# Disentangling the neural bases of action intentions: evidence from fMRI studies

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## INTRODUCTION

The way we interact with manipulable objects varies substantially depending on the goal of the intended action.

Surprisingly, very little is known about the neural underpinnings of planning disparate actions and/or interactions taken with tools.

We tested whether or not the *praxis representation network* (PRN) of the left cerebral hemisphere is involved more in grasping-to-use actions regardless of the hand, action context, and/or its phase.

## METHODS

**Participants:** twenty healthy individuals (age range: 20-29, mean age = 24.7; 10 females), all right-handed (mean Edinburgh Handedness Inventory *Laterality Quotient* = 96.6), none had a history of neurological or psychiatric disorders. They voluntarily participated in block-design and event-related design experiments in which BOLD fMRI signal associated with planning of grasping tools (Exp. 1), or simulating tool-directed actions involving grasping (Exp. 2) with different intentions in mind was measured. All tasks were performed separately with the left or right hand.

**Stimuli:** high-resolution pictures of graspable tools presented at different orientations in their foreshortened views (see **Fig. 1,** cf. also **Fig. 2**).

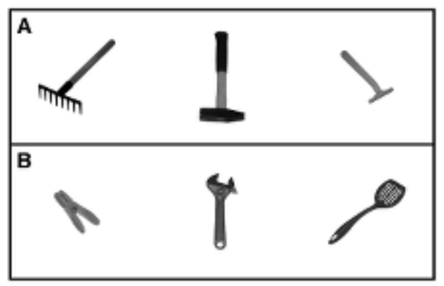


**Figure 1.** Examples of stimuli used in our event-related study. **(A)** Tools shown at 3 different orientations, i.e., 45, 0, or 315° in conditions: "Grasp to use", "Grasp to pass", and "Move". **(B)** Tools presented at another 3 different orientations, i.e., 135, 180, or 225°, in the control, "Grasp to use" condition.

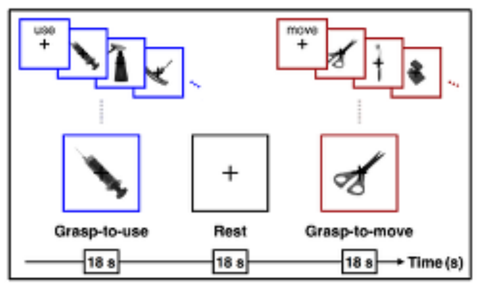


**Figure 2.** Trial structure, timing, and stimuli used in our control block-design study. There were 3 conditions with 6 (18s) blocks per run. Participants either simulated *grasping to use*, or *grasping to move* the depicted tools (n = 6; 3 s per stimulus), or performed no actions during rest periods.

**Design and protocol of the main study:** an optimized event-related design with standard neuroimaging parameters was used (Kroliczak & Frey, 2009). Participants performed four tasks with their dominant right or non-dominant left hands. They planned **(1)** grasping movements of tools with an intention *(i)* to functionally use them, or *(ii)* to pass them to a different person; **(2)** reaching movements directed at tools with an intention to move (or push) them with the backs of their hands, and subsequently **(3)** performed pantomimed execution of the planned actions. There were twelve (~6-min.) functional runs in this experiment, six for the right and six for the left hand, ran on two consecutive days. Trial structure and timing is shown in **Fig. 3**.

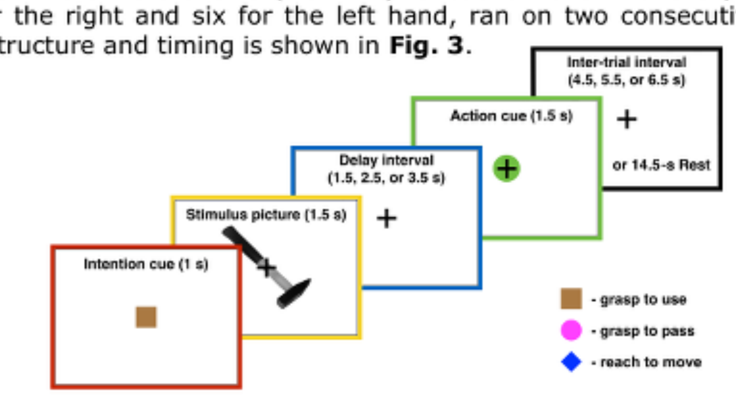


**Figure 3.** Trial structure and timing. The 1-s Intention cue was followed by a 1.5-s Stimulus picture, and a variable (1.5, 2.5, or 3.5 s) Delay interval for action planning. Next, a 1.5-s "Go" cue for the execution of the planned action was presented. ITIs were 4.5, 5.5, or 6.5 s. Additional Rest intervals were introduced pseudo-randomly and their duration was 14.5 s.

## IMAGING PARAMETERS

1) fMRI (BOLD) echoplanar images (T2*-weighted) aquired with a 16 channel head coil
2) 35 contiguous axial slices of 3.1 mm thickness (3.1-mm isotropic voxels)
3) Images sampled every 2 seconds (TR = 2000 ms)
4) Session duration (with all additional localizers, structural and resting state runs) lasted ~95 minutes.

All scanning was performed in the Rehasport Clinic (Poznan, Poland) on a 3-Tesla Siemens MAGNETOM Spectra MRI scanner (Siemens Healthcare, Erlangen, Germany).

## IMAGE ANALYSES

FSL v. 5.0.7 was used for data analyses. For a given participant, each fMRI run was modeled separately at the first level. Inter-session (Level 2) analyses used a fixed-effects model. Inter-subject (Level 3) random effects components of mixed-effects variance were modeled and estimated using FLAME Stage 1 ($Z > 2.3$, $p = 0.05$, corrected for cluster size).

## RESULTS

### Planning grasping-to-**pass** *vs.* grasping-to-**use** with the left hand

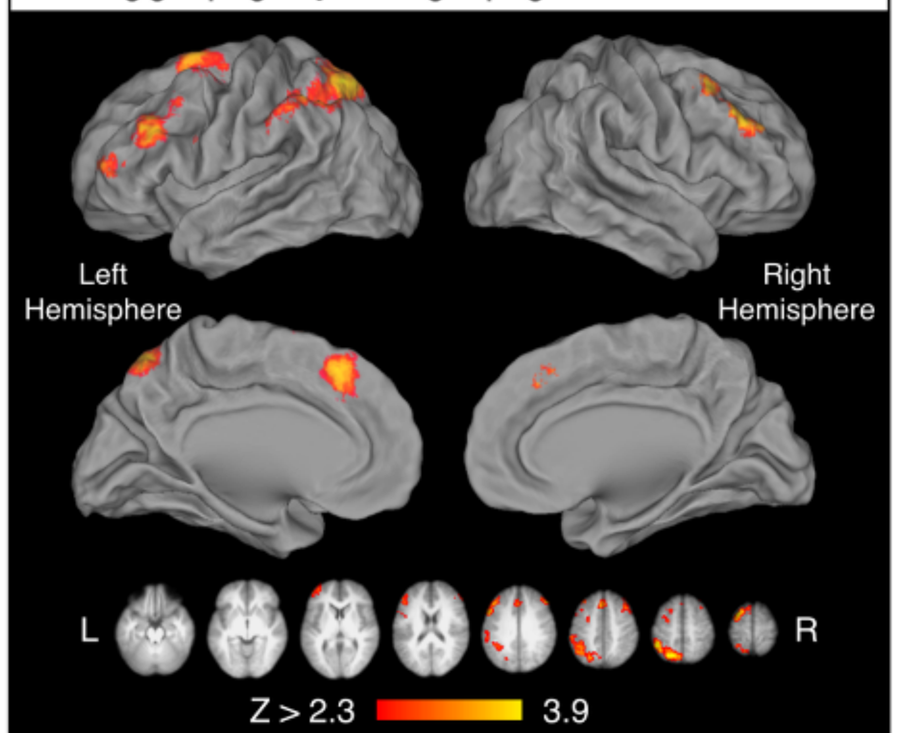


**Figure 4**. FMRI activity associated with planning to grasp a tool in order to pass it (vs. to use it) with the non-dominant, left hand: grip kinematics and hand rotations were matched.

### Planning grasping-to-**pass** *vs.* grasping-to-**use** independent of the hand

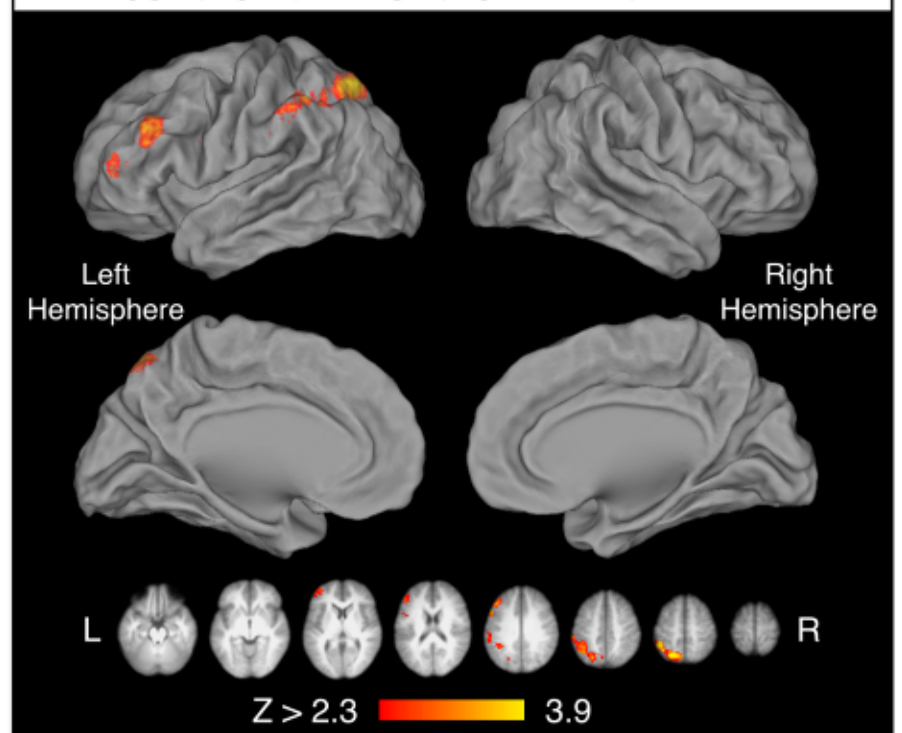


**Figure 5.** FMRI activity associated with planning to grasp a tool in order to pass it (vs. to use it) at the hand-independent level: grip kinematics and hand rotations were matched.

### Grasping to use *vs.* grasping to move (Exp. 2)

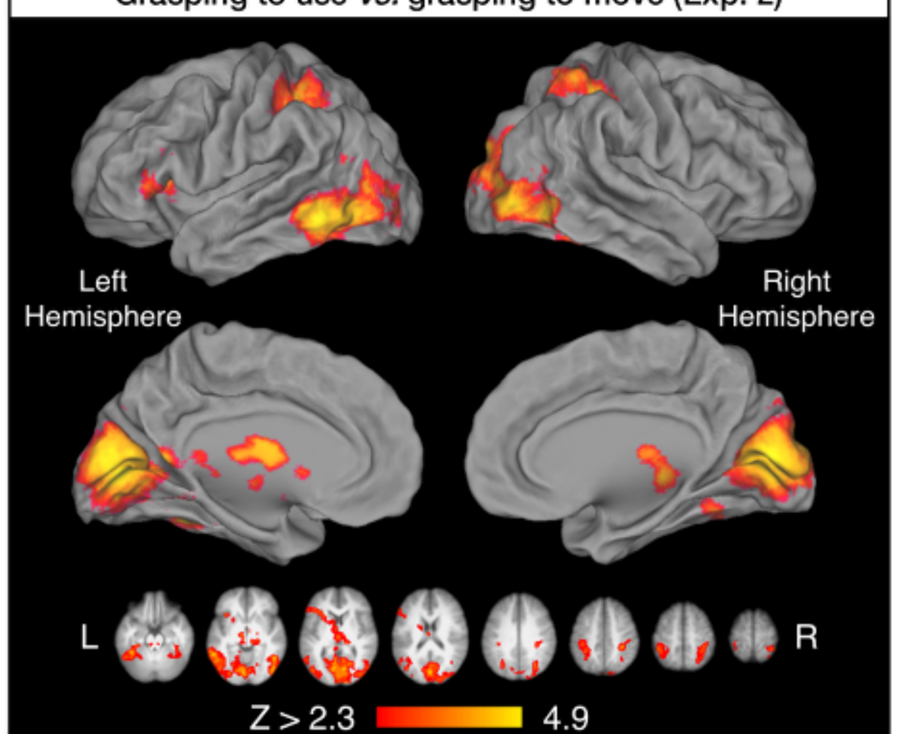


**Figure 6.** FMRI activity associated with with task of a grasping to use a tool (vs. grasping to move it) with both the dominant right and non-dominant left hand.

### Hand-Independent Praxis Representation Network (**PRN**)

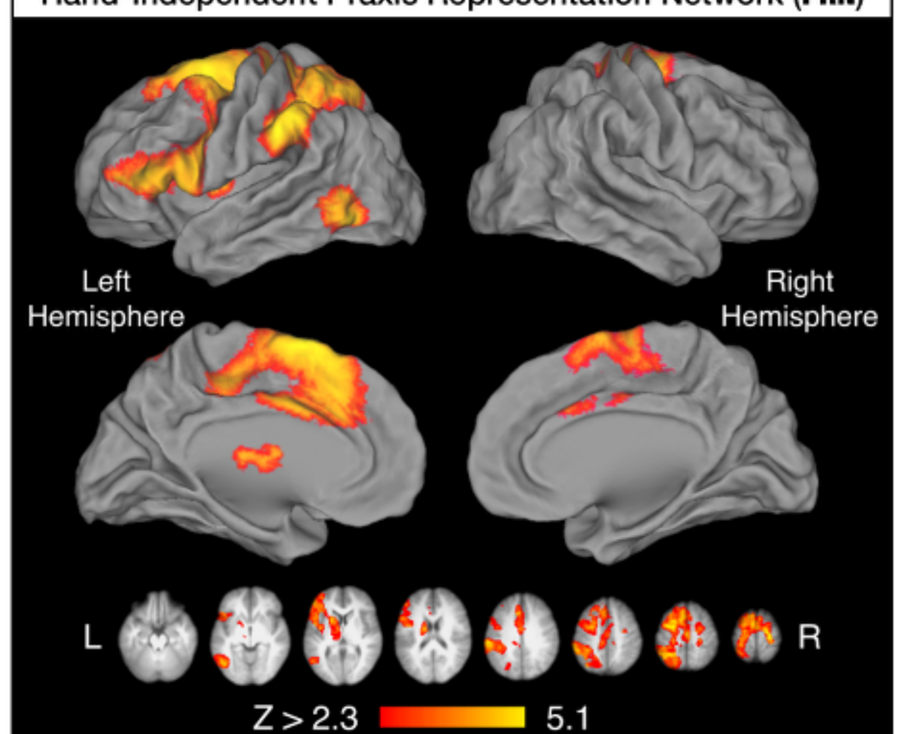


**Figure 7.** FMRI activity associated with pantomimed tool use vs. repetitive abstract hand movements matched for complexity; the activity is depicted at the hand-independent level.

## RESULT DESCRIPTION

**Figure 4** shows BOLD signal increases associated with planning *grasping to pass* (vs. *grasping to use*) a tool, with grasp kinematics and hand rotations accounted for (see also Figure 1 and Figure 3). There was significantly greater engagement of the left parieto-frontal network, with some involvement of the supramarginal gyrus (SMG, mainly its anterior division), ventral premotor cortex (PMv), and much greater bilateral activity, with a clear left-sided bias, observed in the middle frontal gyrus (MFG). Moreover, the superior parietal gyrus (SPG) and anterior divisions of the intraparietal sulcus (aIPS) were modulated only on the left.

**Figure 5** shows significant *hand-independent* BOLD signal increases associated with planning *grasping to pass* (vs. *grasping to use*) a tool, with grasp kinematics and hand rotations accounted for. The common clusters were found only in the left hemisphere, and were located in MFG, SMG, asIPS, and SPG.

**Figure 6** shows significant BOLD signal increases associated with *grasping to use* (vs. *grasping to move*) a tool, averaged across hands. In addition to greater involvement of visual areas, the posterior parts of the middle (MTG) and inferior temporal gyri (including caudal MTG), and SPG were invoked bilaterally, whereas the inferior frontal gyrus (pars triangularis) and anterior divisions of the insular cortex were engaged only on the left.

**Figure 7** depicts all the major areas of the left-lateralized praxis representation network (PRN) at the hand-independent level.

## DISCUSSION

Counter to the hypothesis that PRN would mediate primarily or would be involved more in grasp intentions related to using tools, we found convincing evidence that the crucial nodes of this network - the left supramarginal and middle frontal gyri - are engaged significantly more in preparation for actions that are not use related (cf. Króliczak & Frey, 2009; see also Canessa et al. 2008). This is the case both at the hand-dependent, and at hand-independent level of analyses.

PRN mediates a wide range of visually-guided manual tasks (e.g., Jacobs et al., 2010; Kroliczak et al., 2008; Kroliczak & Frey, 2009). While cMTG and aIPS seem to be activated for all possible actions, SMG, PMv, and MFG involvement is more action specific.

These findings shed a new light on how different goals and/or contexts influence the perception of object affordances, and to what extent they modulate the fMRI activity within the parieto-frontal action networks and beyond them.

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