Tool *use*-responsive regions and tool *object*-responsive regions in the inferior parietal lobule are not identical: Effect of differences in motor goal and target object during imagined transitive movements

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Introduction: Animal research proposed a functional segregation of the dorsal stream into a dorso-dorsal pathway, believed to serve as an object-independent stream involved with on-line control of action, and a ventro-dorsal pathway that provides conceptual input guiding the functional manipulation of objects (Rizzolatti and Matelli 2003). Based on neuropsychological evidence and imaging data, it is suggested that a comparable segregation might exist in humans, one for *acting on* and another for *acting with* objects, and that hand-object interactions follow different streams dependent on the goal to be achieved (Buxbaum et al. 2006; Buxbaum et al. 2007; Daprati and Sirigu 2006; Johnson and Grafton 2003; Johnson-Frey 2004). This fMRI study tests the assumption that increased functional relevance of movement or target preferentially activates inferior parietal regions.

Methods: Fifteen right-handed, normal volunteers varied the intention of their transitive movements by imagining their dominant arm and hand pointing to, grasping to move, grasping to use, or grasping and using three-dimensional representations of target objects depicting graspable neutral shapes, familiar tools, and (equally graspable) unfamiliar tools (Figure 1). With a left-hand button press they indicated the moment their hand 'grasped' the tool, and tools were presented in orientations canonical or non-canonical with a right hand grasp.

Results: The behavioral analysis showed a significant effect of orientation, such that responses toward non-canonically oriented objects were slower. Imagined movements intended to make functional use of familiar objects revealed increased activation in the left inferior parietal lobule. Compared to gestures aimed at displacing an object, functional (use) intentions elicited activation in the anterior and middle portions of the lateral bank of the intraparietal sulcus, suggesting involvement in the higher order control of action (Figure 2A & B). Compared to functionally unfamiliar objects, grasping movements aimed at familiar tools activated the convex portion of the inferior parietal lobule, suggesting a role for the ventro-dorsal stream in object-selectivity (Figure 2C & D).

Conclusions: The behavioral results are in line with imagery research demonstrating that imagined paths simulate the paths used for physically moving the hand between their initial and targeted orientation (Parsons 1987) and is taken as evidence that the volunteers showed adequate motor imagery and task compliance. The fMRI data confirm that stored knowledge for the skillful manipulation of familiar tools of right-handed volunteers is predominantly located in the left inferior parietal lobule, and further suggest that tool *use*-responsive regions and tool *object*-responsive regions are not identical, but may form a local network in which different nodes contribute differently to the representation of functional tool use in humans. The tool *use*-responsive regions in the left intraparietal sulcus appear associated with the evaluation of goal-oriented behavior (anterior portion) (Tunik et al. 2007) and the coordination of hand movements and visual targets (ventral portion) (la-Maggiore et al. 2004). The tool *object*-responsive regions reveal a functional gradient with more posterior activations of the left inferior parietal network when the aim is to functionally grasp the tool (Boronat et al. 2005), and more bilateral and anterior activation during mechanical grasp movements of the same familiar tools (Binkofski et al. 1998).

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Figure 1: Examples of the different movement tasks and target objects and their respective conditions.

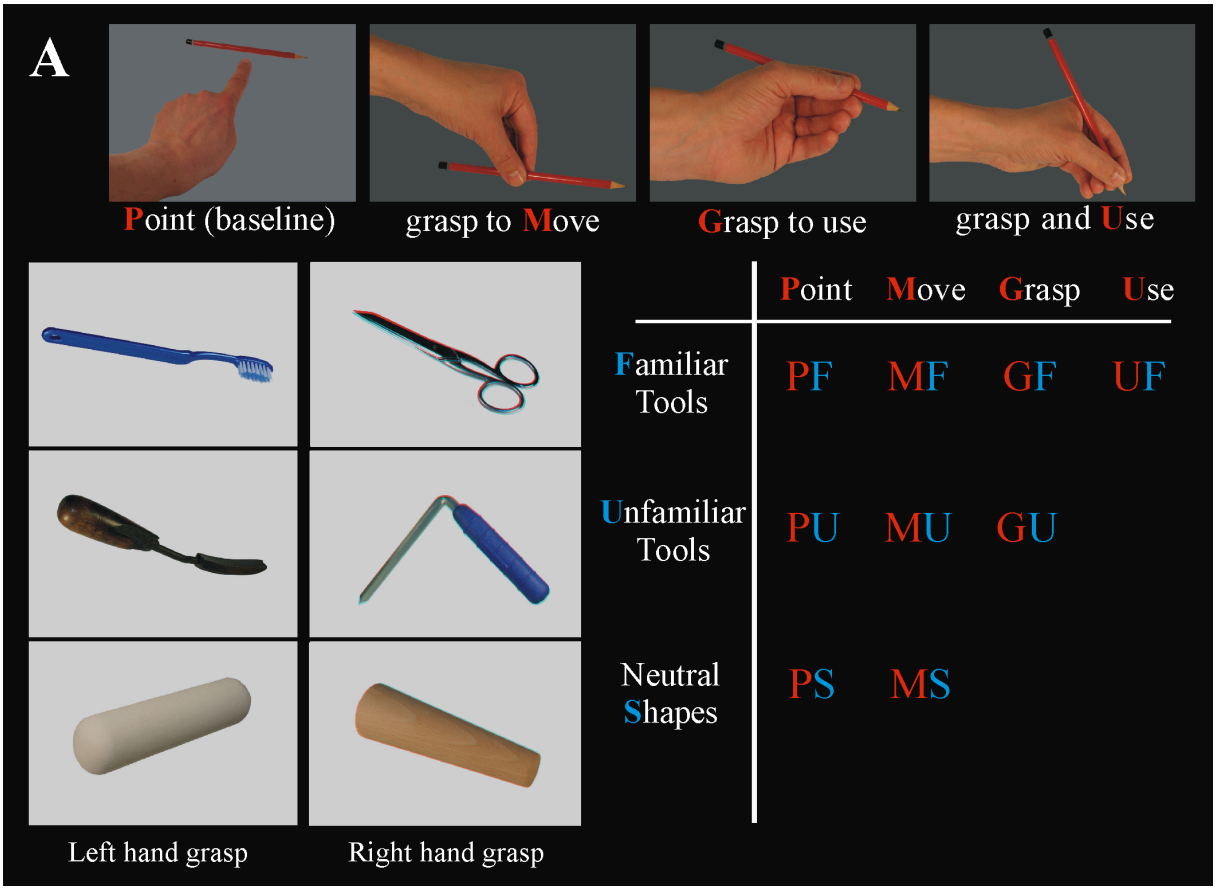

Figure 2: A. Activation maps of hypothesis-driven ROI-analyses (random effects) of using familiar tools versus moving familiar tools at alpha(FDR) < 0.05. Significant voxels are depicted over averaged horizontal slices of VMR data sets of the fifteen volunteers. Coronal slices over an individual brain show the same activation situated in the anterior (y = -30) and middle (y = -43) segment of the intraparietal sulcus (slices at peak activations). B. Cortical activation (random effects) during imagined use of familiar tools at p < 0.001, uncorrected, depicted over an inflated cortical mesh. C. Left inferior parietal lobule activation during imagined displacement of familiar > unfamiliar tools on the coronal slice of an individual brain (p < 0.001, uncorrected). D. Left inferior parietal lobule activation during imagined functional grasping of familiar > unfamiliar tools on the coronal slice of an individual brain (p < 0.001, uncorrected).