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Action observation as a useful approach for enhancing recovery of verb production: new evidence from aphasia

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***Backgrounds*, Evidence exists that the observation of actions performed by others enhance word retrieval and can be used in aphasia rehabilitation to treat naming impairments.**
***Aim*. The aim of the present study was to assess to what extent action observation treatment may improve verb retrieval in chronic aphasics.**
***Design*. This was an observational study.**
***Setting*. Patients were recruited from the Neurorehabilitation Centre of Ancona Hospital.**
***Population*. Six aphasic patients underwent an intensive language training to improve verb naming.**
***Methods*. Language evaluation was carried out before and after the treatment. A rehabilitation therapy based on observation of actions was administered daily to each patient for two consecutive weeks. Four different rehabilitation procedures were adopted: 1) "observation of action performed by the examiner"; 2) "observation and then execution of action"; 3) "observation of videoclips of actions"; and, as a control condition; 4) "observation of action and execution of meaningless movement".**
***Results*. In four participants, a significant improvement in verb retrieval was found for the three experimental procedures (χ^2 (3)=75.212, P<0.0001), with respect to the control condition. No significant improvement was observed in the two patients with severe deficits in verb semantics (χ^2 (3)=0.592, P=0.892).**
***Conclusions*. Action observation therapy may become a useful intervention strategy to promote verb retrieval in aphasic patients.**
***Clinical Rehabilitation Impact*: The observation of videoclips of actions may be an efficacious alternative approach to traditional rehabilitation programs for lexical deficits. This finding endorses the planning of innovative low-cost interventions in language rehabilitation.**

KEY WORDS: Mirror neurons - Stroke - Rehabilitation.

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It is well known that gestures interact with speech production enhancing word retrieval in normal populations and brain-damaged subjects.[1-3] In line with this hypothesis, different rehabilitation therapies based either on the simple use of gesture [4] or on gestures paired with verbal production [5-8] have frequently been used to improve naming impairments in aphasia. Rose *et al*.[7, 8] contrasted the effects of gestural treatments using pantomimes in two groups of aphasic patients with naming disorders due to damage to two different stages of name processing. Gestural treatment was more effective in individual with lexical phonologically-based word retrieval impairments than in those with semantically-based word failure.[8] According to these data, gestures and speech are two separate communication systems, gestures function as an auxiliary support when verbal expression is temporally disrupted or word retrieval is difficult.[1, 3, 9] In more recent years, the hypothesis of a strong connection between language and action has been further investigated. Contrary to the proposal by Hadar *et al.*,[1, 3] Gallese & Lakoff [10] posit that the process of interaction occurs because gesture and speech form a single communication system, closely link to the same neural conceptual representation[11,12]. The motor system and, in particular, the ventral premotor cortex (PMv), Broca's area (BA) 44, in the inferior frontal gyrus (IFG) and the inferior parietal lobule (IPL), are the hypothesized regions involved in the interaction between gesture and words.[13-16] Several lines of evidence have already demonstrated a strong connection between language and action, particularly with regard to language comprehension.

In the work by Buccino *et al.*,[14, 15, 17] the comprehension of words mediating actions performed with different motor districts (*e.g.* the feet "kicks", the hand " picks" and the mouth "eats") enhanced the same neural substrates involved in executing those actions. Moreover, it has also been shown that the observation of actions recruits the same motor representations active during the actual execution of those same actions.[15, 18, 19] These results are congruent with the hypothesis of a shared motor representation for the execution and observation of actions, the so-called "mirror neuron theory, which, by matching observation with execution, allows individuals to understand the meaning of actions performed by others.[19] With regard to word production, rTMS and behavioural studies in healthy subjects [20, 21] have shown that when gestures are performed simultaneously with the pronunciation of a corresponding congruent word, arm kinematics are slowed down and voice parameters (F2) are amplified. Moreover, similar to the results obtained for language comprehension and in accordance with the mirror neuron theory, the authors found that observing a meaningful gestures affected verbal responses in the same way as executing the same gestures.[20] Gentilucci *et al.*[20, 22] hypothesized that the interaction between gesture and word production occurs by transferring the social intention of simbolic arm-gestures to speech at a motor/articulation level by modifying vocal parameters.

However, until recently, with regard to action observation, no studies have been reported on the influence that gestures exert at the lexical production level. Marangolo *et al.*[23] investigated whether the "observation of semantically congruent actions" and/or " the observation and execution of semantically congruent actions" would improve verb-finding difficulties in a group of six aphasic patients. Differently from most of the previous reports,[5, 8] neither treatment was combined with verbal cue. Results showed a significant improvement of verb retrieval only with "action observation" and "action observation and execution" which was still present two months after the two treatments ended. No significant effects were found in the third condition in which patients first observed the action and then had to execute a meaningless movement. Congruently with previous reports,[7, 8] the beneficial effects were present only in the four participants with phonologically-based lexical retrieval disturbances. These preliminary data showing that the same amount of improvement in verb recovery is obtained with "the observation" and/or "the observation and execution of gestures" were intriguing in light of the hypothesized existence of a mirror neuron system in humans which is equally active in the execution and/or observation of actions.[19] In agreement with the multimodal concept representation's proposal,[12] the authors argued that in their work the observation of the performed action is sufficient to activate its corresponding semantic representation, which serves as input at the lexical level and facilitates word retrieval.[23] The role of action observation as an effective strategy in neurorehabilitation has been yet supported by several recent studies showing that action observation has a positive impact on recovery of motor deficits after stroke.[24-26] The study by Ertelt *et al.* study [25] combined observation of daily actions with concomitant physical training of the observed actions in eight stroke patients with moderate, chronic motor deficit of the upper limb. Significant functional improvement on standard scales occured for combined action observation and motor training compared with controls despite a stable pretraining baseline. Very recently, these results were replicated in a larger group of 28 partecipants with chronic upper limb motor deficits and in a group of Parkinson's disease patients.[24, 26]

On the basis of the current available evidences that action observation might be an effective rehabilitation approach in stroke patients,[23-26] in the present study we wanted to further investigate to what extent action observation might be an useful tool in language rehabilitation. Specifically, we contrasted the effects induced by observing actions (*i.e.* "observation of action") and observing and then executing action (*i.e.*" observation and execution of action") with the results obtained by observing visually presented video-clips of actions (*i.e.* " observation of action videoclips") in two patients with semantic verb retrieval deficits and four patients with lexical phonological disturbances. According to previous results,[7, 8, 23] we would expect to find beneficial effects only in the four patients with phonologically-based word retrieval impairments.

Materials and methods

Patients

Six chronic aphasic patients (5 males and 1 female) classified as right-handed according to the Edinburgh Inventory,[27] were included in the study. All subjects had suffered a left cerebrovascular accident (CVA) at least one year prior to the investigation (Figure 1). Inclusion criteria for the study were native Italian proficiency, pre-morbid right handedness, a single left hemispheric stroke at least 6 months prior to the investigation, and no acute or chronic neurological symptoms requiring medication. Patients with previous psychiatric or substance abuse history were excluded from the study. The data analyzed in the current study were collected in accordance with the Helsinky Declaration and the Institutional Review Board of the Ospedale Riuniti Torrette in Ancona, Italy. Prior to participation, all patients signed informed consent forms.

Clinical examination

The aphasic disorders were assessed using standardized language tests (the Battery for the analysis of aphasic disorders, BADA test and the Token test).[28, 29] The six patients were classified as non-fluent aphasics because of their poor spontaneous speech with short sentences and frequent word-finding difficulties. In a naming task, all patients had verb retrieval deficits ranged from mild-to-moderate-severe (Table I).

In a task requiring the ability to match an auditory presented verb to one of two semantically related pictures (Verb Comprehension task), only patient 5 and 6 were still marginally impaired. For commands and auditory sentences, moderate (patient 2 and 3) to severe (patient 5 and 6) comprehension difficulties were present in four patients, while patient 1

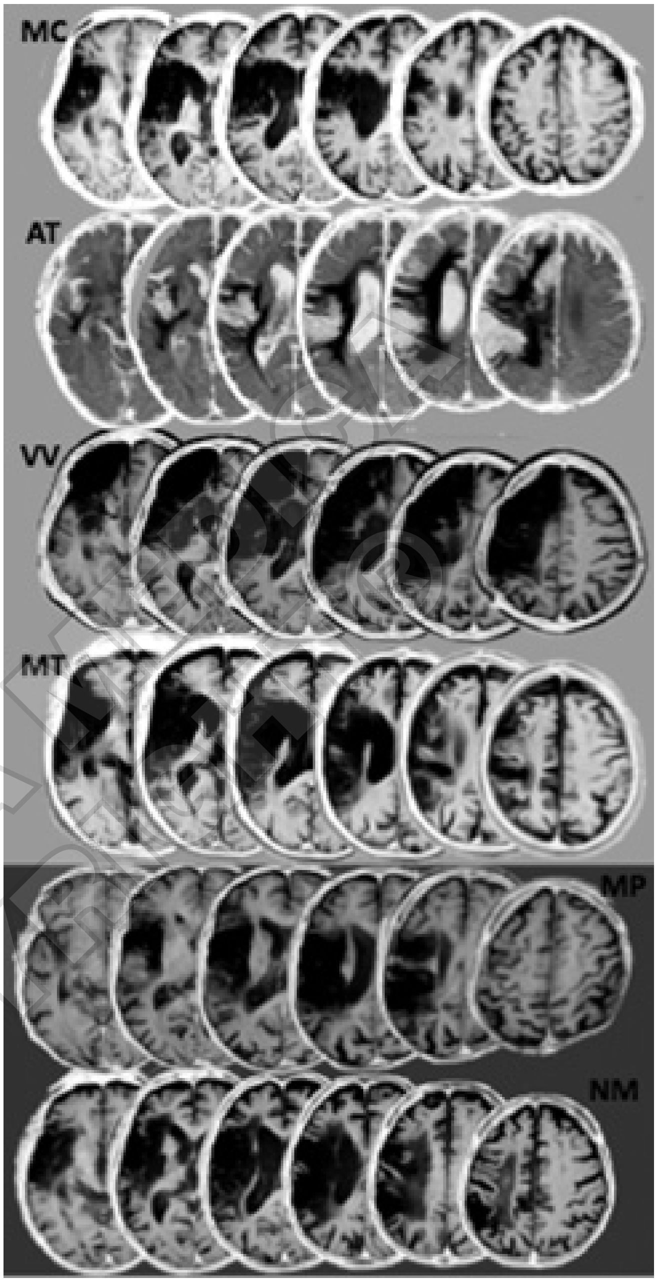

Figure 1.—Patients' brain lesions as visualized from axial view of the same z planes.
All patients had lesions in the territory of the left middle cerebral artery. The left pars opercularis (BA 44) was completely damaged in all of them apart from a little spared portion in patient 2 and 5.;the pars triangularis (BA 45) was also compromised except for a partial sparing in patient 2, 5 and 6. All patients had a lesion in the superior temporal gyrus apart from patient 2. Subcortical lesions including the basal ganglia and the thalamus were evident in patient 1, 3 and 4, while patient 2, 5 and 6 subcortical lesions involved the basal ganglia but not the thalamus.

and 4 had no language comprehension difficulties (29/36 cut-off score, Token Test).[29]

On the ideative, ideomotor and bucco-facial tests [30] no patient revealed an apraxia disorder. Furthermore, the patients had no difficulty on a test of gesture comprehension in which they were asked to view videoclips of intransitive (not involving the use of objects, *e.g.* waving goodbye; N.= 9) and transitive (involving the use of objects, *e.g.* playing a guitar; N.=10) actions performed by a male actor on a computer screen.[31] Each action could be performed either correctly (target, *e.g.* playing a guitar) or incorrectly (distractors, *e.g.* playing a guitar with an object that was inappropriate for that particular action, such as a flute or a broom.). Subjects underwent 19 trials in total. Each trail consisted in the presentation of a videoclip of a correctly executed gesture (target) and two incorrectly executed versions (distractors) of the action. Subjects were instructed to indicate which was the correctly executed version of the gesture by pointing to the target.

Treatment

Before the training, a list of 128 transitive (involving the use of objects, *e.g.* to comb, N.=103) and intransitive (not involving the use of objects, *e.g.* to dance, N.=25) videotaped actions were selected.

In order to investigate if gestural facilitations effects are greater for individuals with phonologically than semantically word retrieval failures,[8, 23] for each patient the selected stimuli were presented for comprehension tasks.

Action verb comprehension

The patients were shown one selected picture at a time. Each picture was presented twice, once with the correct word and once with a spoken semantically related word. The action of kissing, for instance, was presented once with kissing and once with hugging; the action of tasting once with tasting and once with cooking. The patient had to say whether the word corresponded to the picture or not. Responses were considered correct if the correct word was accepted and the semantically related word was rejected. Only two patients (patient 5 and 6) made several semantic errors (84 errors and 70 errors out of 128 stimuli, respectively for patient 5 and 6.). The remaining four patients made no errors in this task.

Description of verb meaning

The patients had to explain the meanings of the selected verbs any way they could. Four patients (1, 2, 3, 4,) always correctly mimed the action and/or used unambiguous words to explain their meanings, while the remaining two patients were not always able to describe the meaning of the action (102 errors and 90 errors out of 128 stimuli, respectively for patient 5 and 6.).

Grammaticality judgements

For each patient, each selected action was presented with three written sentences and they had to point to the correct one. In one sentence all the correct obligatory arguments were present (*e.g.* the girl waters the flowers), in one sentence an incorrect obligatory argument was included (*e.g.*, the girl waters the car), in one sentence an argument was governed by an incorrect preposition (*e.g.*, the girl waters for the flowers). Again, four patients made no errors on this task (1, 2, 3, 4), while the remaining two patients were severely compromised (107 errors and 100 errors out of 128 stimuli, respectively for patient 5 and 6).

In summary, the results of the comprehension tasks indicated that the source of the verb retrieval breakdown differed in our aphasic group. While, for four patients (1, 2, 3, 4) anomic difficulties seemed to arise from an inability to retrieve the word at phonological level, for the other two patients (5 and 6) a semantically based word retrieval impairment was suggested by difficulty across the three tasks.

To measure baseline performance, the 128 videoclips of actions were presented to the patients on a PC screen once a day for three consecutive days and they were asked to name each action without help. They had to respond within 15 seconds. The verbs the patients could not name and for which they always produced an omission were selected and subdivided into four lists of 13 actions for patient 1 (N.=52), 27 actions for patient 2 (N.=108), 22 actions for patient 3 (N.=88), 24 actions for patient 4 (N.=96), 30 actions for patient 5 (N.=120), 29 actions for patient 6 (N.=116), controlled for length and frequency of use. One list was assigned to the control treatment condition and each of the remaining three lists was used for a different rehabilitation procedure.

Each subject was asked to participate in an intensive language training, which included four daily sessions of 30 to 45 minutes each (depending on the number of stimuli to be treated), five days a week, for two consecutive weeks.

In each session, one of the following rehabilitation procedures was adopted:

1) "observation of action", in which the patient observed the therapist actually execute an action and then had to produce the corresponding verb; 2) "observation and execution of action", in which the patient first observed the therapist actually execute the action and then had to perform the observed action and produce the corresponding verb; 3) "observation of action videoclips" in which the patient was asked to carefully observe video sequences containing daily life actions on a computer screen and then had to produce the corresponding verb; and, as a control condition; 4) "observation of action and execution of meaningless movement", in which the patient first observed the therapist actually execute the action and then had to produce an unrelated and meaningless movement and produce the corresponding verb. In all treatments, the therapist was seated in front of the patient and asked the patient to carefully watch her performed action. Transitive actions were perfomed using real objects (*e.g.* cutting a sheet of paper with a pair of scissors), while intransitive actions required the therapist to excute a gesture with her body parts (*e.g.* waving goodbye with the hand or blowing with the mouth). After observing the action, one of the above described procedures was adopted. Neither treatment was combined with verbal cue. During the two weeks, for each subject, the order of sessions was randomly presented. All the answers were manually recorded. If the patient failed to produce an answer or produced an incorrect verb, after 15 seconds, the therapist presented the subsequent action. After two weeks, each patient was asked to rename all the videoclips of actions belonging to his/her own four lists (patient 1, N.=52; patient 2, N.=108; patient 3, N.=88, patient 4, N.=96; patient 5, N.= 120; patient 6, N.= 116).

Results

Sociodemographic and Clinical data of the six aphasic subjects are reported in Table I. All patients obtained the maximum score in the apraxia tests (ideative apraxia: 90/90; ideomotor apraxia: 72/72; buccofacial apraxia: 14/14 correct responses) and in the gesture comprehension test (19/19 correct responses).

In Table II the proportion of correct responses by subject and treatment at the end of each treatment is presented.

As first step, a logistic mixed-effects model approach was used.[32-35] Since the results of the comprehension tasks indicated that the source of the verb retrieval breakdown differed in our aphasic group, two separate models were performed: one for the 4 subjects with lexical-phonologically based disturbances (Group 1) and one for the 2 subjects with verb semantically-based deficits (Group 2). In each model, the dependent variable was accuracy of response at the end of each treatment (0=incorrect, 1=correct); the fixed effect was treatment (1=observation of action, 2=observation and execution of action, 3=observation of action video-clips and 4 = observation of action and execution of meaningless movement, *i.e.* control condition), and the random effect was the subject. For group 1, the random effect had 4 levels (one for each subject: patient 1, 2, 3, 4) and the total number of observations (verbs)

Table I.—*Sociodemographic and clinical data of the six aphasic subjects. For each test, the number of correct responses are reported.*

Participants	Sex	Age	Educational level	Type of aphasia	Time post-onset	Verb naming (BADA	Verb comprehension (BADA)	Token test
1	M	39	17	Non fluent	2 years	22/28	20/20	32/36
2	M	68	17	Non fluent	2 years	11/28	20/20	24/36
3	F	35	13	Non fluent	15 months	19/28	20/20	23/36
4	M	48	17	Non fluent	4 years	6/28	20/20	30/36
5	M	59	13	Non fluent	5 years	4/28	14/20	15/36
6	M	64	5	Non fluent	5 years	5/28	15/20	13/36

TABLE II.—*Proportion of correct responses by participant and treatment after two weeks.*

Subjects	Treatment 1	Treatment 2	Treatment 3	Treatment 4
1	0.84	10.00	0.92	0.23
2	0.44	0.63	0.41	0.07
3	0.63	0.55	0.68	0.13
4	0.58	0.54	0.58	0.08
5	0.07	0.10	0.07	0.07
6	0.14	0.10	0.10	0.07

Total number of observations: N.=108 (27 per cell) for subject A.T., N.=52 (13 per cell) for subject M.C., N.=88 (22 per cell) for subject V.V., N.=96 (24 per cell) for subject M.T., N.=116 (29 per cell) for subject N.M., N.=120 (30 per cell) for subject N.P.

was 344, whereas for group 2 the random effect had 2 levels (one for each subject: patient 5 and 6) with a total number of observations of 236.

The model performed on Group 2 indicated no significant effect of treatment (χ^2 (3)=0.592, P=0.892), therefore no subsequent analyses were conducted.

For group 1, a significant effect of treatment was found (χ^2 (3) = 75.212, p <.0001). In particular, as shown in Table III, treatments 1, 2 and 3 had significant and positive Odds Ratios.

To assess whether the effect of each treatment was homogeneous across subjects, the cross-level interaction "treatment X subject" was tested. Results showed no significant effect (χ^2 (9)=1.321, P=0.998); therefore, the effect of treatment was constant across subjects.

Finally, a set of planned comparisons was performed to assess whether treatments 1, 2 and 3 had differential effect on participants' performance. Specifically, we tested: treatment 1 *vs.* treatment 2, treatment 2 vs. treatment 3 and treatment 1 *vs.* treatment 3. Since none of these comparisons reached statistical significance (all *ps*>0.516), we concluded that no significant difference emerged between the three treatments.

Discussion

In the present study, six aphasic patients with deficit in verb retrieval underwent an intensive language training of four daily sessions using different rehabilitative procedures.

Two important results should be considered: 1) in the four partecipants with lexical-phonologically based disturbances, a significant improvement of verb retrieval was found with "observation of action", "observation and execution of action" and "observation of action video-clips"; 2) the same amount of improvement was obtained through the three procedures without significant differences between them. These results clearly replicate our previous data[23] confirming that not only the observation of actions performed by another person is an effective approach for verb recovery but also that the observation of action videoclips exert the same influence. This finding provides a new strong confirmation of the potential role of action observation for enhancing verb recovery.

To explain how both the "observation and execution of action" and "the observation of action" exert an influence at a lexical level we offered an interpretation in agreement with an embodied cognition viewpoint. This view posits that the representation of a concept is multimodal crucially dependent upon its sensory-motor processes.[10, 12, 19, 23] We suggested that, if a multimodal semantic representation exists, the motor system activated by the observation and/or the observation and execution of the action directly interacts with the semantic system enhancing the activation of its sensory-motor representation. Therefore, contrary to Krauss et al.'s proposal[3, 9] and in accordance to our previous data,[23] the present data confirm that the actual execution of the action is not a necessary prerequisite to enhance naming. Likewise executing actions, observing a videoclip of action is sufficient to activate the sensory-motor attributes of the multimodal verb semantic representation which serves as input at the lexical level and facilitates the retrieval of the word form. In our hypothesis, the mechanism underlying this effect might possibly involve the so-called mirror-neuron system,[19] an action execution/observation matching system, equally active when actions are actually executed and/or are simply observed. This postulated mechanism of motor-language system interaction more likely occurs only for words, as verbs or concrete nouns, grounded in sensory-motor features.

As stated in the introduction, the role of action observation as an effective treatment in neurorehabilitation has been already supported by several recent studies showing its positive impact on the recovery of motor deficits after stroke.[24-26] The hypothesis advanced to explain such benefit was that, in line with the mirror theory, action observation recruits the motor system as does motor execution.[17] These lines of evidence raise the possibility of improving motor performance through systematic exercise based on careful observation and imitation of everyday actions.[17, 26]

Our results support this claim, adding the potentiality that, not only the imitation but also the simple observation of action is sufficient for the recovery of word retrieval impairments. This recover more likely occurs in the absence of semantic deficit. Accordingly, the two patients with verb semantically-based disturbances did not benefit of this treatment. In our hypothesis, the presence of a damage in the verb semantic representation prevent the patients to activate the corresponding sensory-motor features and subsequently the recovery of the word form.[7, 8, 23] Further evidence of the effect of the motor system activation on lexical word retrieval has been recently reported by a study showing that an unspecific activity such as standing had beneficial effects on the naming performance of nonfluent patients.[36] The authors found that standing compared to sitting increased the number of semantic self-corrections that resulted in correct naming, suggesting that an unspecific motor cortex activation is sufficient to facilitate naming in aphasic patients.

In our study, the hypothesis could be advanced that a more specific motor system activation, such as the "observation" and or the "observation and execution of semantically congruent action" more likely facilitates verb retrieval. Accordingly, we did not found an improvement of verb production in the control condition when patients were asked to observe and then to execute a meaningless, unrelated action.

One final point regards the neural substrates which have supported the recovery in our aphasic patients. Although our data are strictly behavioural, since all of our patients had damage to part of the circuit implicated in performing and/or observing action[19] and, specifically, to the left inferior frontal gyrus (BA 44, 45) (Figure 1), we might speculate that the four patients which showed improvement of verb recovery might have benefited from an activation of the homologous right mirror circuit, which leads them to improve verb retrieval.[13] This hypothesis is supported by a recent Transcranical magnetic Stimulation (TMS) study which showed a functional connection in aphasic patients during language production between regions mediating hand movements in the right hemisphere and the left hemisphere language network.[37] However, given the fact that not all patients showed an improvement, we considered that anatomical differences in their left hemispheric lesion sites might be the most responsible factor for the observed results. In order to analyze the neural correlates responsible for verb recovery, a lesion subtraction analysis was made (Figure 2).

Figure 2 shows the superimposed lesions of the four subjects who benefited from the treatments subtracted from the lesions of the two subjects who did not benefit.

It is evident that those patients who benefited from treatment had spared cortex around the most posterior part of the Sylvian fissure (maxov x:-38; y:-43; z:31 and x:-39; y:-30; z:15) and, specifically, to Broadmann's area 22 and 40 corresponding to the posterior temporal gyrus (Wernicke's area) and the inferior parietal lobe. It is widely documented that the posterior temporal gyrus plays a crucial role in word comprension tasks, such as lexical-semantic processing[38]. Accordingly, it has been recently demonstrated that the recognition of the semantic and spatial properties of action is associated with lesioned voxels in the posterior cerebral regions. The posterior temporal gyrus appears to serve as a central node in the association of actions and meanings; while, the inferior parietal lobe, held to be a homologue of the monkey parietal mirror neuron system, is critical for encoding object-related postures and movements, a circumscribed aspect of gesture recognition.[39] Therefore, in agreement with our behavioral results, the hypothesis could be advanced that only patients with preserved verb semantics and spared areas in the posterior part of this action recognition system [40] can be the best candidates for action observation treatment. Our results support this claim.

Conclusions

In conclusion, our data clearly confirm that Action Observation is an useful intervention strategy to

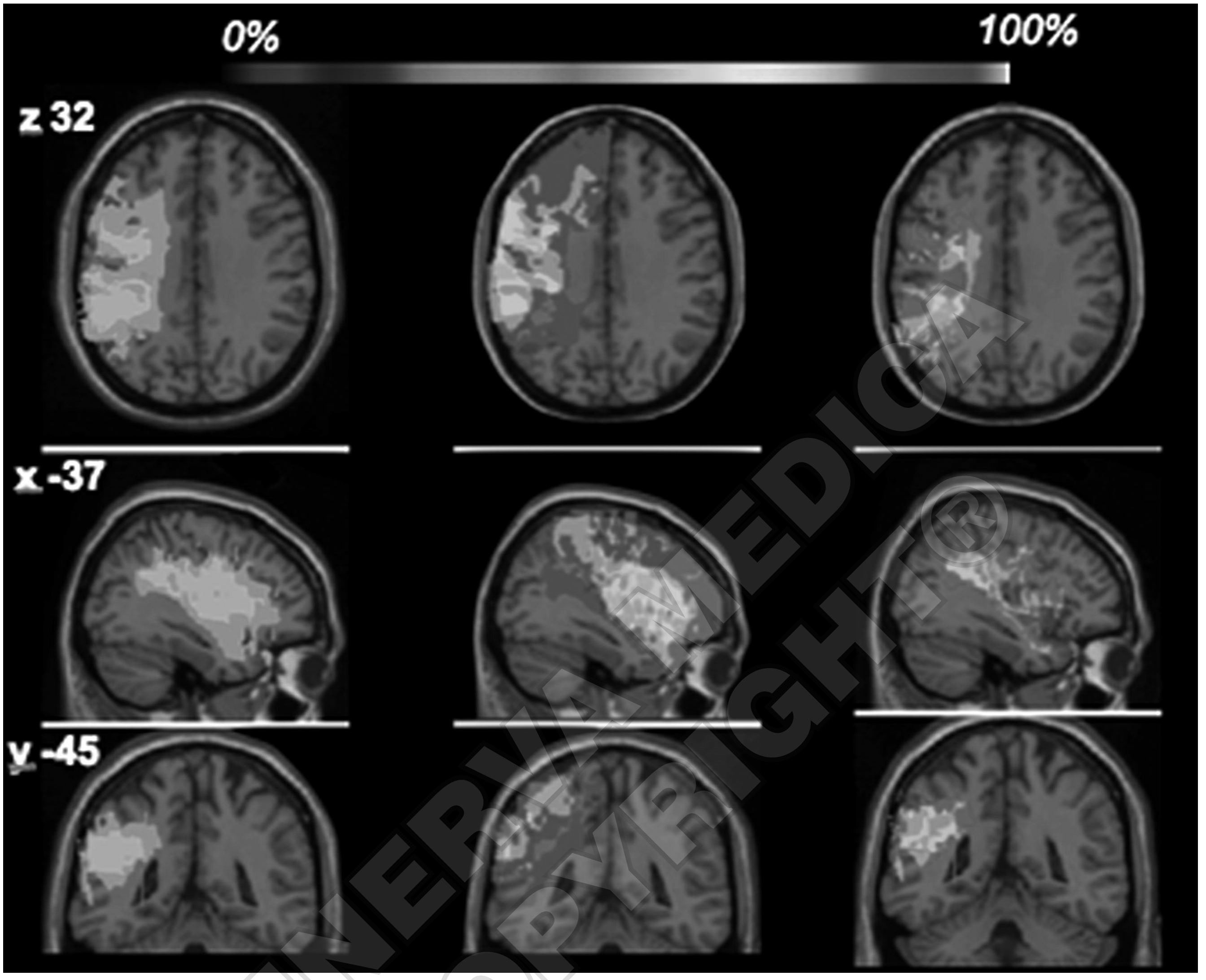

Figure 2.—Coronal sagittal and axial views of colour coded probability map of lesion overlap (range 1%, darkpurple to 100%,white). Individual volume lesions were transformed into a standardized stereotaxic coordinate system using a computational semi-automatic procedure of REGISTER, software provided by Brain Imaging Center, Montreal Neurological Institute, McGill University.
Averaging the labelled voxels of the individual lesion volumes re-aligned in Talairach space generated the probability map revealing the localisation of areas of maximal lesion overlap (maxov). The probability maps of the lesions of patient 5 and 6 who did not benefit from the treatments (left column) and of patient 1, 2, 3, and 4 who benefited from the treatments (center column) were calculated. Comparisons between these two groups were run by subtracting the probability map of patient 5 and 6 from that obtained averaging patient 1, 2, 3 and 4. The resulting map is reported in the right column. It is evident that those patients who benefited from the treatments had spared cortex around the most posterior part of the Sylvian fissure (maxov x:-38;y:-43;z:31 and x:-39;y:-30;z:15).

promote verb recovery in chronic aphasic patients. We postulate that the function outcome of patients with verb lexical retrieval deficits can be influenced by tasks simply involving observation of actions. However, since the number of patients was small, the facilitation found and its corresponding neural correlates deserve further investigations. We believe that these new findings represent an efficacious alternative approach to traditional rehabilitation programs for lexical deficits.

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