

Supplemental Data

S1

Aplasics Born without Hands Mirror the Goal of Hand Actions with Their Feet

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Supplemental Experimental Procedures

Subjects and General Procedures

Typically Developed Individuals

Sixteen healthy volunteers (14 right and two left handed; nine female and seven male; mean age 31 yr, ranging 25–45 yr; the same subjects used in [S1] and [S2]) with normal or corrected to normal vision were tested on two different days. On the first day of scanning, they viewed movies of robotic and human hand-object interactions contrasted with static controls (for space constraints, the data on the robot stimuli are presented in full details in a separate paper [S2]). On the second day, they executed mouth, hand, and feet actions in the scanner.

Aplasic Subjects

Aplasia is a defective development resulting in the absence of all or part of an organ or tissue. In our case, we searched for subjects born without hands and arms. We found only three subjects in the Netherlands showing this extremely rare form of limb aplasia, but one had to be excluded from the experiment because of chronic back pain that would have made scanning too painful. The remaining two subjects were invited to participate in the study. At the time of the experiment, they were aged 32 and 33 yr, respectively, and both held cognitively demanding jobs, were otherwise healthy, and had normal or corrected to normal vision. They performed daily motor tasks mainly by substituting their missing hands with their feet (with a predominance of the left foot) and their mouth. We tested them on two different sessions: observation of human hand-object interactions (the same movies showed during the first scanning day of the typically developed group, except for the robotic actions) and execution of mouth and feet actions in the scanner.

All subjects were informed about the content of the study on a session-by-session basis, remaining naive to the content of the tasks to follow. Subjects signed an informed consent. All experiments were approved by the Medical Ethical Commission (METc) of the University Medical Center Groningen (NL).

Movies

Movies were of two categories: (1) HandActions, a hand-object interaction on a table, with a hand entering to grasp and manipulate an object; and (2) HandStatic, a static-control stimulus, in which the arm of the agent was placed behind the same objects used in (1). Each stimulus category came in six variants, corresponding to six complex objects and appropriate actions: moving a tea bag out of a cup, grasping a small coffee cup from the handle, grasping a cocktail glass by the stem, placing the lid on a sugar box, taking a spoon full of soup from a bowl, and grasping and swirling a wine glass. Each example was presented in two variants: one with the right hand of the agent entering from the right and one with the right hand entering from the left.

TDs were additionally tested with the following stimuli: (1) Hand-Movement, for which the same hand used in HandAction entered the screen to rest on the table without engaging in any manipulation; and (2) Robotic Movies, for which the human agent was replaced by an industrial robot for the categories HandAction, HandMovement, and HandStatic [S2]. Given the nonbiological kinematics of the robotic agent, these stimuli enabled the quantification of the impact of differences in the way actions or movement are performed on the response of the MS.

Movies were recorded with a digital video camera, elaborated with AdobePremiere (www.adobe.com), presented with Presentation (www.neuro-bs.com), and projected with an LCD projector on a semiopaque screen placed at the head end of the bore and seen through a mirror placed on the head coil. The duration of the action

movies ranged from 2.5–4 s, and the static controls were presented for a matched duration.

Visual Experimental Design

All conditions were presented in a block design, with four exemplars of each condition picked out pseudorandomly to form 13.5 s blocks containing four different actions or four different static images, separated by 200 ms intervals of blank screen (Figure 1A). The order of blocks was pseudorandom, and consecutive blocks were separated by a 10 s pause of blank screen with a fixation cross. The experiment was split in two runs with a total of 12 repetitions per condition. Half of the blocks depicted only hands entering from the right of the screen, and half of the blocks depicted only hands entering from the left of the screen. Subjects were instructed to watch the movies carefully and pay particular attention to the relationship between the hands and the objects. These data were acquired prior to the action execution to avoid biasing the observation of the actions toward the motor system.

Motor Task

Three different tasks (1–3) were performed with the typically developed individuals in three different sessions (previously described in [S1, S2]), whereas only two of them (2 and 3) were used with the aplasic subjects. Sessions were acquired in counterbalanced order.

(1) HandExecution for Typically Developed Group Only

Subjects performed a single run of motor testing. Before scanning, the subject was shown the T shaped table that would be placed on his/her lap during scanning. The table contained four objects. The two lateral branches of the T contained a high-stemmed plastic glass. The intersection of the T contained a plastic bowl with a plastic spoon. The bottom of the T contained a plastic cup with a handle. Subjects were then trained on their task. The task sequence was as follows: At the commencement of each trial, subjects viewed a diagram of the table on the screen, with a pink rectangle at the left or right to indicate what hand to use and a red cross in one of the four object locations indicated which objects they had to act upon. When the red cross turned to green, subjects had to perform the action compatible with the object. For the glass, they had to reach for the glass, grasp it, bring it toward their mouth, but stop before reaching the mouth, and then replace it in its original location. For the cup of coffee, they had to do the same action, but grasping the cup by the handle. For the bowl, they had to perform the same action as above but with the spoon, as if drinking soup with a spoon. Subject were then placed in the scanner, with their heads and lower arms firmly strapped onto the scanner bed to avoid actions that would lead to significant head motion (in all subject within session head motion remained lower than 1 mm of translation and 3° of rotation). We ensured that subjects were unable to see their own actions, and they were then trained to perform the actions blindly. The timing of the actions was rehearsed to last approximately 5 s, but an experimenter within the scanner room documented the beginning and end of each action by using a button box to determine the actual duration of the action, and this duration was then used to define the design matrix for data analysis.

Within a single scanning session of 500 s, subjects performed 18 ~5 s actions with their right hand and 18 with their left. Their arms never crossed the table (i.e., right hand only grasped the right glass, and left hand only grasped the left glass), and the 18 actions were composed of six actions involving each of the three objects. Conditions were fully randomized with 13 ± 2 s lapsing between the onset of two conditions.

(2) MouthExecution for All Subjects

Subjects had to manipulate a small object hanging from a wooden rod by only moving their lips. The appearance of a central green

cross indicated the beginning of the action, whereas its disappearing indicated the end. The experimenter lowered the rod on the basis of acoustical instructions matched in time with the appearance of the green cross. Each single manipulation lasted for 4 s and was repeated 16 times.

(3) FeetExecution for All Subjects

Subjects had to manipulate a pencil or a spoon by using their first and second toe. Again, the appearance of a green cross indicated the beginning of the action, and its disappearing indicated the end. The position of the cross relative to the side of the screen (left or right) indicated the foot to be used. The experimenter received acoustical instructions with the side and the object to use. Each manipulation lasted 4 s and was repeated 16 times for each foot (eight times with the pencil and eight with the spoon for the right side, and eight times with the pencil and eight with the spoon for the left side).

FMRI

Scanning was performed with a Philips Intera 3T Quaser, a synergy SENSE head coil, 30 mT/m gradients and a standard single shot EPI with TE = 30 ms, TA = TR = 2 s, 39 axial slices of 3 mm thickness, with no slice gap and a 3 × 3 mm in plane resolution acquired to cover the entire brain and cerebellum.

General Data Processing

Data were preprocessed with SPM2 (www.fil.ion.ucl.ac.uk/spm). EPI images from all sessions were slice time corrected and aligned to the first volume of the first session of scanning. High-quality T1 images were coregistered to the mean EPI image and segmented. The coregistered gray-matter segment was normalized onto the gray-matter template, and the resulting normalization parameters were applied to all EPI images. Smoothing with 6 × 6 × 6 mm FWHM was applied to all normalized EPI images. Data were then analyzed by application of a general linear model separately for each individual, either to each voxel separately, with SPM, or to the mean signal of the voxels contained in a region of interest (ROI), with MarsBar (<http://marsbar.sourceforge.net>). The contrast values obtained for each subject were then analyzed at the second level with t tests to implement a random-effect analysis. All conditions were modeled with boxcar function convolved with the hemodynamic response function (hdr). Observation sessions were modeled with two predictors for the aplanic individuals (HandAction and HandStatic) and four for the TDs (HandAction, HandStatic, RobotAction, and RobotStatic). Execution sessions were modeled with a single predictor for MouthExecution and two predictors (left and right) each for HandExecution and FeetExecution.

Statistical Thresholding

All results will be reported with a threshold of $p < 0.001$ at the voxel level, corrected at $p < 0.05$ for the entire brain with false discovery rate (FDR). Only clusters composed of at least ten contiguous voxels are reported. When masking an image with another or applying logical “and”s between images, we applied the voxel level threshold separately to all images and applied the FDR correction and minimum voxel-size requirement after the operation.

Analyses of Motor Data

Inspection of the realignment parameters revealed that head motion within the motor run was below one voxel and below 3° of rotation in all subjects. Data were analyzed both with and without taking the six motion parameters (x,y, and z translation; and rotations around the three axes) into account as covariates. There were only minimal differences between the two models, and we only report the analyses with motion covariates here.

(1) HandExecution

Data were analyzed with a general linear model with two experimental conditions (actions performed with the right and action performed with the left hand), modeled as a boxcar function convolved with the hdr. For each subject, this resulted in separate parameter estimates for actions of the right and left hand, and these estimates were then averaged (i.e., weight of 0.5 in the contrasts definition) together to provide a single estimate of the brain activity during hand actions and carried to the second level of analyses.

(2) MouthExecution

Data were analyzed with a general linear model with a single experimental condition, modeled as a boxcar function convolved with the hdr.

(3) FeetExecution

Data were analyzed as described in (1).

Analysis of Visual Stimuli and Mirror Areas

Data from each scanning session of the movies were analyzed with a general linear model with a separate predictor for the left and right versions of each stimulus category convolved with the hemodynamic response function. Parameter estimates for the right and left versions of each category over all runs were then averaged to provide a single estimate of the brain activity for each stimulus category. Brain activity to the vision of the actions was contrasted against the static-control stimulus.

Voxel-Wise between Group Comparison

For comparing aplanic and TDs, for each voxel of the normalized brain separately, the HandAction-HandStatic contrast values were entered in two-sample (unmatched) t test that compares the 16 TDs to the two aplanic individuals using SPM at the second level of analysis (random-effect analysis). This analysis, as implemented in SPM, uses the general linear model instead of a classic two-sample t test. This approach calculates a t statistics based on the comparison of the difference between the means of the two groups (i.e., HandAction-HandStatic APL versus HandAction-HandStatic TDs) with the residual error. This residual error reflects how much any subject deviates from the mean of his/her group and therefore pools the variance of the aplanic group and the TD group. This approach remains valid for unequal sample sizes in the two groups. Because it does not estimate the variance of the two groups separately, it remains valid even if one of the group contains a single subject (see [S3] and Karl Friston, SPM Mailing List, <http://www.jiscmail.ac.uk/cgi-bin/webadmin?A2=ind0704&L=spm&O=D&F=&S=&X=740FB861DA7A6B8242&Y=c.keyser%40med.rug.nl&p=23636>). Results of this test were first thresholded at $p < 0.005$ uncorrected in each voxel and then corrected with false discovery rate (FDR) correction at $p_{\text{FDR}} < 0.05$ to correct for the increase in false positive when repeating this test for all the voxels in the brain. Given that no significant differences were observed, we repeated this analysis without any uncorrected threshold and only a very liberal threshold of $p < 0.5$ FDR corrected, to examine for the presence of smaller differences between the groups, but still no significant differences were observed.

Mirror Regions

For defining putative mirror regions, the results of the contrast HandAction-HandStatic were inclusively masked with results from motor execution as detailed in the text. To be considered putatively “mirror,” a voxel thus had to show a significant response during action observation and action execution. The visual contrast had to survive a threshold of $p < 0.001$ uncorrected, and the motor contrast had to survive the same threshold. FDR correction at $p < 0.05$ was then applied to the result of the inclusive masking. This analysis was performed at the level of the single subject with fixed-effect analyses, and at the level of the group for the 16 TDs by entering their contrast values into a one-tailed, one-sample t test to implement a random effect analysis.

ROI Analysis

To avoid the problem of multiple comparison and increase the sensitivity of the between-group comparison, we defined three regions of interest in the group of typically developed individuals. These regions were obtained at the second level in the TDs with the contrast HandAction-HandStatic at $p < 0.001$ inclusively masked with HandExecution at $p < 0.001$, FDR corrected at $p < 0.05$. The four clusters attributed to the premotor cortex (right ventral, right dorsal, left ventral, and left dorsal premotor cortex) were combined into a single ROI. The two main clusters in the parietal cortex (left and right) were combined into a single ROI, and the right and left mid-temporal clusters were combined into the third ROI. For each of these ROIs, the BOLD signal of all the voxels within the ROI were averaged for each acquired volume and analyzed with Marsbar

with the same GLM used for the voxel-wise analysis. The contrast values were then compared with nonparametric measures (quartiles) and the Mann-Whitney U test with the program Statistica (StatSoft, Tulsa, OK) on the basis of the procedure of Dinneen and Blakesley [S4]. The Mann-Whitney U test is a nonparametric test examining the rank order of the data and is a powerful test to examine data from small groups, on the basis of the idea that if the TDs and Aplasic individuals do not differ from each other, there should be similar numbers of TDs with contrast values larger than those of the aplasics than TDs with values smaller than the Aplasic.

Anatomical Descriptions

Anatomical descriptions are based on the probabilistic cytoarchitectonic maps of the brain mapping group in Juelich, Germany (http://www.fz-juelich.de/ime/ime_brain_mapping) as implemented in the SPM anatomy toolbox (http://www.fz-juelich.de/ime/spm_anatomy_toolbox). This approach is based on probabilistic cytoarchitectonic maps of various brain areas. At present, such maps do not exist for all brain areas, and outside of the identified areas, locations are described anatomically (e.g., “precentral gyrus”). This means that a reference to precentral gyrus means that the activation was in a sector of the precentral gyrus that did not fall within any of the cytoarchitectonically identified areas (e.g., BA6).

Motor Decomposition and Characterization of Visual Activations

In order to characterize the motor nature of the neural representations activated by the sight of actions, we decomposed the visually activated clusters in subclusters with particular motor properties.

Decomposition of Visual Activations in Aplasic Individuals

We inclusively masked the HandAction-HandStatic contrast with the results of the individual's own motor (mouth/feet) execution. Figure S2A shows, on the first row, visually responsive voxels (HandAction-HandStatic, $p_{unc} < 0.001$) that show effector preference for the feet in yellow (FeetExe-Rest, $p_{unc} < 0.001$; and FeetExe-MouthExe, $p_{unc} < 0.001$) and for the mouth in red (MouthExe-Rest, $p_{unc} < 0.001$; and MouthExe-FeetExe, $p_{unc} < 0.001$). On the second row, Figure S2A shows those that respond significantly and similarly during execution of actions with both effectors in green (FeetExe-Rest, $p_{unc} < 0.001$; and MouthExe-Rest, $p_{unc} < 0.001$; and FeetExe-MouthExe, $p_{unc} > 0.001$; and MouthExe-FeetExe, $p_{unc} > 0.001$). The vast majority (APL1 80% and for APL2 70%; Table S4) of the visual activations fell in regions common to both effectors (green area), suggesting the importance of effector-independent motor programs in the processing of the sight of hand actions in these subjects.

According to the idea of a genetic blueprint [S5, S6], one might expect the vision of hand actions to activate regions that in the group of typically developed individuals are selectively involved in HandExecution. To examine this possibility, we used the data from the TD's motor execution (HandExe-Rest, $p_{unc} < 0.001$; HandExe-FeetExe, $p_{unc} < 0.001$; and HandExe-MouthExe, $p_{unc} < 0.001$) to mask the visual contrast HandAction-HandStatic, with the visual activation determined at the single-subject level as above but with motor-execution properties defined at the group level, with the random-effect analysis of the TDs. Figure S2C illustrates the fact that areas that are hand selective in TDs were indeed visually activated in the aplasic individuals. What motor function do these blue areas have in the aplasic subjects that never had an arm? To examine this question, we first compared the location of the blue areas with that of the yellow, red, and green areas of the first two rows of Figure S2A. For both aplasic subjects, a substantial part of the blue area fell within the green areas common to mouth and foot execution (50% for APL1 and 81% for APL2). For APL2, the remainder of the blue area fell mainly in the foot-selective area (14%) with only a negligible part (5%) falling outside of the areas of Figure S2A. For APL1, the other 50% of the blue area fell outside of the regions of Figure S2A. Extraction of the mean signal in these remaining 50% revealed the following: significant responses during FeetExe ($p_{unc} < 0.002$), marginally above our voxel-wise threshold; no significant response during MouthExe ($p_{unc} > 0.6$); and significantly larger activation during FeetExe compared to MouthExe ($p_{unc} < 0.05$). In conclusion, the motorically hand-selective mirror representation of

TDs is replaced, in aplasic individuals, by a combination of effector independent and foot-selective areas. The latter is in line with the fact that they tend to perform traditional hand actions mainly with their feet. This suggests some form of motor plasticity [S5, S6]: Depending on the availability or not of a hand, these patches of cortex specialize in hand execution and remain effector independent or remain feet selective, respectively.

Decomposition of Visual Activations in Typically Developed Individuals

For comparison, the visually active voxels in the group of typically developed individuals were also split into (1) voxels showing effector preference during execution and (2) voxels responding similarly during execution with all effectors (Figure S2B). As shown from the Table S4, for aplasics, areas common to all effectors play an important role in the mirror responses. The second most important contribution stems from areas dedicated to the effector (hand) that TDs would use to perform the observed actions.

In an additional experiment [S1], we compared visual activations in these same subjects while viewing robotic and human hand actions. There was no difference (all $p_{unc} > 0.05$) in the mean BOLD response in the motorically-hand-selective regions of Figure S2B between the vision of robotic and human actions, suggesting that this area does not reflect a strictly congruent mapping of hand observation on hand execution, but rather the broadly congruent mapping of an observed action (be it robotic or human) on the effector most likely to be used by the observer to perform a similar action (hand).

Conclusions

Together, this data suggest that, for both aplasic and TD participants, there are two main contributions to the mirror responses to the observation of manipulative hand actions. The first contribution stems from regions common to all tested effectors. The second stems from the region devoted to the effector that the observer would use to perform the observed action: the hand for TDs and the foot or mouth for aplasics.

Technical Notes

By using this approach, in the interest of simplicity, we do not visualize voxels that have intermediate motor responses, e.g., responding during execution of all effectors but with hand > mouth but mouth = feet. All thresholds were applied either at the single-subject level (APL1 or APL2) or second level (TDs).

The same threshold used in the main paper was used throughout (i.e., 0.001 uncorrected applied to all elements of a masking or logical operation; this was followed by FDR correction at 0.05 and an extent threshold of ten voxels per cluster).

Supplemental References

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- S6. Melzack, R. (1990). Phantom limbs and the concept of a neuro-matrix. *Trends Neurosci.* 13, 88–92.

HandAction-HandStatic

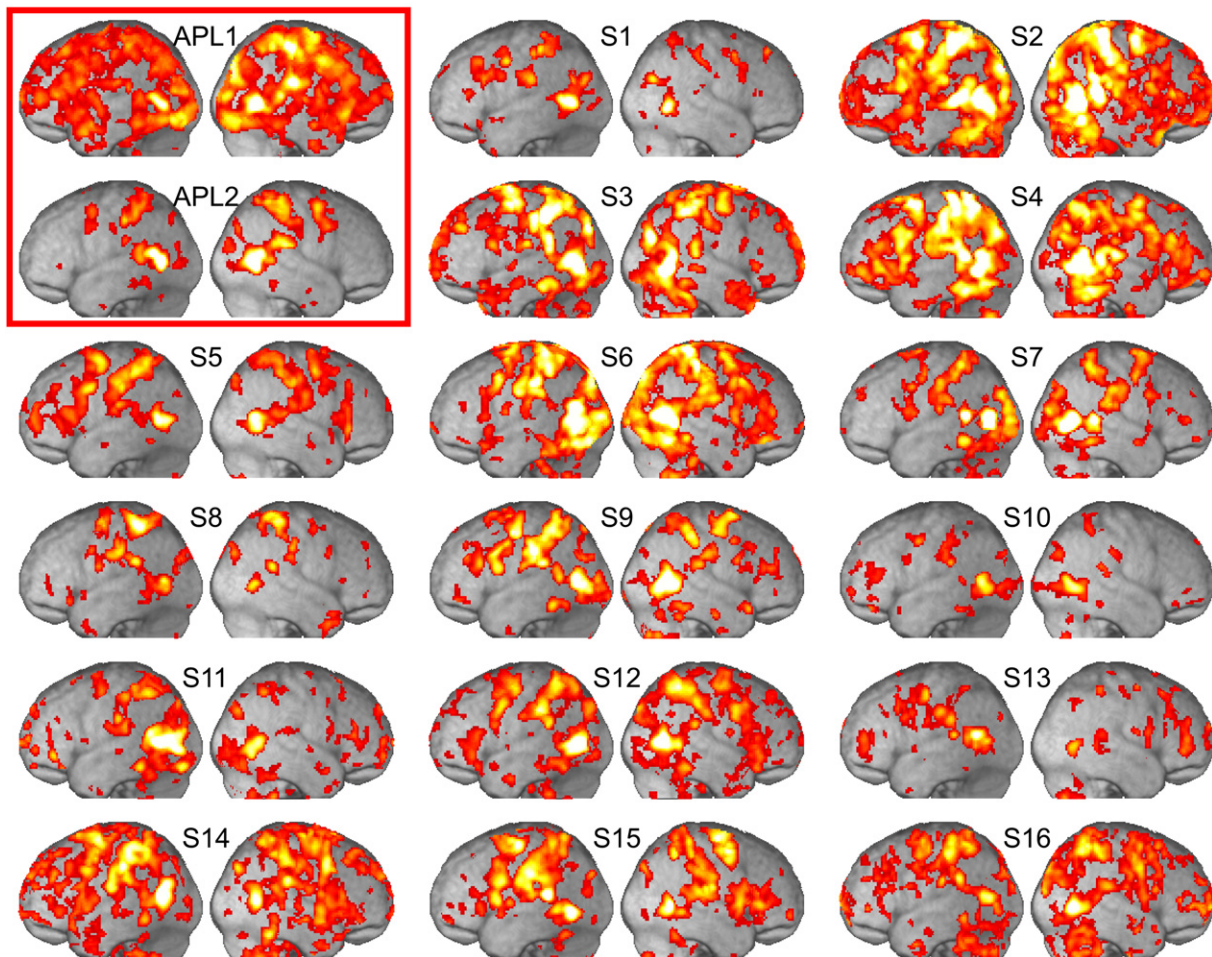
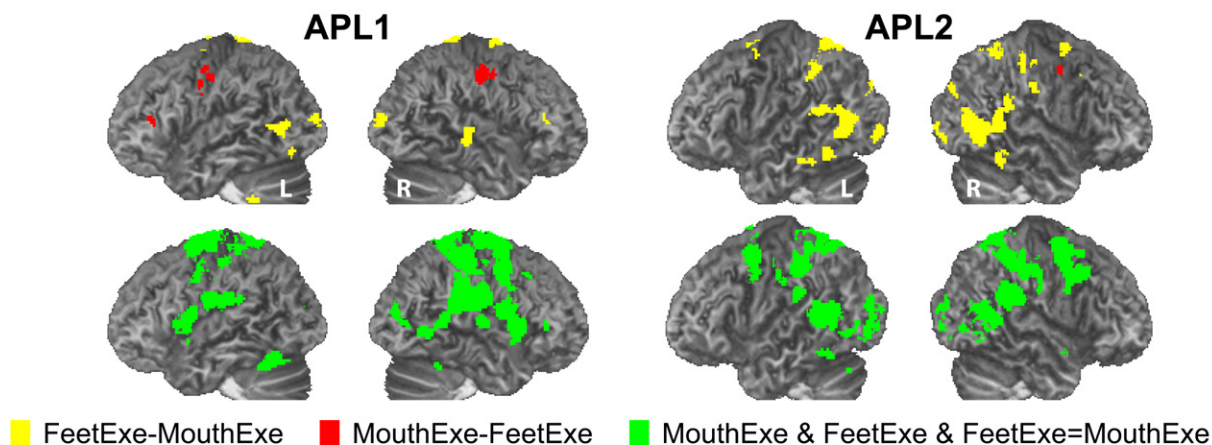


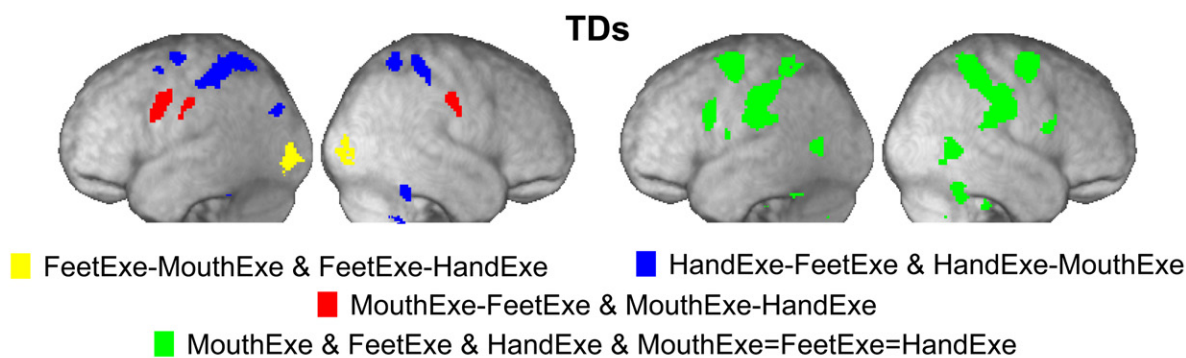
Figure S1. Subject-by-Subject Activations in the MNS

Activation during action observation defined subject by subject (HandAction-HandStatic; $p_{unc} < 0.001$, minimum of ten contiguous voxels). "S1"–"S16" represent the TD individuals, and APL1 and APL2 represent the two aplasic subjects. All activations are rendered on the average T1 weighted anatomy of all 18 subjects to facilitate comparison.

A HandAction obs. incl. masked with Aphasics's execution



B HandAction obs. incl. masked with TDs' execution



C APL's HandAction obs. incl. masked with TDs' HandExecution

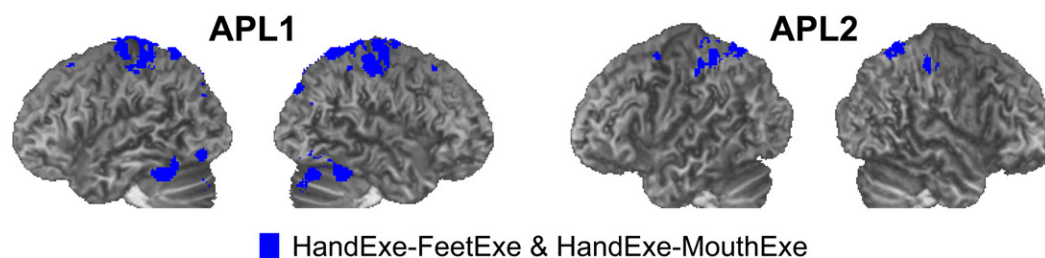


Figure S2. Motor Decomposition of Visual activations

Results of masking the visual contrasts HandAction-HandStatic inclusively with results of the motor execution of the aphasic individuals (A) or the TDs (B and C) as defined in the color legend below each panel. See Supplemental Experimental Procedures section "Motor Decomposition and Characterization of Visual Activations" for further details. Results are shown on the aphasic individuals' normalized anatomy (A and C) and on the averaged T1 of only the 16 TDs (B) in order to provide a realistic illustration of the aphasic subjects' brains. Equal signs stand for "no significant difference" at 0.001.

Table S1. HandAction-HandStatic

Hem.	Anatomical Description	k	p _{cor}	T	MNI (x, y, z)
Aplasic Subject 1					
R	Fusiform/Cerebellum/ITG/MTG/IOG/MOG/Hippocampus/ Amygdala/Putamen/TemporalPole/Insula/SII/SI/M1/BA6/ IPL/SPL/MCC/PCC/SFG/MFG/Cuneus/Precuneus/SMG	62246	0	16.49	44, -60, 2
R	MFG	190	0	6.35	36, 22, 60
L	IFG	124	0	4.82	-30, 34, -14
R	MCC	71	0	3.86	4, 18, 40
L	MTS	55	0	3.95	-50, -10, -14
L	ITG	46	0	4.1	-34, 6, -42
L	Superior Orbital Gyrus	39	0	4.26	-18, 26, -12
R	Midorbital Gyrus	35	0	4.02	2, 62, -6
R/L	Rectal Gyrus	34	0	3.87	0, 44, -20
R	ACC	32	0	3.8	4, 46, 6
L	ITG	31	0	4.26	-40, -10, -36
L	Hippocampus	31	0	4.21	-18, -6, -28
R	TE	24	0	3.96	58, -6, -2
L	MTG	21	0	3.79	-62, -10, -8
Aplasic Subject 2					
R	MTG/MOG/STG/IPL(supramarginal)	2314	0	17.44	44, -64, 4
R	SI/SPL/Precuneus/IPL	1821	0	8.39	44, -38, 62
L	MTG/STG/iPL(supramarginal)	1425	0	17.31	-46, -66, 6
L	SI/SPL/IPL	1256	0	7.92	-38, -30, 46
R	MFG/SFG/Precentral/BA6	825	0	7.95	34, -2, 58
L	MFG/SFG/Precentral/BA6	556	0	5.94	-24, 2, 54
L	MOG/BA17-18	241	0	4.78	-12, -78, -2
L	ITS/Fusiform	193	0	4.42	-44, -50, -16
R	SOG/BA17-18/Cuneus	156	0	5.13	22, -86, 16
R	SOG/Cuneus	146	0	5.83	20, -80, 38
R	BA6/MCC	137	0	5.51	10, -18, 50
R	Fusiform Gyrus	83	0	4.83	38, -44, -16
L	Supramarginal Gyrus	80	0	5.34	-46, -32, 26
R	Amygdala	73	0.001	4.11	24, -2, -16
L	IPL/SI	56	0.001	4.2	-56, -18, 38
L	BA6 mesial	45	0	4.31	-28, -78, 46
L	SPL/IPL	45	0.001	4.27	-12, -16, 48
R	BA17/18	38	0.002	3.86	18, -86, 2
L	Amygdala	34	0.003	3.81	-24, -8, -20
R	SFG	31	0	4.4	22, 12, 54
R	Precuneus	27	0.002	3.85	12, -56, 24
L	IFG	27	0.004	3.69	-46, 32, 0
L	SI	22	0.002	3.88	42, -20, 34
L	Cerebellum	16	0.003	3.79	-32, -66, -30
R	BA6/SMA	16	0.008	3.47	10, 4, 74
R	Hippocampus	14	0.006	3.57	32, -4, -36
R	Fusiform Gyrus	12	0.004	3.65	42, -14, -40
L	Fusiform Gyrus	12	0.005	3.62	-32, -8, -40
Typically Developed Group					
L	SI/SPL/Precuneus/IPL/IPC/SII/STG/MTG/ITG/Fusiform/Cerebellum	4866	0	11.93	-30, -50, 58
R	M1/SI/SPL/IPL	1687	0	8.69	40, -42, 58
L	BA6/SFG/MFG/Precentral/BA44	1646	0	8.37	-22, -4, 52
R	BA17/18	1146	0	7.6	8, -72, -2
R	MTG/ITG	990	0	9.54	50, -58, 2
R	BA6/SFG/MFG/Precentral	705	0	7.09	34, 0, 56
R	Cerebellum	612	0	8.26	20, -72, -24
R	Cerebellum	560	0	7.68	14, -76, -46
L	SOG	312	0.001	6.24	-20, -86, 34
R/L	Thalamus	293	0.001	6.58	0, -28, -4
R	SOG	244	0.001	5.95	26, -84, 34
L	MCC	173	0	7.57	-12, -24, 40
R	BA44	140	0.001	6.62	52, 14, 24
R	MCC	69	0.001	5.56	12, -22, 44
L	Cerebellum	63	0.001	6.7	-10, -78, -46
R	BA17/18	34	0.005	4.39	14, -94, 8
L	MFG	33	0.001	6.2	-34, 18, 44
L	Putamen	32	0.001	6.33	-32, -14, -2
R	BA17	31	0.004	4.54	24, -58, -2
L	Insula	27	0	7.97	-36, -4, 14
R	Cerebellum	27	0.005	4.51	4, -58, -38

Table S1. *Continued*

Hem.	Anatomical Description	k	p_{cor}	T	MNI (x, y, z)
L	Cerebellum	21	0.005	4.52	-10, -54, -50
R	IPL	20	0.004	4.64	50, -40, 20
R	Amygdala	18	0.003	4.99	26, 0, -20
R	IFG	17	0.006	4.34	42, 12, 36
R	Fusiform Gyrus	17	0.008	4.07	44, -48, -18
L	MFG	15	0.003	5.02	-34, 44, 8
R	BA45	13	0.005	4.41	52, 30, 18
L	IFG	11	0.005	4.38	-38, 24, 18

Visual Activity. Results of the contrast HandAction-HandStatic for aphasics subject 1 and 2 (single-subject analysis) and the typically developed group (random effect analysis of $n = 16$ subjects) thresholded at $p_{unc} < 0.001$ and $k = 10$ are shown. For each cluster, from left to right, we describe the following: the hemisphere containing the cluster; the anatomical/cytoarchitectonic description of the cluster; the number (k) of $2 \times 2 \times 2$ mm voxels contained in the cluster; information regarding the peak voxel in the cluster, namely its fdr -corrected p and T values; and its coordinates in MNI space. The following abbreviations are used: MFG (midfrontal gyrus), IFG (inferior frontal gyrus), SFG (superior frontal gyrus), SMG (superior medial gyrus), MCC (mid-cingulate cortex), ACC (anterior cingulate cortex), PCC (posterior cingulate cortex), ITG (inferior temporal gyrus), MTG/S (midtemporal gyrus/sulcus), TE (temporal area E), STG/S (superior temporal gyrus/sulcus), IOG (inferior occipital gyrus), MOG (midoccipital gyrus), SOG (superior occipital gyrus), SII (secondary somatosensory cortex), SI (primary somatosensory cortex), M1 (primary motor cortex), BA6 (Brodmann Area 6, premotor cortex), IPL (inferior parietal lobule), SPL (superior parietal lobule), BA17/18 (primary visual cortices), SMA (supplementary motor area), BA44 (Brodmann Area 44, premotor cortex), and BA45 (Brodmann Area 45).

Table S2. Results of the Contrasts HandAction-HandStatic Masked with FeetExe or MouthExe for Aphasics Subject 1 and 2 and the Typically Developed Group

Hem.	Anatomical Description	K	p_{cor}	T	MNI (x, y, z)
Aphasic Subject 1					
L/R	ITG, right MTG, STG, right supramarginal, right SII, SI, BA6, M1, SPL, MFG, SFG, right BA44, and right putamen	9672	0	15.92	46, -60, 2
L/R	BA17/18	3899	0	9.75	-2, -84, -2
L	SII,SI,BA6,BA44	836	0	6.16	-40, -24, 24
R	Fusiform/cerebellum	314	0	6.98	18, -74, -16
L	Putamen	157	0	5.68	-18, 0, -12
L	Rolandic	86	0	5.62	-46, 2, 10
L	Cerebellum	83	0	5.8	-6, -70, -38
R	Precuneus	59	0	5.07	8, -76, 44
L	MTG	46	0	7.94	-44, -58, 8
L	Cerebellum	40	0	4.67	-20, -44, -48
L	Cerebellum,BA17	36	0	6.7	-8, -86, -18
R	MCC	30	0.001	3.86	4, 18, 40
R	Hippocampus	23	0	5.05	16, -4, -12
R	Insula	22	0	6.35	40, -14, 6
R	SOG	20	0	7.58	24, -86, 10
R	MTG	14	0	5.44	52, -2, -18
R	Thalamus	10	0.002	3.76	12, -18, 10
Aphasic Subject 2					
R	STS/STG (V5/MT), supramarginal, MTG/MTS, ITG, and MOG	2193	0	17.44	44, -64, 4
R	SI,SPL	1790	0	8.39	44, -38, 62
L	STS/STG (V5/MT), MTG/MTS, and ITG	1350	0	17.31	-46, -66, 6
L	SI, SPL, and IPL	1241	0	7.92	-38, -30, 46
R	Precentral, MFG, SFG, and BA6	802	0	7.95	34, -2, 58
L	Precentral, MFG, SFG, and BA6	539	0	5.94	-24, 2, 54
L	BA17/18 and MOG	241	0	4.78	-12, -78, -2
R	SOG	153	0	5.13	22, -86, 16
L	Fusiform and ITG	148	0	4.42	-36, -50, -16
R	BA6	137	0	5.51	10, -18, 50
L	SII and supramarginal	80	0	5.34	-46, -32, 26
R	Fusiform	77	0	4.83	38, -44, -16
R	SOG	69	0	5.83	20, -80, 38
L	SI	56	0.001	4.2	-56, -18, 38
R	Amygdala	51	0.001	4.11	24, -2, -16
L	BA6	45	0.001	4.27	-12, -16, 48
R	BA17/18	38	0.002	3.86	18, -86, 2
R	SFG	31	0	4.4	22, 12, 54
R	SI	22	0.002	3.88	42, -20, 34
L	SPL	16	0.002	3.84	-24, -78, 50
L	Cerebellum	16	0.003	3.79	-32, -66, -30
L	IFG	16	0.004	3.69	-46, 32, 0
R	BA6	16	0.008	3.47	10, 4, 74
Typically Developed Group					
L	SI, SPL, IPL, postcentral, supramarginal, SII, and precuneus	1885	0	11.93	-30, -50, 58
R	SI, SPL, STS, postcentral, supramarginal, SII, and precuneus	1433	0	8.69	40, -42, 58
L/R	BA17/18	906	0	7.6	8, -72, -2
L	SFG, precentral, MFG, and BA6	641	0	8.37	-22, -4, 52
R	MTG (V5/MT) and ITG	500	0	9.54	50, -58, 2
R	SFG, MFG, and BA6	498	0.001	7.09	34, 0, 56
L	Cerebellum and fusiform	310	0.001	6.75	-26, -66, -22
L	Precentral and BA44	293	0.001	6.2	-48, 6, 36
L/R	Thalamus	289	0.001	6.58	0, -28, -4
R	Cerebellum	280	0.001	6.67	22, -72, -22
L	MTG (V5/MT) and MOG	256	0	9.73	-46, -70, 2
L	MCC	147	0	7.57	-12, -24, 40
R	Cerebellum	134	0	7.27	14, -76, -44
R	BA44	84	0.001	6.62	52, 14, 24
R	MCC	64	0.002	5.56	12, -22, 44
R	BA17/18	29	0.009	4.39	14, -94, 8
L	Insula	27	0	7.97	-36, -4, 14
L/R	Pons	26	0.009	4.4	6, -36, -38
L	Cerebellum	25	0.001	6.2	-10, -76, -46
L	Cerebellum	16	0.007	4.52	-10, -54, -50

HandAction-HandStatic Masked FeetExe or MouthExe ($p < 0.001$, $k = 10$). Conventions as in Table S1.

Table S3. Results of the Contrasts HandAction-HandStatic Masked with HandExe of the Typically Developed Group

Hem.	Anatomical Description	K	P_{cor}	T	MNI (x, y, z)
Aplasic Subject 1					
R/L	ITG, right MTG, STG, right supramarginal, right SII, SI, BA6, M1, SPL, MFG, SFG, right BA44/45, right putamen, precuneus, right insula, right IFG/MFG, right fusiform, cerebellum, right lingual, BA17/18, and thalamus	17690	0	15.58	44, -58, 4
L/R	MCC, SMA/BA6, and M1	1805	0	8.49	-10, -18, 46
L	BA44, Rolandic, IFG, and Insula	1073	0	6.25	-56, 14, 22
R	Putamen and insula	666	0	6.35	40, -14, 6
L	MTG/MOG and ITG/IOG	449	0	12.16	-46, -68, 0
L	SII, STG, and supramarginal	446	0	6.27	-46, -34, 18
R	MTS	56	0	4.56	52, -26, -6
L	Cerebellum	50	0	4.74	-17, -46, -48
R	MCC	48	0.001	3.86	4, 18, 40
L	ITG and fusiform	43	0	6.2	-44, -46, -18
L	Insula	39	0	4.39	-32, 14, 8
L	BA6	18	0.001	3.92	-16, -24, 72
L/R	BA6	16	0.003	3.49	2, 16, 58
L	MTS	11	0	4.17	-46, -50, 6
Aplasic Subject 2					
R	SI, SPL, Precuneus, and IPL	1434	0	8.39	44, -38, 62
R	MTG, ITG/S(V5/MT), STG, supramarginal, and SII	955	0	14.77	50, -66, 6
L	SI, postcentral, and IPL	737	0	7.92	-38, -30, 46
L	MTG (V5MT)	447	0	17.31	-46, -66, 6
R	MFG, precentral, SFG, and BA6	317	0	7.95	34, -2, 58
L	MFG, precentral, and SFG	162	0	5.94	-24, 2, 54
R	BA6/SMA	137	0	5.51	10, -18, 50
L	Supramarginal and SII	80	0	5.34	-46, -32, 26
R	Cuneus and SOG	58	0	5.83	20, -80, 38
L	SI	44	0.001	4.2	-56, -18, 38
L	Precentral	43	0	4.58	-50, 0, 40
R	IFG/BA6	22	0	6.14	56, 10, 38
L	BA6	21	0.001	4.27	-12, -16, 48
L	SI	17	0	4.69	-54, -34, 46
R	Fusiform	15	0.002	4.07	38, -42, -18
R	Amygdala	11	0.006	3.77	22, 0, -16
L	Fusiform	10	0.006	3.76	-34, -54, -20
Typically Developed Group					
L	SI, SPL, IPL, postcentral, supramarginal, SII, and precuneus	2388	0	11.93	-30, -50, 58
R	SI, SPL, STS, postcentral, supramarginal, SII, and precuneus	1505	0	8.69	40, -42, 58
L	SFG, precentral, MFG, and BA6	869	0	8.37	-22, -4, 52
L/R	BA17/18	701	0	7.6	8, -72, -2
L	MTG, MOG, ITG, and V5/MT	578	0	9.73	-46, -70, 2
R	MTG (V5/MT) and ITG	577	0	9.54	50, -58, 2
R	SFG, MFG, and BA6	572	0	7.09	34, 0, 56
L	Cerebellum and fusiform	429	0.001	6.75	-26, -66, -22
R	Cerebellum	355	0	7.8	20, -70, -24
L	BA44 and Precentral	221	0.001	6.2	-48, 6, 36
L	Thalamus	166	0.001	6	-6, -26, 0
L	MCC	154	0	7.57	-12, -24, 40
R	Cerebellum	143	0	7.15	14, -56, -50
R	Thalamus	72	0.001	5.95	12, -26, -2
R	MCC	64	0.002	5.56	12, -22, 44
L	SOG	62	0.001	6.24	-20, -86, 34
R	BA44	45	0	7.27	14, -76, -44
R	Cerebellum	45	0.001	6.03	54, 14, 22
L	Putamen	32	0.001	6.33	-32, -14, -2
L	Cerebellum	24	0.001	6.2	-10, -76, -46
L	Cerebellum	21	0.006	4.52	-10, -54, -50
L	Insula	20	0	7.97	-36, -4, 14
R	STS	14	0.005	4.64	50, -40, 20
R	SOG	13	0.004	4.95	22, -78, 36
R	BA17	13	0.006	4.54	24, -58, -2

HandAction-HandStatic Masked TDHandExe ($p < 0.001$, $k = 10$). Results are shown separately for apasic subject 1 and 2 and the typically developed group. Conventions are as shown in Table S1. TDHandExe refers to the hand action execution of the TD subjects.

Table S4. Motor Decomposition of Mirror Responses in Aplasics and TDs

Motor Selectivity	Definition (all at $\alpha_{unc} = 0.001$)	Color in Figure S2B	% of Total Volume
APL1			
Feet	FeetExe-Rest and FeetExe-MouthExe	Yellow	6
Mouth	MouthExe-Rest and MouthExe-FeetExe	Red	15
Common to feet and mouth	MouthExe-Rest and FeetExe-Rest and no significant difference between effectors	Green	79
APL2			
Feet	FeetExe-Rest and FeetExe-MouthExe	Yellow	30
Mouth	MouthExe-Rest and MouthExe-FeetExe	Red	1
Common to feet and mouth	MouthExe-Rest and FeetExe-Rest and no significant difference between effectors	Green	70
TD Group			
Feet	FeetExe-Rest and FeetExe-MouthExe and FeetExe-HandExe	Yellow	4
Mouth	MouthExe-Rest and MouthExe-FeetExe and MouthExe-HandExe	Red	4
Hand	HandExe-Rest and HandExe-FeetExe and HandExe-MouthExe	Blue	16
Common to feet, mouth, and hand	HandExe-Rest and MouthExe-Rest and FeetExe-Rest and no significant difference between effectors	Green	76