Active Sampling supported Comparison of Causal Inference Models for Agency Attribution in Goal-Directed Actions

Beck TF, Endres D*, Lindner A, Giese MA* (* Equal contribution.)

Perception of own actions is influenced by visual information and predictions from internal forward models [1]. Integrating these information sources depends critically on whether visual consequences are associated with one's own action (sense of agency) or with changes in the external world unrelated to the action [2] and the accuracy of integrated signals [3]. Attribution of percepts to consequences of own actions depends thus on the consistency between internally predicted and actual visual signals.
However, is the attribution of agency rather a binary decision (‘I did, or did not cause the visual consequences of the action’ [4]), or is this process based on a more gradual attribution of the degree of agency? Both alternatives result in different behaviors of causal inference models, which we try to distinguish by model comparison.

METHODS. We used a virtual-reality setup to manipulate the consistency between pointing movements and their visual consequences. We investigated the influence of this manipulation on self-action perception.
We compared two Bayesian causal inference models to the experimental data, one with a binary latent agency variable [2], and one with a continuous latent agency variable [4]. Here, subject-specific regions for stimulus conditions that maximally differentiate between the two models were identified online using Active Sampling methods [7] to evaluate relative model evidences with a small number of samples.

RESULTS/CONCLUSION. Both models correctly predict the data, and specifically empirical agency ratings showing high attribution of agency for small deviations between sensory and predicted feedback. Some participants show signatures of a binary internal representation of agency. In addition, relationships with other causal inference models [6] are discussed.

[1] Wolpert et al.,Science,269,1995.
[2] Körding et al.,PLoS ONE,2(9),2007. Shams&Beierholm,TiCS,14,2010.
[3] Burge et al.,JVis,8(4),2008.
[4] Beck et al.,JVis,11(11),2011.
[5] Beck et al.,Jvis,13(9),2013.
[6] Marko et al.,JNPhys,108,2012. Ernst,Jvis,7(5),2007.
[7] MacKay,NeuralComp,4(4),1992. Paninski,NeuralComp,17(7),2005.

Acknowledgements
This work was supported by: German Federal Ministry of Education and Research: BMBF, FKZ: 01GQ1002A, EU Commission, EC FP7-ICT-248311 AMARSi, Deutsche Forschungsgemeinschaft: DFG GI 305/4-1, DFG GZ: KA 1258/15-1, European Commission, Fp 7-PEOPLE-2011-ITN(Marie Curie): ABC PITN-GA-011-290011, HBP FP7-ICT-2013-FET-F/ 604102; Koroibot FP7-ICT-2013-10/ 611909