

LETTER TO THE EDITOR

Reply: Apraxia: a gestural or a cognitive disorder?

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Sir,

It is intriguing that our article 'Critical brain regions for tool-related and imitative actions: a componential analysis' was the sole subject of a recent positive Scientific Commentary in *Brain* by Professor Georg Goldenberg 'Challenging traditions in apraxia' (Goldenberg, 2014) noting that the paper 'excels by virtue of its methodical astuteness, large sample size and the clarity of its results', as well as a more critical Letter to the Editor by Francois Osiurak and Didier Le Gall (2014). We are very pleased that our paper has stimulated discussion. Drs Osiurak and Le Gall raise three points of concern, all focused on our interpretation of results. The first concern is with our suggestion that the inferior parietal lobe provides the basis for the kinematic component of praxis actions, contributing to the planning of movement trajectories in terms of extent, direction, and timing. The second is with our claim that the posterior temporal lobe supports the stored, representational components of praxis. Finally, they note a concern that our account has been modified since it was originally proposed in 2001. We will address each of these criticisms in turn.

Osiurak and Le Gall suggest that the kinematic hypothesis is unable to account for the difficulty of many patients with left brain damage to select the appropriate tool to solve problems. Rather, they prefer to conceptualize the difficulty as a failure of technical reasoning. But what are the core underlying mechanisms that enable one to 'reason' about physical object properties? We suggest that selection of the appropriate tool (and pantomime of tool use) require a simulation (which some have likened to a predictive 'forward model') (Tian and Poeppel, 2012; Pickering and Clark, 2014) of how the arm, hand, and tool will move through space once the tool is picked up and used. In support of the claim that apraxic patients are deficient in predicting how movements will unfold (in advance of actually moving), we have shown that apraxics are unable to predict how they would position the hand

to comfortably grasp a 3D shape were they to actually move, in the context of normal performance once permitted to actually reach out and grasp. Moreover, the magnitude of the prediction deficit is strongly correlated with the magnitude of deficit on tool pantomime and imitation, and with parietal lesions (Buxbaum *et al.*, 2005). These and other findings (Ochipa *et al.*, 1997; Jax *et al.*, 2006, 2014; Mutha *et al.*, 2010; Sunderland *et al.*, 2011, 2013; Eidenmuller *et al.*, 2014) support our proposal that a kinematic planning deficit is a core component of the apraxia syndrome. There are many fascinating questions to be explored here, including the format of the kinematic planning deficit, that is, whether it is restricted to the planning of body movements *per se*, or rather, a deficit in a more abstract process that is relevant to representing any complex trajectory, body-related or not (see Wong *et al.*, 2014 for the latter view).

Osiurak and Le Gall are also critical of our interpretation of the posterior temporal involvement in the semantic aspects of tool actions seen both in the present study and our previous paper in *Brain* assessing gesture recognition (Kalenine *et al.*, 2010). They note that there are reports of patients with isolated semantic deficits who are able to use both familiar and novel tools. Although the organization of the semantic system is a matter of continued debate, a view held by many is that conceptual knowledge is feature-based and distributed across visual, auditory, tactile, olfactory, and action properties (Allport, 1985). Without further specification it is unclear that a given 'semantic deficit' will disrupt action semantics, specifically. In fact, apraxics are frequently intact in knowledge of the function (purpose) of tools, while deficient in manipulation knowledge (i.e. action semantics) (Buxbaum and Saffran, 1998, 2002).

There are a number of lines of evidence supporting the claim that knowing how to use a tool does not emerge solely from mechanical reasoning (although certainly, kinematic planning

processes that underlie mechanical reasoning are likely to play a complementary role, as we and others have discussed previously) (Vingerhoets *et al.*, 2011; Buxbaum, 2014). Chief among them is that skilled tool actions influence performance incidentally, even on tasks for which action is irrelevant. For example, Yee *et al.* (2013) showed that semantic judgement and naming tasks with tool words and pictures of tools were reliably disrupted by the performance of a concurrent, unrelated motor task (playing a hand-clapping game), and furthermore, that this disruption was modulated by how much experience participants had in manipulating those tools (see Witt *et al.*, 2010 for a similar result). When asked to locate a named tool in an array with other tools, neurologically intact participants fixate on distractor tools that are manipulated similarly to the target, despite the irrelevance of the tool action to the task (Campanella and Shallice, 2011; Lee *et al.*, 2013). Apraxic participants exhibit a slowing and diminishment of such fixations on competitors (Myung *et al.*, 2010); and the magnitude of this slowing is reliably correlated with their deficits in a tool pantomime task and with lesions in the left temporal and parietal lobes (Lee *et al.*, 2014; and see Helbig *et al.*, 2006; Myung *et al.*, 2006; Beauchamp and Martin, 2007; Campanella and Shallice, 2011; Kiefer *et al.*, 2011, 2012; Bracci *et al.*, 2012 for related data from healthy participants). Moreover, there is confirmatory evidence from numerous functional neuroimaging studies that the posterior temporal lobe stores information about the characteristic motion of familiar tools, perhaps in a visual format (Beauchamp and Martin, 2007; Bracci *et al.*, 2012; Kiefer *et al.*, 2012). It is implausible that the brain would store tool-use information but not make use of it.

Osiurak and Le Gall suggest that rather than having a deficit in tool action concepts, apraxic patients fail to understand the examiner's expectations when tools are presented in isolation, and may perform a gesture that, although associated with the tool, is not the precise one sought by the examiner. Aside from the evidence discussed above showing that patients with apraxia do have a deficit in action concepts, this explanation is implausible for at least two reasons. First, the great majority of the tools in this study have a single use action associated with them (e.g. scissors, comb, bottle opener, eraser, cigarette lighter). Second, our scoring system awards credit to alternative gestures that are performed by our normative sample (e.g. shaving the face or legs), deducting points only for inaccuracy in the spatiotemporal and postural aspects of the gesture.

Osiurak and Le Gall note with apparent concern that our account has been modified since originally proposed. The aspects of praxis tasks that are subserved by the temporal versus parietal lobes remain a matter of great interest. Indeed, there is evidence, for example, that the left supramarginal and inferior frontal gyrus may play important roles in representing the pool of possible tool actions and in selecting among them (Vingerhoets *et al.*, 2013; Schubotz *et al.*, 2014; Watson and Buxbaum, in review). Although it may be surprising to some, the evidence we have provided strongly suggests that when understanding skilled action as well as when producing it, the posterior temporal lobe provides critical input. Scientific theories, including ours, need to grow and change to accommodate new data. Setting aside the need to conceptualize apraxia as either a cognitive or gestural disorder, one of our

major goals is to articulate the cognitive architecture and processing dynamics of the tool-use network, and its disruption in apraxia. Accordingly, we recently characterized the action features that shape semantic action space, and demonstrated that the representational similarity of 'use' action features influences competition between tools (Watson and Buxbaum, 2014). Moreover, we showed that 'use' action features play a critical role not only in tool similarity, but also in the relationships between tools and other objects participating in events (i.e. thematic relationships; Tsagkaridis *et al.*, 2014). Understanding how tool-use action features are activated and selected from amongst candidate actions, how they influence tool conceptual organization, and how they interact with kinematic planning processes in the healthy and damaged brain remains a fascinating challenge for the future.

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