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The Neurobiological Building Blocks of the False-Belief Task

Comment on Gallagher's 'The Problem with 3-Year-Olds'

Gallagher (this issue) reviews some well-known theories that provide explanations as to why children fail at false-belief tasks, taking into account various aspects as to why children may fail to pass this mental test.

In this commentary I approach the topic from a different perspective, discussing the cortical and neurochemical roadblocks that inhibit children at the age of three years in passing *common* theory of mind (ToM) tests, providing some neurological evidence to take into consideration when reflecting on what is key to the success of false-belief tests. The upshot is neither a supplement to the enactivist view defended by Gallagher, nor a critical comment on it. It instead provides some interesting bases for an alternative view.

Tasks requiring behavioural inhibition and memory seem to occur between 3–6 years of age. Popular experimental paradigms that examined the above mechanisms include the A-not-B error (Zelazo, Frye and Rapus, 1996), 'appearance-reality' task (Flavell, 1993), the Go-No-Go task (Casey *et al.*, 1997), and the 'theory of mind' and 'false-belief' tasks (FB) (Fritz, 1991). All of the above paradigms share similar if not identical results since children under the age of three fail to effectively carry out the task whereas children above the age of four succeed.

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Journal of Consciousness Studies, **22**, No. 1–2, 2015, pp. 183–6

The most discussed paradigm of this problem is the 'theory of mind task' or the 'false-belief task' in which an object of interest is placed at a pre-defined location while both the agent and the child observe the process. Then in the absence of the agent the object is relocated and when the agent returns the child is asked to answer the question of where the agent should look for the object in question. The child in this task is required to *indicate where the agent would think that the object is* as well as *conceal the item's true location*. Remarkably, a child below 3–4 years is unable to inhibit an inclination to say where the object really is, even though the child is aware of the fact that the given answer is 'wrong' (Fritz, 1991). To successfully perform these tasks children not only need to recall instructions from one's memory and acquire knowledge into another's behaviour, but most importantly *disengage* from a previously rewarded response (where the object was) and engage with a new one. This 'error' is *attachment-based* and has two components to it, *location* and *reward* (Luciana, 2001). Conflict resolution between incompatible responses involves constant conscious awareness of the required action, regardless of unconcealed cognitive noise (Posner and DiGirolamo, 1998). This challenge of cognitive nature involves the projection of an individual object that contains two dichotomous cognitive cues. The projected cues are not always congruent and as a prerequisite for the experimental task participants have to select a subdominant object or a response over the presence of a conflicting dominant one (Botvinick *et al.*, 2001). Cortical regions mediating this task involve the seeking system (Panksepp, 1998), made up by the inhibitory orbitofrontal cortex (Casey *et al.*, 1997), the working memory dorsolateral prefrontal cortex (Baddeley, 1992), as well as limbic and mesolimbic regions of appetitive responding (MacLean, 1990).

One possible reason explaining the failure of 3-year-olds to pass the FB task is, as Carruthers (2013) suggested, the fact that efficient connections between mindreading systems and executive systems (or both systems) have not matured sufficiently, with this argument being independent of the fact that 3-year-olds are capable of understanding and responding to complex linguistic tasks (Scott *et al.*, 2012). Indeed, children at the age of three seem to have the cognitive capacity to understand complex instructions, however they seem deficient in conflict resolution tasks. This is partly paradoxical as the frontal cortex, despite the fact of being responsible for both language production and conflict resolution, at the age of three has not yet adequately matured to allow *sufficient conflict monitoring, irrelevant of the linguistic nature of the task*. Evidence for this statement comes from conflict resolution tasks. The Stroop task involves language stimuli and revolves around the conflict between the word name and its ink colour. The Flanker task on the other hand entails non-language spatial conflict in which the shape as a whole depicts the general direction or tendency made up of congruent, incongruent, and neutral sub-parts (Fan *et al.*, 2002).

Researchers from Cornell University have studied this phenomenon of cognitive incongruence, observing regions that are common in both linguistic and spatial related conflict paradigms. What was observed was that, despite the expected fact that incongruent stimuli had longer reaction times than congruent ones, both models of conflict shared similar brain networks. The anterior cingulate and prefrontal cortex were common in both tasks, however as researchers argue these sites seem to be only monitoring conflict and not resolving it (Fan *et al.*, 2003).

On the other hand, the increased success rate of children in the 'Duplo-task' applied by Rubio-Fernández and Geurts (2013) bypasses one important element of the FB: problems of working memory. The dorsolateral prefrontal cortex provides the station in which temporary information is being processed (Smith *et al.*, 2004). The objects are not only present in this task but most importantly throughout the process the experimenter aids the child to track the mental perspective of the agent, in this case the 'Duplo-girl', as well as act upon it. The experimenter guides the child through a series of targeted questions: 'Can the girl see me from where she is?', 'She hasn't seen what I did, has she?', 'What happens next?… What is she going to do now?' Thus by tracking the perspective of the agent during the relocation of the object, as well as allowing to the child to be a part of the final act, regarding where the 'agent-Duplo-girl' will search for the object (her bananas), suggests that a child at the age of three does in fact acquire a theory of mind. This is mentioned by Gallagher: 'The 3-year-old seems capable of successfully doing all three tasks — mindread, understand the experimenter's speech, and formulate a response — and has seemingly been capable of the first task for at least two years. She just can't do all of this at once.'

The probable reason that the child fails to pass the widely established false-belief test is not only because of cortical immaturity but most importantly neural signalling. Dopamine provides the neural gel that orchestrates successful interaction of the above mentioned regions (Luciana, 2001), and deficiencies in this task may not be related so much to the immaturity of the dorsolateral prefrontal cortex but to inconsistent or insufficient signalling of dopamine during the tasks contextual change (*ibid.*).

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