuli in our navigation paradigm. A cue was presented at the start of each trial indicating the direction of navigation in the upcoming trial. This was followed by a six-second video of the start room. After a twelve-second baseline interval the navigation video resumed revealing the end room in the sequence. The participants' task was to predict the end room in the trial. The bottom right quadrant of the stimuli was hidden behind an occluder. This allowed us to isolate voxels which have no feedforward input and observe the feedback activations in these voxels in isolation. We conducted the experiment at 3 Tesla and 7 Tesla fMRI.

Trial Timeline

Analysis

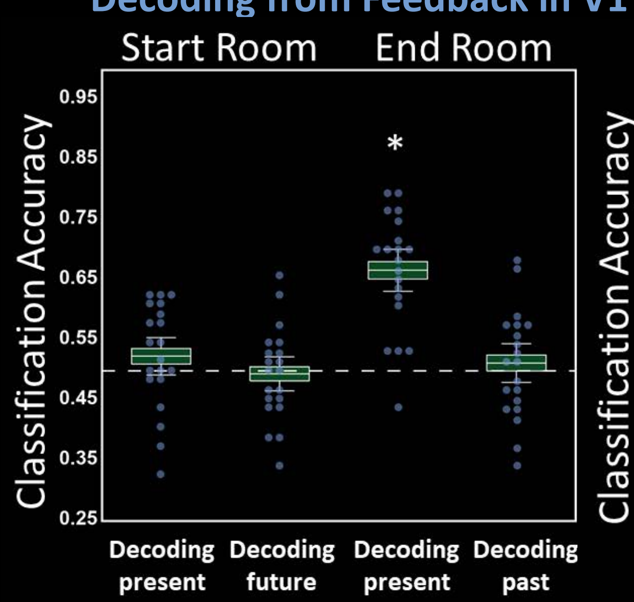
We applied MVPA analysis on recorded activations from unstimulated voxels during the start and the end room videos to see if we can decode information about the current room, the anticipated future room and the past, based on feedback signals. The higher resolution at the 7T magnetic field allowed us to look at decoding accuracies across six cortical depth layers of the visual cortex at 0.1, 0.26, 0.42, 0.58, 0.74, and 0.9 mm depth.

Results from Experiment at 3 Tesla, N=20

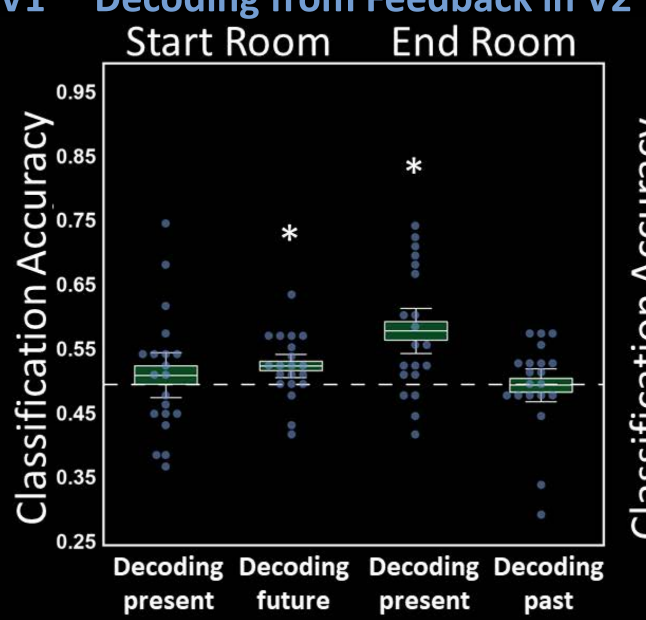
Decoding of the present room was successful in V1, V2 and V3 only from activations elicited by the end room video. The inability to decode the present room from BOLD responses to the start room suggests that the presence of feedback related to anticipating the future is competing with that related to the present.

Decoding the anticipated future room from activations elicited by the start room video was significantly above chance in areas V2 and V3 ((p<0.05), chance level = 0.5). In the box plots below, significant results are marked with *.

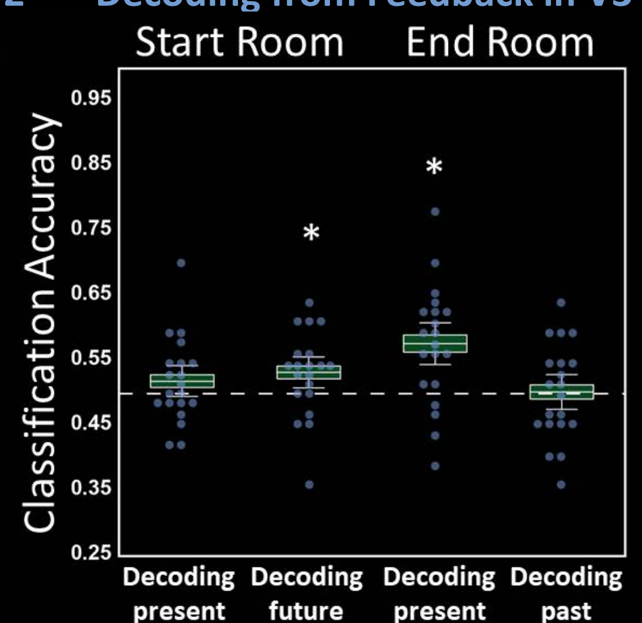
Decoding from Feedback in V1



Decoding from Feedback in V2



Decoding from Feedback in V3



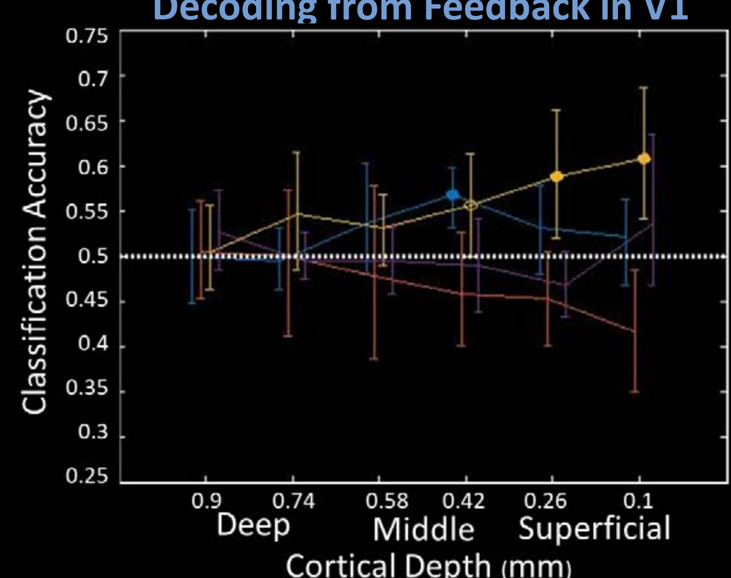
Results from experiment at 7 Tesla, N=6

When applying the classification on signals elicited by the end room video, we could successfully decode the present room from superficial layers of V1, middle and superficial layers of V2, and deep and superficial layers of V3. Decoding the present during the start room video was successful only in middle layers of V1 and deep layers of V2.

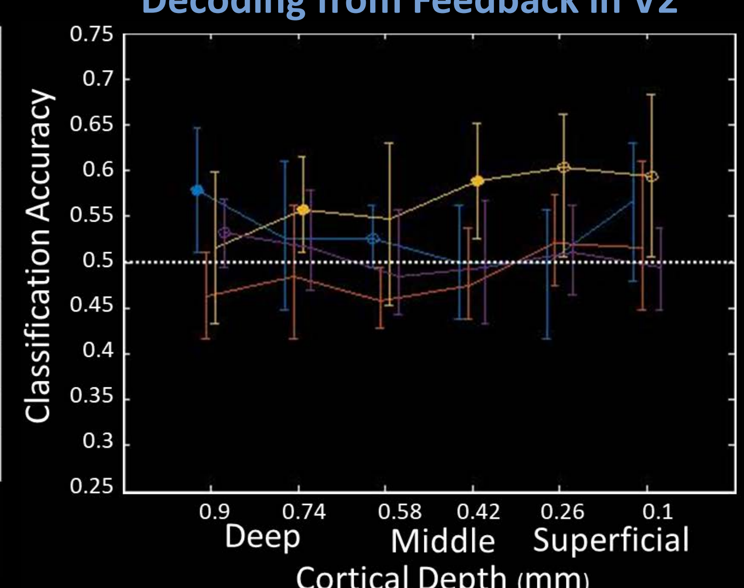
The classifier performed above chance level in decoding the future room only in superficial layers of V3. The results are presented In the line graphs below, error bars indicate 95% confidence interval around the median; significant decoding accuracies after Bonferroni-correction are marked with coloured dots.

- Decoding the present during Start room
- Decoding the future during Start room
- Decoding the present during End room
- Decoding the past during End room

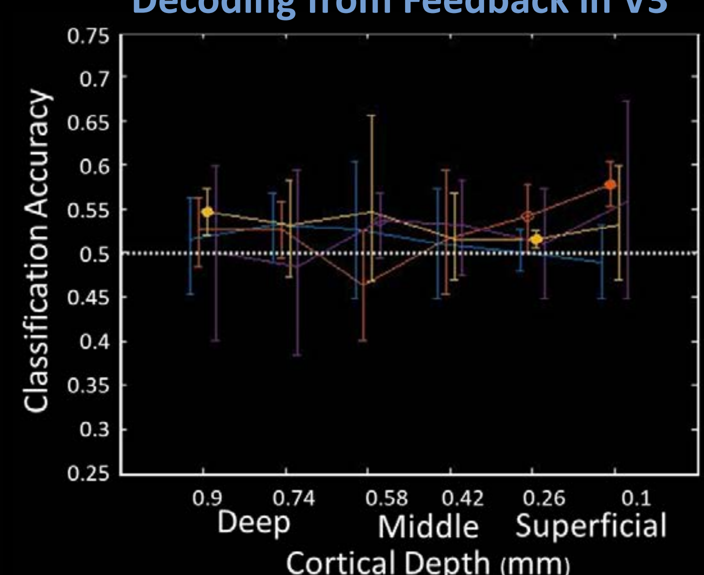
Decoding from Feedback in V1



Decoding from Feedback in V2



Decoding from Feedback in V3



Conclusions

- Predictions about 12 s into the future coexist with immediate sensory information and can be read out from retinotopic visual cortex.
- Feedback activations related to the immediate present have a different layer-specific profile compared to anticipatory feedback related to potential future scenarios. These profiles vary across the different hierarchical levels of the visual cortex. Information about the present was found in the superficial layers of V1. In V3 the predicted future room was decodable from activation of superficial layers, while the present room was detected in signals in the deep as well as the superficial layers.

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