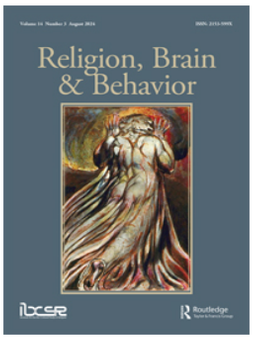

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Testing the enactive model of agency detection—a commentary on Teehan

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We welcome the opportunity to comment on Teehan's article, which we found very relevant to the scientific study of agency detection. We appreciate the paper's main idea of reconceptualizing the concepts of Cognitive Science of Religion (CSR)—in general—and agency detection—in particular—as an entangled embodied interaction rather than a representational process. Our general impression is that the enactive approach, as compared to the classic account, provides a much more holistic picture of how cognition works, especially whenever we detect an agent in our vicinity. However, as with every such "big" picture, the question naturally arises how to derive testable predictions from the framework presented. Here we briefly discuss this issue and address two related matters: our ideas regarding studying the embodied and situated aspects of agency-attunement and the use of virtual reality as a research tool with high(est) ecological validity.

Starting with the testability problem, Teehan's ultimate motivation is to establish a more solid scientific foundation for CSR through adapting an enactive approach. He recognizes that an inaccurate conceptual framework, particularly one based on a representational account of cognition, can result in drawing misleading conclusions from empirical data. However, even with an improved framework, empirical testing of its predictions remains crucial. In the case of enactive agency-attunement, determining specific predictions and methods for their falsification poses significant challenges.

Consider, for example, the idea endorsed by the author that while agency detection may have created the mental capacities for religious beliefs to emerge throughout our evolutionary history, it is doubtful that individual differences in agency detection could explain why humans acquire supernatural beliefs today. This observation is to the point; however, without testing if humans indeed possess a culturally-universal, developmentally natural capacity for agency detection, we cannot confidently assert that agency detection was a prerequisite for the emergence of supernatural beliefs—and even then, as with every hypothesis regarding our evolutionary history, the claim runs at the risk of being unfalsifiable. Furthermore, we feel that there is an overlap of *explanandum* and *explanans* in the paper. According to Teehan, agency-attunement was part of our cognition before the emergence of religion, so it could play a role in explaining the development of supernatural beliefs. However, he argues that the fact that supernatural agents are ubiquitous elements of religion adds "evidential weight to the (…) argument for the role of embodied agency-attunement in the evolutionary origins of religion." As we read it, on the account by Teehan, agency-attunement can explain religion, and the existence of religion supports that we are agency-attuned; this seems to be a case of circular reasoning. While the foundational work on agency detection seems vital to the explanation of the evolutionary origins of supernatural beliefs, the lack of methods to provide evidence for that hypothesis has

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motivated researchers to look for a more proximate relationship between agency detection and religious phenomena: for instance, Andersen (2019) proposed a model of how agency detection feeds on and reinforces *already existing* supernatural beliefs.

More critically, as much as we endorse the idea of "putting" the body and our *praxis* back in the realm of cognition, the author himself notices that it is difficult to find a way to test the enactive approach and its particular application in this paper, namely, agency-attunement. While in a representational cognitivist framework, agency detection is considered a function of threat (Maij et al., 2019), ambiguity (Barrett & Lanman, 2008) or prior beliefs (Andersen, 2019), which makes it easy to make testable predictions, we find it harder to find a good measurement or manipulation of important factors for agency-attunement to arise. We acknowledge that Teehan provides support for his proposal citing relevant findings concerning the involvement of the amygdala in threat-detection. However, this evidence is indirect and shows only that there are parts of our brain which work in line with agency-attunement. In the holistic picture drawn by Teehan, the detection of agents is brought about by a variety of factors: from our evolutionary and experiential priors, through action, to embodied emotions. As encompassing as it is, this picture does not provide a model which can be tested against empirical data. In other words, based on this framework, it is difficult to answer the question of "Under what conditions does a person enact illusory agents?."

In an attempt to provide some ideas for direct, testable hypotheses that could be in support of Teehan's proposal, we here focus on the non-trivial involvement of the (1) body, (2) action, and (3) environment in agency-attunement. We will then argue for the need to use virtual reality to test these hypotheses.

Starting with the notion of "enactive embodiment," an implication of the proposed framework is that agents with different bodies would enact agency in different ways. Consider, for example, that humans of varying body size might have their perceptual system attuned to different parts of the environment and employ different action policies. This is not only because their perceptual apparatus is literally placed higher or lower with respect to the floor, but also because they attend to the environment with different experiential priors regarding what they can do and what kind of danger they should avoid. Similarly, individual differences in physiological reactions, "gut feelings," and following affective states might be strongly related to agency-attunement, as—especially in the predictive processing view—we try to make sense of all the available sensory data, including interoceptive signals. The role of interoceptive data in agency-attunement could be studied with respect to participant's subjective feelings, where it would be interesting to see how beliefs about interoceptive signals (see, e.g., Legrand et al., 2022) bias the detection of agents. A possible prediction, related to the already hypothesized relationship between threat and agency detection (see Maij et al., 2019) is that an artificial increase of one's heart rate (e.g., through exercise or medical intervention) will affect agency-attunement, working as a bodily cue for anticipation and for choosing the right action policy.

At the same time, Teehan points to action being a constitutive part of all cognition. Based on this insight we believe that one problematic part of most previous studies on agency detection was that they asked participants to detect agents (or agent-like patterns), instead of adapting a more ecologically valid approach, where participants' ability to detect agency keeps them safe *while* they engage in purposeful actions. Obviously, it is hard to measure the detection of agents without asking participants to react whenever they detect an agent, but this measurement could be included in the empirical setting as an additional task next to a proper, meaningful action (e.g., such as hunting for food or navigating through a maze).

Finally, Teehan writes also about the constitutive role of the environment for agency-attunement. We believe that this is an important remark, as to date, most studies on agency detection have focused only on one feature of the environment, namely, the sensory data ambiguity/unreliability. However, environments can provide various perceptual conditions, offer different action policies and they can be more or less meaningful (see Van Leeuwen & van Elk, 2019). We believe that agency detection capacities can be recruited differently and selectively not only

based on one's experiential priors, but also on their motivations regarding the environment and the topology and meaning of the environment itself.

We argue that these ideas allow for predictions that could be tested in a virtual reality (VR) setting. However, before moving on to possible study designs, we need to address a doubt expressed in the target article, namely, that VR is not an ecologically valid tool to study agency detection. In short, Teehan notes that a VR setting—akin to a regular computer screen—neglects the role of the body and is ultimately situated within the safe environment of a laboratory. However, we feel that this is an overstatement, as VR might not be an ideally ecologically valid tool but is definitely a *more* ecologically valid than traditional experimental paradigms. In fact, there are multiple studies showing that we immerse ourselves into virtual environments and can feel as if we were actually present in the virtual reality environment (e.g., Villani et al., 2012), sometimes to the extent that the real world starts to feel unreal (Aardema et al., 2010). Moreover, virtual reality-induced hypnosis has been found to decrease pain (see, e.g., Kotlyar et al., 2008; Rousseaux et al., 2023; Yu et al., 2018) and virtual simulations can be used to reduce, among others, arachnophobia (e.g., Bouchard et al., 2006). Furthermore, virtual environments can evoke strong emotions and physiological responses (Martens et al., 2019), and many effects found in natural settings are also present in virtual reality, including illusory ownership over body parts or different avatars (e.g., Slater, 2009). All these results lead us to conclude that VR can have a strong influence on our cognition and, to put it metaphorically, people indeed can "get lost" in the virtual world. Faced with ethical issues related to studying agency detection in "real life," we must resort to the best tools that we have —and VR is one of them. Indeed, more and more studies on agency detection are now being conducted with the use of VR (Andersen et al., 2019; Maij et al., 2019; Tratner et al., 2020) and so far, they suggested that VR can reliably induce false positive agent detections. Notably, we speculate that augmented reality may also offer unique opportunities for assessing agency detection in real-life settings, but so far, no studies have yet explored this possibility.

With the tool of VR in hand, we can translate ideas for the hypotheses formulated above into proper experimental designs. First, within VR, the effect of one's perceptual bodily position can be easily manipulated, so that participants in different conditions can explore the world with varying virtual body sizes. Additionally, subjects can be asked to enter the virtual reality with different body postures, which has been found to affect the assessment of deities' powerfulness (Kundtová Klocová, 2014) and could work similarly in agency detection. Namely, our prediction would be that participants asked to kneel or crouch during the exploration of a virtual environment would interpret detected agents as more dangerous, powerful, or otherwise dominating. When it comes to interoceptive signals and emotions, the first author of this commentary is currently conducting a study where subjects' emotional attitude towards agents is manipulated. In this study, one group explores a dark, agentless, virtual forest believing it to be inhabited by hostile beings, while the other group has more neutral expectations about the agents (Szymanek et al., in prep.). Here, finding an effect of feeling of threat on the numbers of detected agents could indicate the existence of a HADD (see Maij et al., 2019) or could be in line with the notion of evolved priors for agency detection (see Asprem, 2019) which increase the estimated prior probability of detecting an agent in a situation of danger. However, such an effect could also suggest that detection of an agent is more likely when there are relevant bodily cues taken into account. Or, to put it in enactive terms, our bodies are more attuned to agency when they are already put in a state of fearful anticipation.

The impact of other interoceptive signals and "gut feelings" could also be studied in virtual reality paradigms, with physiological and subjective measures administered to test if participants attune to agency differently—both qualitatively and quantitatively—when their bodies are put in conditions of stress or effort. Consider, for example, asking participants to perform an intense physical exercise before entering a virtual environment. Elevated heart rate can attune our body to a specific type of action policy: consciously or not, we might instinctively seek a place to rest and restore our energy. In such conditions, any predator lurking nearby poses a greater threat, which might result in an increased tendency for agency detection.

At the same time, as within the enactive approach action and perception are two sides of the same coin, attunement to agency could strongly depend on what kind of activity the participant engages in and, at the same time, how motivated they are to complete it. For example, different groups of subjects could enter the same, natural-like, virtual setting, with some of them asked to collect "points" (e.g., fruits) and some asked to simply explore the environment. Our prediction is that participants performing tasks that can be disrupted by the presence of other intentional agents would be more attuned to subtle cues of agency (and thus, presented more false positive detections) as well as display other patterns of activity and visual attention (e.g., picking up a fruit, looking around, moving to another fruit, and so on) which could be measured with an eye-tracker device.

A final study design inspired by the proposed theoretical framework would involve changing some aspects of the virtual environment in order to see if being presented with different affordances leads to a change in action policies and—in turn—to a change in agency-attunement. Possible experimental manipulations include increasing sensory unreliability (like in the study by Andersen et al. (2019)) but also adjusting the level of interaction with the environment, means for exploration, scenery, and number of agency cues. For instance, one could compare the quantity and quality of agency detection reported in two environments differing only in the extent of concealment they provide. As our embodied priors "couple with specific recurrent features of the environment," we can easily tell whether we would be able to hide from somebody else behind a specific object (e.g., a bush) and thus we enact possible agents that in turn might be hiding from us. Considering this, our prediction is that the environment filled with hiding spots should make participants more agency-attuned.

To conclude, while we very much hope to see more work set within the "enactive science of religion," here we shared our concerns regarding the testability of the account put forward by Teehan. We also presented some ideas on empirical designs that could inform further conceptual work on how enactive agency-attunement emerges depending on (1) the body, (2) action policies and (3) the environment. We congratulate the author for his article and invite him to consider our empirical suggestions, at the same time calling for further studies with the use of virtual reality which can contribute to our knowledge on conditions for the detection of intentional agents and its connection to supernatural beliefs.

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