**4. Discussion**

We hypothesised that information about beliefs can feed into motor predictions concerning an observed agent’s potential actions. To test this hypothesis, we adapted a widely replicated ball-detection false belief task. Given existing evidence that such motor predictions can accelerate our execution of the same action and decelerate our execution of an incompatible action (Brass, Bekkering, Wohlschlager, & Prinz, 2000; Cracco, Bardi, Desmet, Genschow, Rigoni, De Coster, et al., 2018), our hypothesis generates the prediction that these motor predictions may be responsible for the P−A+ < P−A− (false belief) effect observed in the ball-detection task. To test this prediction we used “mumification” to manipulate whether the observed agent in our ball-detection task was free to act (Free-Agent version) or whether she was visibly constrained from acting (Constrained-Agent version). As predicted, we found that the P−A+ < P−A− effect was elicited in the Free-Agent version but not in the Constrained-Agent version.

Our findings converged with studies of interference effects showing that physical constraints on others’ action possibilities are mapped onto observers’ own representations of the environment (e.g., Costantini et al., 2011; Liepelt et al., 2009). Costantini et al. documented that reaction-time advantages in adults’ predispositions to act towards a graspable mug – triggered whenever participants observed that the target object was presented within another person’s reaching space – disappeared when a transparent barrier was interposed between the agent and the mug. Their argument was that the transparent barrier prevented any potential action on the part of the agent, and inhibition of motor simulation impacted upon participants’ own representation of appropriate goal-related acts towards the object. Our findings add that reaction-time effects which are sensitive to an observed agent’s beliefs (and not merely to her action possibilities) can be similarly modulated by preventing any potential action on the part of the observed agent.

Just here we face an objection. Participants may not have shown reaction time benefits in the Constrained-Agent version of the ball-detection task because the agent’s “mummified” appearance in the outcome phase was perceptually novel. Anticipating this objection, we included a third, Loose-Sheet version of the ball-detection task as a control for perceptual novelty. In the Loose-Sheet version, the agent also returned with a novel appearance involving a sheet, but he remained visibly able, potentially, to act upon the ball. In further support of our primary prediction, we found that the P−A+ < P−A− effect was elicited in the Free-Agent *and* Loose-Sheet versions but obstructed in the Agent-Constrained version. This is in line with the predictions of our hypothesis and contrary to what we would expect if the objection about perceptual novelty were correct.

Our inspiration was Bardi and Brass (2016)’s suggestion that motor processes and belief tracking may be connected. As they note, it is now well established that motor processes may be influenced by facts about the goals of withheld actions (e.g., Avenanti, Annella, Candidi, Urgesi, & Aglioti, 2013; Bonini, Maranesi, Fogassi, & Rizzolatti, 2014; Kühn, Gevers, & Brass, 2009; Maranesi, Livi, Fogassi, Rizzolatti, & Bonini, 2014). Our findings raise the new and exciting possibility that motor representations in an observer may be influenced not only by goals of the observed agent’s actions but even by the observed agent’s beliefs.

Theoretically, this leaves many possibilities open. One such possibility is that automatic belief-tracking processes are distinct from, but can influence, motor processes. If this possibility is correct, we would expect that belief tracking is still occurring in the Constrained-Agent version of the ball-detection task, but that it is not feeding into motor processes to modulate participants’ behavioural responses. Another, more radical possibility is that some automatic belief-tracking processes are so closely bound up with motor processes that impairing the motor processes also prevents those belief-tracking process from occurring. If so, we would expect that belief tracking is not occurring (or not occurring in the same way) in the Constrained-Agent version.

More research will be needed to determine whether belief-tracking processes occur even when motor processes in participants are impaired. For example, aside from measuring the latencies of participants’ key-press responses, researchers might simultaneously measure skin conductance and pupil dilation effects (\*citations). If automatic belief tracking processes are motor processes, we would expect “mummification” to eliminate indications of belief tracking not only in response times but also in skin conductance and pupil dilation.

Do our findings allow us to predict that wherever we have a fast belief-tracking process, impairing motor representations will impair the process? We think they do not. Our findings indicate that *some* of the fast belief-tracking processes may influence, or may even be bound up with, motor processes. But accepting this conclusion leaves us open to the possibility that *other* fast belief-tracking processes have nothing at all to do with motor processes. For instance, some belief-tracking may be based on perceptual processes. We therefore remain open to the idea that there is heterogeneity in the processes and representations supporting belief-tracking.

~~What would distinguish when fast belief-tracking is motorically or perceptually based? Different manipluations selectively interfere with either kind of representation: mummification of an agent should impair motor but not perceptual processes; while manipulation of lighting effects (e.g., an object that is suddenly masked by darkness) should impair perceptual processes involved in maintain representations of a scene while not impairing motor processes. [EXPAND]~~

To conclude, we have been building on evidence about the role of motor processes in enabling us to understand others. Until now, most evidence concerns tracking the goals of others’ actions. Our novel finding is that information about another’s false beliefs can influence motor processes in an observer. To make a leap, this is a hint that motor processes may underpin the primary ways in which human beings engage in social cognition.

~~Researchers still do not have a good handle over whether and to what extent different responses may be dominated by certain processes and representations (Butterfill & Apperly, 2013; Edwards & Low, 2017). However, if the P+A- < P-A- effect is a consequence of the way that information about beliefs feeds into motor predictions of the agent and how those motor representations then facilitate (or not facilitate) response times – as our current findings documented – then we can begin to appreciate that automatic belief tracking can have functional consequences for generating expectations of potential action by how it interfaces with motor control.~~