A Reinforcement learning model develops causal inference and cue integration abilities

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2009

Preprint:

This is an accepted article published in Proceedings of the 2009 Bernstein Conference on Computational Neuroscience, Frankfurt. The final authenticated version is available online at: https://doi.org/[DOI not available]

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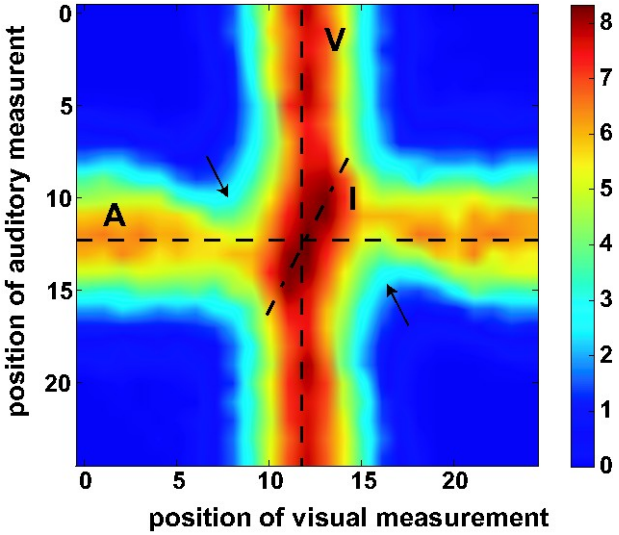
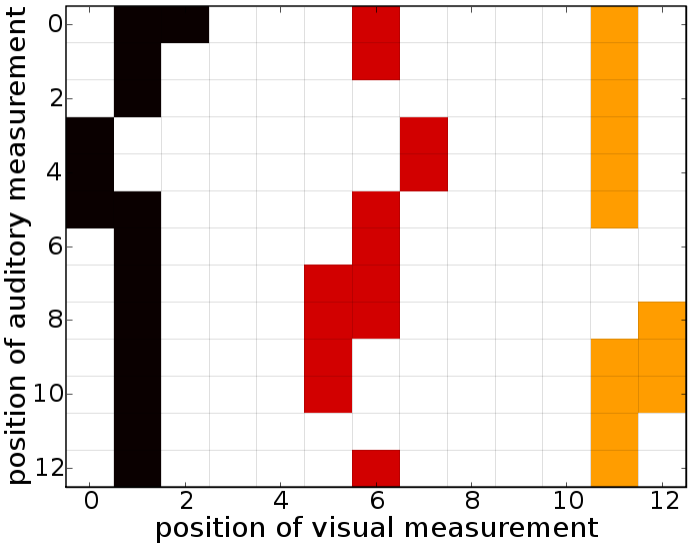


1) Reward predictions for all possible states for one specific action after training a reinforcement learning agent in an orienting task. A state is defined as the positions of the visual and auditory measurement. If one of the two measures has the same value as the action (lines A and V), expected reward is relatively high. Additionally it is higher in the visual (V) than in the auditory (A) case. This is the way the model represents the differences in reliability (visual reliability is higher). In the cases were the two cues deviate only little but with opposite signs from the action the model predicts even higher rewards (line I). It integrates the two measurements weighted according to their reliabilities, which is shown by the tendency of I towards the visual measurement. The area around the arrows shows also integration, only that here both cues are smaller or bigger than the action, so they favor a different action.



2) Policy of the fully trained agent. Plotted are the audio-visual states where the agent expects the highest reward for an action to position 1 (black), 6 (red) and 11 (yellow). For states where the visual and the auditory measurements are far apart (like in the lower left or upper right), the model takes the action that corresponds to the more reliable visual measure. In contrast, if both measurements are close together (diagonal from upper left to lower right), the best action is defined by an integration of both measurements. This shows that the agent uses different strategies depending on the state - it uses causal inference.