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Perspective-Taking in Mental Imagery of the Actions of Others

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Abstract

Motor imagery involves simulating action using brain areas involved in performing that action. Right and left-handers typically perform actions using different sides of their body, and correspondingly, recruit different sides of the premotor cortex in motor imagery about their own actions. How do people perform mental imagery about the actions of others? If people take an egocentric perspective, then people should imagine performing the action as they themselves would, according to their own handedness. However, if people take an allocentric perspective, then people should imagine performing the action as a right-hander would, regardless of their own handedness, since others are mostly right-handed. We used functional magnetic resonance imaging to examine premotor activity in right- and left-handers imagining their own actions versus actions performed by others. Imagery induced by second-person action verb phrases preferentially activated the left premotor cortex in right-handers and the right premotor cortex in left-handers, while imagery induced by third-person action verb phrases preferentially activated the left premotor cortex in both right and left-handers. People imagine their own actions by simulating the action as they typically perform it themselves, but imagine the actions of others by simulating the action as others typically perform it. This finding suggests that language-induced motor imagery about the actions of others involves allocentric perspective-taking.

Keywords: motor imagery, perspective-taking, handedness, fMRI

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Perspective-Taking in Mental Imagery of the Actions of Others

Mental imagery, the mental simulation of things and events beyond the here and now, is a commonplace feature of our mental life. We often engage in mental imagery of scenes we read about in literature, happenings described in newspapers, the faces of past friends, alternate versions of the past, and events we hope or desire in the future. In particular, we often perform mental imagery about motor actions: either actions of our own, or actions of others. We imagine throwing our first pitch or writing in our diary tonight, and we imagine a friend picking up the phone or the president signing a bill.

How is it that we perform imagery about actions? Past research on mental imagery about action suggests that it involves generating an action plan (Decety et al., 1994). In addition, mental imagery of various actions (e.g. kicking, licking) is known to activate the motor cortex, which is involved in executing action (Buccino, 2001), as well as the premotor cortex, which is involved in planning action (Grèzes & Decety, 2001). Of particular interest is the fact that the activation of the motor cortex is somatotropic, meaning that imagery for each type of action (e.g. kicking, licking) activated the same areas of the motor cortex responsible for executing that action (e.g. leg-area, mouth-area) (Buccino, 2001). These results suggest that motor imagery involves covert motor execution and recruits motor areas.

If motor areas play a critical role in mental imagery of action, then people may perform mental imagery differently on the basis of different motor experiences (Casasanto, 2008, 2011). A systematic way in which motor experience differs across people is handedness. Right-handed people typically perform unimanual actions with their right hand, and left-handed people with their left hand. This difference in motor experience is reflected in different neural activation when performing mental imagery about actions: right-handed people show activation in left premotor cortex circuits that control the right hand, and left-handed people exhibit activation in right premotor areas controlling the left hand (Willems et al., 2009). These data show that the same motor systems used for performing actions are also used for motor imagery about oneself performing that same action.

However, it is not clear whether we always use an egocentric perspective in mental imagery. Willems et al. 2009 used verbs in the infinitive form (e.g. “to throw”) as stimuli for mental imagery, leaving the subject of the verb unspecified and thus open to a first-person interpretation (e.g. “I throw”). As the authors of Willems et al. 2009 recognize, their results may thus be specific to mental imagery about one’s own actions. The authors then pose the question that this study seeks to address: how we perform mental imagery when imagining the actions of others?

One hypothesis is that mental imagery for one’s own actions involves the same process as mental imagery for the actions of others. People imagine other people’s actions from an *egocentric perspective,* by simulating *how they themselves would perform the actions*. For an example, a right-handed person would imagine another person throwing as throwing with their right hand, and a left-handed person would imagine another person throwing as throwing with their left hand. On an alternative hypothesis, people imagine other people’s actions from an *allocentric perspective*, i.e. by simulating *how they typically see others perform the actions*. The vast majority of people in the world are right-handed, and in our perceptual experience, we typically see others perform actions using their right hand. As a result, a person, regardless of their own handedness, would imagine another person throwing as throwing with their right hand.

One study attempted to address the question of how we imagine the actions of others, egocentrically or allocentrically. Tomasino et al. (2007) used functional magnetic resonance (fMRI) imaging to study how right-handers imagined the actions described by first-person versus third-person motor action phrases (e.g. “I kick” vs “He kicks”). Tomasino et al. (2007) found that right-handers exhibited differential left primary motor cortex activation during mental imagery, and that such a pattern did not differ when right-handers were performing imagery induced by first-person motor action phrases or performing imagery induced by third-person motor action phrases. From this result, Tomasino et al. concluded that the primary motor cortex plays the same role in motor imagery, regardless of whether people are imagining their own actions or the actions of others. Tomasino et al. (2007) suggest that people use an egocentric perspective, by imagining an action as they would perform it themselves, regardless of whether they are imagining their own actions or the actions of others.

However, it is critical to note that the egocentric and allocentric hypotheses for how we imagine the actions of others make the same prediction for right-handed people, who have been the near-exclusive population for past neural studies on mental imagery. The egocentric hypothesis and the allocentric hypothesis both predict that right-handers will imagine the actions of others as right-handed actions. The egocentric hypothesis makes such a prediction because right-handers perform actions in a right-handed manner, and the allocentric hypothesis makes such a prediction because most people in the world are right-handed. As a result, the results from Tomasino et al. (2007) are compatible with either egocentric or allocentric hypotheses about how we imagine the actions of others. Right-handers are not the population that will allows us to differentiate between the two hypotheses. Previous research is thus inconclusive on how we imagine the actions of others.

To tease apart the egocentric and allocentric hypotheses, left-handed people are the critical population. The egocentric hypothesis predicts that left-handers will imagine the actions of others as left-handed actions, while the allocentric hypothesis predicts that left-handers will imagine the actions of others as right-handed actions. Running both right-handers and left-handers will enable us to distinguish the egocentric and allocentric hypothesis for mental imagery of the actions of others.

In this study, we used fMRI to measure neural activity in right- and left-handers who imagined unimanual and nonmanual actions. Participants saw short phrases describing an action on the screen, and then imagined the corresponding action. The phrases were either second-person verb phrases describing an action (e.g. “you throw”), or third-person verb phrases describing an action (“she throws”). When imagining their own actions, we predicted people to use an egocentric perspective in understanding the phrase. That is, when imagining actions described by second-person verb phrases, right-handers should recruit the left premotor cortex to simulate right-handed action, while left-handers should recruit the right premotor cortex to simulate left-handed action. However, when imagining the actions of others, as cued by the third-person verb phrases, people may use an allocentric perspective instead. That is, when imagining actions described by third-person verb phrases, right-handers and left-handers should both recruit the left premotor cortex to simulate right-handed action. Including both handedness and grammatical person as variables allows us to differentiate between egocentric and allocentric perspectives in mental imagery about the actions of others (Figure 1).

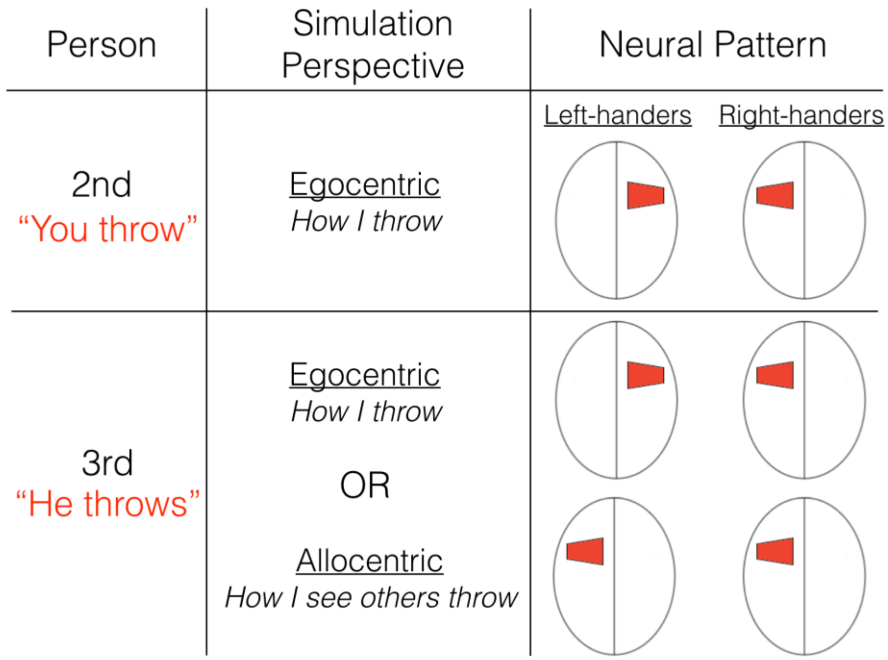


Figure 1. Egocentric versus allocentric perspectives for mental imagery about the actions of others. Red represents activation in premotor cortex. Note that left-handers in the third-person condition provide the critical contrast between egocentric and allocentric hypotheses.

Methods

Participants

39 healthy monolingual English-speaking adults living in the Chicago area were recruited. In an eligibility screening, participants were administered a verbal form of the Edinburgh Handedness Inventory (Oldfield, 1971). All participants were screened for MRI eligibility, were asked for their preferred pronouns, and provided informed consent.

6 participants were excluded (3 left-handed, 3 right-handed; 3 male, 3 female) as a result of failure to complete tasks within time constraints (n=2) or due to falling asleep (n=1), misinterpretation of task instructions (n=1), technician error (n=1), or eyetracker failure (n=1).

33 participants were included for data processing and analysis, of whom half were left-handed (n=16; 9 male, 7 female; EHI score M=-79.6, SD=16.6, range=-42.9 to -100, mode=-

100) and half right-handed (n=17; 5 male, 12 female; EHI score M=70.2, SD=18.0, range=40 to 100, mode=60).

Stimuli

Stimuli were 96 English verb phrases containing a subject and a verb (e.g. “she throws”). The subject was either a second person pronoun (i.e. “you throw”), which participants pragmatically interpret in the first-person with themselves as the subject (“I throw”) (Brunyé et al 2009), or a third person pronoun that was not the preferred pronoun used by the participant (e.g. “he throws” or “she throws”). The verb was either a unimanual action verb (e.g. “she throws”), or a nonmanual abstract verbs (e.g. “she thinks”). The set of unimanual and nonmanual verbs, matched for frequency and length, was drawn from Willems et al (2010).

The verb phrases were organized into 8 blocks of 12 verb phrases each. Each block had an equal number of grammatical person x verb type (i.e. 6 second person unimanual, 6 third person unimanual, 6 second person nonmanual, and 6 third person nonmanual). Individual words were randomly sampled from the entire set, without replacement.

Procedure

Participants performed two tasks, a lexical decision task and a mental imagery task, in a magnetic resonance imaging (MRI) scanner, as in Willems et al (2010). Stimuli were presented using PsychoPy and projected onto a screen visible from inside the scanner. Before the start of the experiment, participants practiced performing a lexical decision task of the following format on a computer with verb phrases that did not appear in the experiment.

In the first task of the experiment, participants performed a lexical decision task totaling 256 trials (192 target trials, 64 catch trials). On each trial, participants saw a white fixation cross on a black background for 500ms, then a stimulus verb phrase (e.g. “she throws”) for 1500ms.

To ensure that the participant attended to the phrases presented in the target trials, a quarter of all trials (64 trials) were catch trials that presented phonotactically legal nonwords as the pronoun or as the verb. In catch trials, stimulus presentation was followed by a question of whether the previous words were existing English words or not, with the two possible responses (‘yes’ and ‘no’) displayed below the question. Participants had 1500ms to respond by pressing their left or right index finger, whichever corresponded with the on-screen yes or no. The relative position of ‘yes’ and ‘no’ varied unpredictably from trial to trial, and each response label appeared equally often on the left and right side of the screen. Trials were organized into 8 runs; after each run, the participant was offered the opportunity to take a break.

In the second task of the experiment, participants performed an explicit visual imagery task with the same set of stimuli. On each trial, participants read the phrase, closed their eyes, vividly imagined the action that the phrase describes, and opened their eyes to trigger the next trial. Eye closing and opening was tracked by an Eyelink 1000 eyetracker mounted in the scanner. Trials were organized into 8 runs; after each run, the participant was offered the opportunity to take a break.

After the tasks, participants exited the scanner and performed a similarity judgment task on a computer. In the similarity judgment task, participants were given the list of unimanual action words used in the study, and were asked to place them into a circle such that similar words were closer together and dissimilar words far apart. Participants then repeated the similarity judgment task with the list of nonmanual action words used in the study. The order of the lists used for the two rounds of the similarity judgment task was counterbalanced.

Participants were then debriefed about the study, filled out a language history questionnaire, and were compensated in cash for their time.

Data Acquisition

During both tasks, echo-planar imaging (EPI) with z-shimming of the whole brain was conducted with a Philips Achieva 3T MRI scanner at the University of Chicago hospital. A repetition time (TR) of 2,060 ms, an echo time (TE) of 30 ms, and a 85° flip angle were used. Z-shimming was used to restore signal in the orbitofrontal cortex. 31 transversal slices were collected per volume, with a .5 mm inter-slice gap and a voxel size of 3.5 x 3.5 x 3 mm. Between the two tasks, structural images were collected.

Data Processing

Preprocessing was conduced with FSL and the Nipype-based tool FMRIPREP (Gorgolewski et al 2011). Preprocessing involved z-shim combination, skull-stripping, realignment, normalization to the Montreal Neurological Institute template, motion correction, coregistration, smoothing, and artifact detection.

Each T1-weighted (T1w) volume was corrected for intensity non-uniformity using N4BiasFieldCorrection v2.1.0 and skull-stripped using antsBrainExtraction.sh v2.1.0 (using the OASIS template) (Tustison et al 2010). The brain-extracted T1w volumes were spatially normalized to a brain-extracted version of ICBM 152 Nonlinear Asymmetrical template version 2009c using nonlinear registration with the antsRegistration tool of ANTs v2.1.0 (Fonov et al, 2009, Avants et al, 2008). The brain-extracted T1w volumes were segmented for cerebrospinal fluid, white-matter and gray-matter using fast (FSL v5.0.9) (Zhang et al, 2001).

Motion-correction was performed on functional data using mcflirt (FSL v5.0.9) (Jenkinson et al, 2002). The resulting data were then co-registered to the corresponding T1w using boundary-based registration with 9 degrees of freedom, using flirt (FSL) (Greve & Fischl, 2009). Motion correcting transformations, BOLD-to-T1w transformation, and T1w-to-template

(MNI) warp were concatenated and applied in a single step using antsApplyTransforms (ANTs v2.1.0) using Lanczos interpolation.

Physiological noise regressors were extracted applying CompCor (Behzadi et al, 2007). Principal components were estimated for the two CompCor variants: temporal (tCompCor) and anatomical (aCompCor). A mask to exclude signal with cortical origin was obtained by eroding the brain mask, ensuring it only contained subcortical structures. Six tCompCor components were then calculated including only the top 5% variable voxels within that subcortical mask. For aCompCor, six components were calculated within the intersection of the subcortical mask and the union of CSF and WM masks calculated in T1w space, after their projection to the native space of each functional run. Frame-wise displacement was calculated for each functional run using the implementation of Nipype (Power et al, 2013).

Many internal operations of FMRIPREP use Nilearn, principally within the BOLD-processing workflow (Abraham et al, 2014).

Smoothing was performed using a full width half-maximum smoothing kernel (fwhm) of 8mm. Artifact detection was performed by visual inspection: runs with slice order artifacts and runs with heavy ghosting were excluded.

Data Analysis

We followed the analysis procedure in Willems, Hagoort, & Casasanto 2010.

Analysis of the behavioral data from the imagery task involved calculating the duration of imagery for each trial, which was calculated as the time from stimulus onset to eye opening. Trials were dropped if an eye opening time was not recorded by the eyetracker.

Whole brain analysis involved a three-level approach. The first-level examined each run of each subject, creating a model with verb type (manual vs nonmanual) and person (second vs third) as regressors, with durations as the onset of the stimulus to the time that eyes were detected opening. The second-level collapsed across runs of each subject. The third-level was a group analysis across subjects of the same handedness, with subjects as a random factor. Contrasts of interest were manual verb > nonmanual verb, second person manual verb > second person nonmanual verb, and third person manual verb > third person nonmanual verb. Contrast values were uncorrected (without cluster thresholding) and thresholded at $z=2.3$ (corresponding to $p<0.1$, uncorrected).

Region of interest (ROI) analysis involved creating 4-mm spherical ROI around the maximally activated voxel (without thresholding) within each of left Brodmann’s area (BA) 6 and right BA6 in the manual verb > nonmanual verb contrast. ROI were cut off if they extended into the opposite hemisphere. z-values from each ROI were extracted for the second person manual verb > second person nonmanual verb contrast, and the third person manual verb > third person nonmanual verb contrast. We analyzed these z-values using a repeated measures ANOVA with the following factors: within-subjects ROI (left BA6 vs right BA6), within-subjects person (second vs third), and between-subjects handedness (left-handed vs right-handed).

Data Quality

A significant portion of our data was affected by severe corruption caused by scanner issues. Runs with visibly severe corruption (e.g. slice order artifacts, heavy ghosting) were excluded, leaving most subjects with incomplete runs. Consequently, we report in this paper solely on the results of the imagery task, where we anticipated signal would be strongest. There are plans to replace the dataset at a future time.

Results

Behavioral Results

Left-handers performed mental imagery for an average of 4.54 seconds, and right-handers for an average of 4.99 seconds. To rule out that differences in imagery between conditions could explain the effects of interest, we tested the three-way interaction between the contrasts of interest: handedness x verb type x grammatical person, which was not statistically significant ($\chi^2(1)=.07$, $p=0.80$).

Whole Brain Analysis

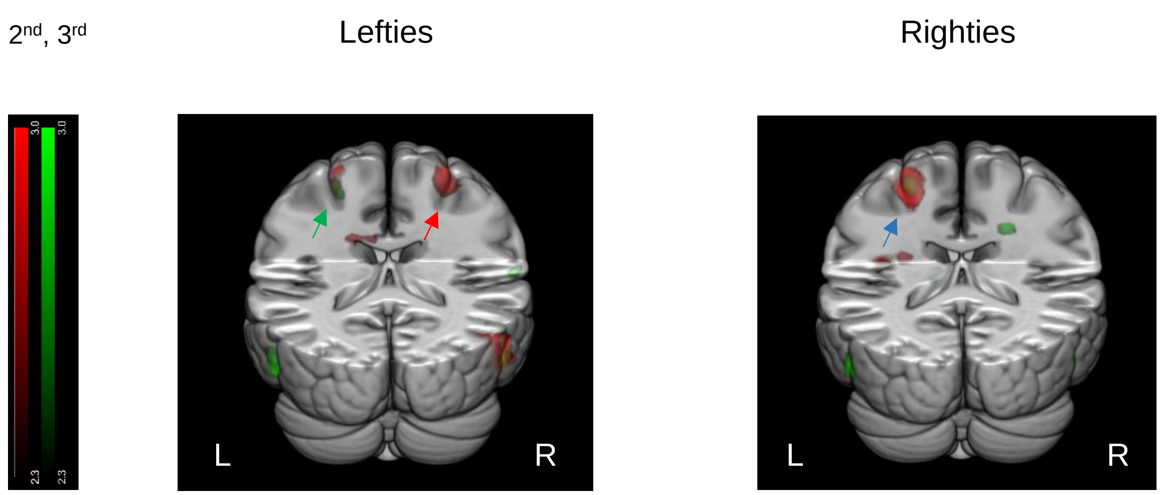


Figure 3. z-values for manual verbs > nonmanual verbs in the mental imagery task for left-handers versus right-handers, by grammatical person (second person in red, third person in green). Note that right-handers exhibit similar left-lateralized activity for both 2nd and 3rd person (blue arrow), while left-handers exhibit right-lateralized activity for 2nd person (red arrow) and left-lateralized for 3rd person (green arrow).

The data were first examined using whole brain analysis, as a preliminary exploratory approach. The full results from whole brain analysis are beyond the scope of this paper, so we only briefly summarize the results here. Right-handers exhibited unilateral activation of left BA6 when imagining the actions described by both second and third person manual verbs, versus nonmanual verbs. Such a result suggests that right-handers imagined performing actions in a right-handed manner, regardless of whether they were imagining their own actions, or the actions of others. In contrast to right-handers, left-handers exhibited more bilateral activation of left and right BA6 when imagining the actions described by second and third person manual verbs, versus nonmanual verbs. The possible difference for left-handers between second and third person manual verbs versus nonmanual verbs was targeted for more sensitive study using ROI analysis, as described below.

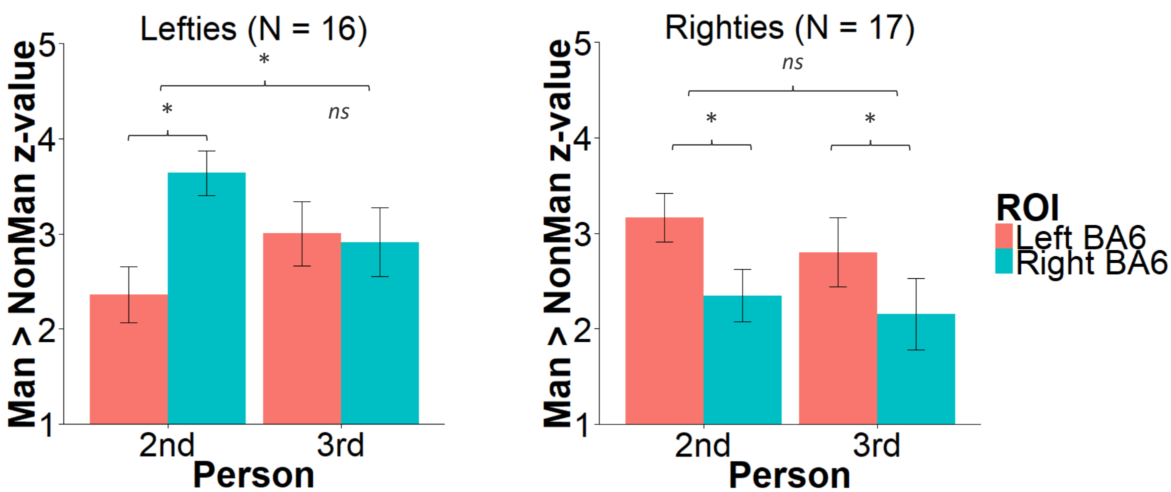
ROI Analysis

Depending on people's handedness, grammatical person affected BOLD responses to imagery of manual actions differentially in left and right BA6 (marginal three-way interaction of handedness x person x ROI ($F(1, 93)=2.98$, $p=0.09$)). Overall, there was also a significant interaction between handedness and ROI ($F(1, 93)=8.86$, $p=0.004$). There was no main effect of handedness, person, or ROI (all $p>0.3$).

We first examine the critical three-way interaction by breaking it down by handedness, that is, examining right-handers and left-handers separately (Figure 3).

Right-handers showed stronger BOLD activation in left BA6 than right BA6 for both 2nd and 3rd person manual verbs relative to nonmanual verbs (main effect of ROI, ($F(1, 48)=5.28$, $p=0.03$)). As predicted, grammatical person did not differentially affect this lateralization (statistically non-significant two-way interaction of person x ROI, $F(1, 48)=0.07$, $p=0.79$). That is, right-handers exhibited the same pattern of activation when imagining their own actions and when imagining the actions of others. This effect thereby replicates the findings from Tomasino et al., and are compatible with either egocentric or allocentric hypotheses.

In contrast, left-handers showed a different pattern. When imagining actions performed by themselves, left-handers showed a pattern consistent with egocentric simulation: stronger BOLD activation in right BA6 than left BA6 for second person manual verbs relative to third person nonmanual verbs (main effect of ROI within second person, F(1,15)=11.89, p=0.004). Yet, when imagining actions performed by others, this lateralization disappears: there is no statistically significant difference between right and left BA6 for third person manual verbs relative to third person nonmanual verbs (no main effect of ROI within third person, $F(1, 15)=0.27$, $p=0.87$). The difference in activation patterns between second and third person is supported by a statistically significant two-way interaction between person x ROI (F(1, 45)=4.86, $p=0.03$)). When imagining actions performed by themselves, left-handers imagine left-



handed action, but when imagining actions performed by others, left-handers imagine more right-handed action.

Figure 3. Contrast values from manual verbs > nonmanual verbs in the mental imagery task for left-handers versus right-handers as a function of grammatical person and ROI.

The critical three-way interaction can also be examined by breaking it down by person, that is, examining second person and third person separately. The second person trials reveal how people perform imagery about their own actions, which should use an egocentric perspective. The third person trials reveal how people perform imagery about the actions of others, for which the left-handed participants serve as our critical group to distinguish between egocentric and allocentric perspectives.

When imagining actions described by second person verbs, namely when imagining their own actions, left and right-handers performed mental imagery in a manner consistent with an egocentric body-centric perspective. Right-handers showed stronger left-lateralized BOLD response (main effect of ROI: $F(1, 16)=5.99$, $p=0.03$), while left-handers showed stronger right-lateralized BOLD responses (main effect of ROI: $F(1, 15)=11.89$, $p=0.004$). The difference between right and left-handers is statistically significant (two-way interaction of handedness x ROI: $F(1, 31)=17.73$, $p=0.0002$).

When imagining actions described by third person verbs, namely when imagining the actions of others, left and right-handers performed mental imagery similarly (non-significant two-way interaction of handedness x ROI within third person: $F(1, 31)=0.52$, $p=0.48$). This pattern is consistent with the use of an allocentric perspective, since people regardless of their own handedness imagine others performing actions in a right-handed manner.

Discussion

Mental imagery of the actions of others involves allocentric perspective-taking

This fMRI study tested whether we used an egocentric or allocentric perspective when imagining the actions of others. When imagining one's own actions, people imagine actions according to an egocentric perspective, as they themselves would perform the action. Right-handers imagined right-handed action (as indexed by stronger activation of the left premotor cortex), while left-handers imagined left-handed action (as indexed by stronger activation of the right premotor cortex) when imagining the action described by second person unimanual action verbs over second person nonmanual abstract verbs. In contrast, when imagining the actions of others, people imagine actions according to an allocentric perspective, as others (mostly right-handers) would perform the action. Both right and left-handers imagined right-handed action (stronger activation of the left premotor cortex) when imagining the action described by third person unimanual action verbs over third person nonmanual abstract verbs.

Our findings about how people perform mental imagery about their own actions is consistent with the body-specificity hypothesis proposed in Casasanto (2009) and first explored in the domain of mental imagery in Willems et al. (2009). Willems et al. (2009) suggest that motor imagery is influenced by the way people habitually perform motor actions with their particular bodies, such that people with different bodily experiences form different representations in motor imagery. In Willems et al. (2009), right-handers performing motor imagery exhibited left-lateralized activity in premotor cortex, while left-handers exhibited right-lateralized activity in premotor cortex. Given that Willems et al. (2009) used verbs in infinitive form, their participants likely interpreted the verbs as first-person, and performed mental imagery of their own actions. This study replicated their result concerning how people perform mental imagery of their own actions, and explicitly explored how people perform mental imagery of the actions of others.

The results from right-handed participants during mental imagery is consistent with the prior literature: right-handers imagine right-handed action, regardless of whether they are imagining their own action or someone else's action (Tomasino et al., 2007). While consistent with the prior literature, this result is ambiguous between the two target hypotheses about mental imagery of the actions of others. If people use an egocentric perspective in imagining the actions of others, right-handers should imagine others performing action as they themselves do, in this case, with the right-hand. If people use an allocentric perspective, right-handers should imagine others performing action as others are typically seen to do, namely also with the right-hand.

The results from left-handed participants that show the first evidence for an allocentric perspective, rather than an egocentric perspective, in mental imagery of the actions of others. When imagining others performing an action, we imagine others performing the action as we typically see others perform it, namely with the right-hand. This result suggests that mental imagery about the actions of others involves taking an allocentric perspective, by imagining the action as other people would typically perform it. Mental imagery thus relies on one’s own motor experience, as well as one’s perceptual experience of seeing others act. The former is recruited in mental imagery of one’s own actions, while the latter is recruited in mental imagery of the actions of others.

Could the scanner issues and additional introduction of noise into our data account for our findings? It is true that artifacts differentially affected the data from left-handers, our critical population. However, any kind of noise in our experimental paradigm, even noise that differentially affected the data from left-handers, would have made it less likely for us to find the critical three-way interaction that we did. In other words, the noise was a source of type II error, rather than type I error. Noise would have to not only differentially affect left-handers, but also differentially affect only left-handers across grammatical person, and across unimanual vs nonmanual verbs, in order to account for the critical three-way interaction we found. Noise would also have to affect each of those factors in the direction predicted by the allocentric hypothesis. It is thus unlikely that our results can be attributed to the additional noise in our data. Our results are interpretable as is, and the fact that they support the allocentric hypothesis for how we perform mental imagery about the actions of others still stands.

Mental imagery of the actions of others may be grounded in perceptual experience

Allocentric perspective-taking in mental imagery of the actions of others suggests that mental imagery of the actions of others is grounded one’s perceptual experience of seeing others act. The precise manner in which mental imagery of the actions is grounded in perceptual experience, as opposed to motor experience, is a ripe topic for further exploration. Past studies have shown that the premotor cortex is not only involved in planning motor action and forming action plans during mental imagery, but is also involved in perceiving differences between bodily actions (Urgesi et al., 2007). Future studies could explore whether short-term manipulation of our perceptual experience of seeing others act (e.g. short-term experience of seeing others perform actions left-handed) affects how we perform mental imagery about the actions of others (e.g. imagining actions performed left-handed). It may also be interesting to explore how we perform mental imagery about actions for which our personal motor experience and perceptual experience of others are strongly imbalanced. For an example, how do we imagine another person performing an action for which we have a wealth of personal motor experience, but perhaps scarce perceptual experience? Conversely, how do we imagine ourselves performing an action for which we have scarce personal motor experience, but a wealth of perceptual experience? Both are edge cases where it is plausible one might take a rich source of experience (e.g. one’s own motor experience) and translate such an experience into the imagery required (e.g. another’s motor experience), through an act of perspective-taking.

Such edge cases also raise the interesting question of how we imagine the actions of others who have radically different bodily experiences from us, beyond a mere difference in handedness. Human beings exhibit a remarkable diversity in their physical experiences and capacities. Bodily experience is a much broader concept than handedness, which is only one dimension of variation. How do we imagine the actions of other beings with experiences and capacities for physical action that differ greatly from our own?

Implications of language-induced mental imagery for language processing

Lastly, it is a matter of speculation whether these findings about mental imagery translate to language processing. Mental imagery and language processing are traditionally regarded as separable processes; language processing can occur without explicit mental imagery. Nevertheless, in this particular study, mental imagery was induced using verb phrases. It is possible that some of the patterns of neural activity we detected are the product of language processing, rather than mental imagery, or in tandem with mental imagery. Do people understand language about the actions of others by simulating performing that action as they typically see others perform that action? The inclusion of a lexical decision task in this study, along with the mental imagery task, was intended to address this question. However, the data from the lexical decision task are extremely noisy, thus leaving the question open. The use of an allocentric perspective in understanding language about the actions of others would suggest that our representations of action semantics not only involve one's body-specific motor experience, but one's perceptual experience of others. Such a suggestion would be consistent with the centrality of perceptual-motor experiences in the embodied cognition framework.

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