THE TALKING HANDS?

THE RELATION BETWEEN GESTURE AND LANGUAGE IN APHASIC PATIENTS

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To my parents and my sister
who did not see me much in the last years

Prologue

This thesis is composed of two individual but interconnected studies. The first study investigated the gestural ability of aphasic patients in comparison with healthy speakers, by analysing both qualitatively and quantitatively co-speech gestures during a story-retelling task. The objective was to understand the relation between language and gesture ability in the aphasic patient: whether impairments in language production influence gesture production, as suggested by the long existing notion "asymbolia". If this is *not* the case, gesture then may play a very potential role in aphasic daily communication and rehabilitation, as suggested by researchers and clinicians (e.g., Marshall, 2006; Rodriguez et al., 2006) who proposed the use of gesture as a compensatory and facilitative means to assist aphasic individuals to communicate. In our first study, four aphasic patients and four age-matched healthy speakers were recruited. They were requested to retell stories after watching eight short films from the cartoon "Tweety and Silvester". Both verbal and non-verbal production from the participant were video-taped for analyses. Group and individual analyses were performed to examine representational and non-representational gestures in per-100-word and per-minute measures. We found that in aphasic subjects, as a group, gestures were quantitatively indistinguishable from those produced by normal controls. Also, qualitative analyses demonstrated that the aphasic subjects tended to use representational gestures to cue or substitute for difficult-to-name words. This supports the notion that gesture may cue naming and may be a potential treatment approach in aphasia rehabilitation.

The second study explored treatment efficacy of three approaches in aphasia rehabilitation – the Gesture-based, the Language-based, and the Combined approach, aiming to understand the effects elicited by these techniques in improving single word naming ability in aphasic patients. Previous research suggested that gesture training can facilitate word naming (see Rose, 2006 for review). Language-based treatment aiming to reconstruct concepts and restore phonological information on difficult-to-name words has been widely studied, but the therapeutic role played by gesture in language recovery has been rarely considered. Our second study recruited four chronic aphasic patients with word-finding difficulty to explore the effects of three types of treatment – Gesture-based, Language-based, and Combined, on the retrieval of nouns and verbs. It was hypothesized that gesture and language-based treatments alone would yield positive effects and that combined treatment would result in the largest improvement of single-word naming. In gesture-based treatment, patients were trained to produce a gesture that can be mapped onto a corresponding word. In language-based treatment, Semantic Feature Analysis and Phonological Component Analysis were used. The combined treatment includes the same materials used in the gesture-based and language-based treatments, but materials were alternated across sessions. Training materials included verbs of hand-related actions and nouns of manipulable objects. We found that all types of treatment, as hypothesized, led to significant item-specific improvement in both verb and noun naming. Three of four subjects showed the largest recovery following combined treatment, especially on verbs. This suggests that gesture, when combined with logopedic treatment, can boost naming skills.

Declaration

I declare that, except where otherwise stated, this dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration. No part of this dissertation has been submitted at any other University for a degree or other qualification.

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Contents

1. Introduction **8**
- **Aim of this thesis** **10**
- **Overview of the thesis** **10**
- **References** **12**

2. Can Aphasic Patients Gesture? **14**
- **Non-verbal ability in aphasics** **15**
- **Limb praxis processing model** **16**
- **Co-speech gestures in aphasic patients** **19**
- **References** **23**

3. Study One: The Co-speech Gesture Study **26**
- **Methods** **26**
  - Participants 26
  - Procedure 27
  - Materials 28
  - Transcribing speech 28
  - Identifying and coding gestures 29
  - Gesture categorization 29
  - Data analysis 31
- **Case reports** **32**
  - Case 1: MAD 32
  - Case 2: PAS 32
  - Case 3: FIP 33
  - Case 4: SYH 33
- **Results** **34**
  - Rate of representational gestures per 100 words 36
  - Rate of non-representational gestures per 100 words 36
  - Rate of representational gestures per minute 40
  - Rate of non-representational gestures per minute 41
  - Percentage of word finding difficulty solved by gestures 47
- **Discussion** **49**
  - Interpretation from methodological perspectives 50
  - The relation between aphasia and gesture production 51
  - Episode effect in representational gestures 53
  - Function of gesture in aphasic communication 55
  - Concluding remarks 57
- **References** **58**

4. On Aphasia Treatments **60**
- **Logopedic approach** **60**
- **Gestural approach** **61**
- **Combined approach** **62**
- **Verb v.s. noun retrieval** **63**
- **Problems unsolved** **64**
- **References** **66**

5. Study Two: Three Treatment Approaches and Their Effects **69**
- **Method** **69**

Participants 70
Study design 71
Materials 73
Data analysis 75
Case reports 76
Case 1: SYH 77
Case 2: CAC 80
Case 3: PAS 83
Case 4: FIP 86
Summarized results from Individual cases 89
Generalization 89
Discussion 91
Treatment efficacy 92
Gesture facilitates naming and its interaction with language 93
Aphasia type and utilising gesture 96
Some limitations of the study 97
Concluding remarks 99
References 99

6. Conclusions and Future Directions 103
Conclusions 103
Future directions 104
References 105

7. Appendices 107
Appendix 1 - Description of Cartoon Episodes 107
Appendix 2 - Phonological Components Analysis (PCA) 110
Appendix 3 - Semantic Feature Analysis (SFA) for Objects 111
Appendix 4 - Semantic Feature Analysis (SFA) for Actions 112

1. Introduction

Speaking and writing are not the only means of communication. Messages can be conveyed through a non-verbal channel as well. Gesture is one of the instances. When non-verbal communication cooperates with the verbal channel, information can be effectively exchanged: verbal expressions are emphasized, clarified or completed by gestures, while spoken messages help disambiguate the meaning of gestures (Kendon, 2004). This bi-directional relationship between gesture and language has been tackled by many empirical studies (e.g., Bangerter, 2004; de Ruiter, 2007; Meliger & Kita, 2007). When acoustic transmission is interfered with by environmental obstacles - for example, talking to someone in distance at a noisy bar - speakers often use gestures as an adaptive means to improve the conversational setting. Similar observations were reported from experimental settings in which normal speakers who were prevented from producing verbally-based communication created compensatory and comprehensible references, such as object and action miming, to deliver their opinions and wishes, and to get the information across (Goldin-Meadow, McNeill, & Singleton, 1996). Theories and hypotheses pertaining to the interplay between gesture and speech have been broadly studied and tested, and the bi-directional relation has been well established, but mainly in healthy speakers. The ability to use gesture to replace speech in aphasic patients is more questionable (Borod, Fitzpatrick, Helm-Estabrooks, & Goodglass, 1989; Feyereisen, Barter, Goosens, & Clerebaut, 1988), and the relation between gesture and speech in this group remains almost unexplored in tightly designed experimental settings and yet to be examined with qualitative analyses.

Aphasia is a language disorder that results from damage to brain areas responsible for various language functions. It can be caused by stroke, tumors, cerebrovascular accidents, trauma or brain infection. Aphasic individuals are confronted with serious communication difficulties in production and/or comprehension of language. Sbjects with acquired language disorders conventionally receive either intensive or extensive speech therapy, aimed at recovering their expressive and receptive communication skills. Nevertheless, many of them fail to reacquire adequate spoken language skills (Nickels, 2001).

Gesture provides an alternative means for communicating when speech production is impaired. In the past three decades, several researchers proposed to use gesture as an alternative tool in aphasic treatment as a facilitative and compensatory intervention (see Rose, 2006, for review). An array of empirical studies was conducted to investigate the efficacy of geture-based training programs, in order to examine the facilitative and adaptive role of gesture use. For example, in a treatment study, Pashek (1997) trained four aphasics to use gesture as a facilitation to cue words, aiming to improve single word naming ability. He reported that training involving highly iconic gestures facilitated single word naming in patients with word-finding problems. In a more recent study, Daumüller and Goldenberg (2010) trained 23 aphasic patients with 24 communicative gestures, intending to ameliorate patients' daily life communication. Even though the argument - gesture may be potentially useful in aphasic treatment - attracted considerable interest among clinicians and researchers, three issues regarding gesture use in aphasia remain unclear: (1) the actual ability of aphasic subjects to use gestures; (2) the relation between gesture use and language deficits in this population; (3) whether gesture can be a potential treatment technique in aphasia rehabilitation.

Aim of this thesis

The aim of this thesis is twofold: first, to investigate gesture production ability in aphasic patients by examining co-speech gestures in these subjects, as compared with healthy speakers; second, to understand whether gesture is potentially useful in aphasia rehabilitation.

Two individual but interconnected studies were conducted for this thesis. The first study investigated gestural ability in four chronic aphasic patients in comparison with four age-matched healthy speakers. Co-speech gestures produced during a story-retelling task were collected, transcribed, and analysed both qualitatively and quantitatively. In the first study, we tried to investigate whether or not aphasia influences gesture production. The second study explored the efficacy of three treatment approaches in aphasia rehabilitation – a Gesture-based, a Language-based, and a Combined approach - aiming at understanding which technique is most effective in improving word naming in aphasic patients. In the second study, the research questions are (1) Among the gesture-based, the language-based and the combined approaches, which one is most effective in improving naming accuracy? (2) How might gestural facilitation diverge in the treatment of nouns vs verbs? (3) What is the relation between type of cognitive damage and response to the gestural approach?

Overview of the thesis

A brief literature review to the research and studies related to aphasic patients' gesture ability - starting from Finkelnburg's (1870) notion of "asymbolia" to recent models pertaining to limb praxis and language processing (Rothi et al., 1991; Rumiati et al., 2010) - is presented in chapter two. Empirical studies which explored the communicative function of gesture in aphasic patients are also reviewed in this chapter.

Chapter three reports the first study: the co-speech gesture study in aphasic patients and in healthy speakers. The gestural ability of aphasic patients in comparison with healthy controls was examined by a story-retelling task. Qualitative and quantitative analyses of representational and non-representational gestures co-occurring with verbal production were conducted. A detailed description of the experimental setting, of the clinical and linguistic profile of each subject, of data analysis techniques and of the study results are provided. This study shows that there are no significant qualitative/quantitative differences between aphasic and non-aphasic participants in terms of either representational and non-representational gestures in the story retelling task.

Based on these results, we further explored the potential role of gesture in aphasia rehabilitation. In chapter four, the literature related to aphasia treatment techniques, including those based on linguistic tasks and those using gesture as a compensatory and facilitative means is reviewed. Issues, such as the presence of distinct neural networks for retrieving nouns and verbs and their possible interaction in gesture production, and the aphasic patients' response to different treatment approaches to noun and verb naming are also discussed in this chapter.

Chapter five reports the second study. The treatment study used a single-subject, multiple-baseline design to investigate the effects of three types of treatment approaches - gesture-based, language-based, and combined - on word naming, with both verbs and nouns. Four chronic aphasic patients with word-finding difficulty were recruited for this study. It was hypothesized that gesture-based and language-based treatments alone would yield positive effects, and that a combined treatment would result in the largest improvement of word naming. Treatment design, the materials used for treatment, and data analysis methods are described in detail. Results are presented in a *small group, single-case* format. Clinical profile and response to each treatment technique are individually examined and reported on. A summary of the treatment results observed in the four subjects as a group is also provided. All types of treatment, as hypothesized, led to significant, item-specific improvement on both verb and noun naming. Three out of four subjects showed the largest recovery following the combined treatment, especially for verbs. This suggests that gesture, when combined with logopedic treatment, can boost naming skills. At the end of the chapter, how gesture production interacts with word processing is discussed.

At the end of this thesis, in chapter six, the main results of the two studies conducted for this thesis are summarised. The conclusions drawn from the experimental evidence are reviewed. Future studies to address the unsolved issues from the current project are also addressed in this chapter.

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2. Can Aphasic Patients Gesture?

Aphasic individuals find it difficult to conduct verbal-oriented communication. Even if they receive logopedic treatment to remediate their linguistic impairments, aphasic patients still encounter difficulty in their daily communication (Parr, Byng, & Gilpin, 2003). Feyereisen and Seron (1982) observed that gestures were frequently used by aphasic individuals due to the necessity to organize the semantic structures of the conversation and to sustain the attention of their interlocutors. Several research groups and clinical aphasiologists proposed that aphasic patients should be encouraged to employ gestures as an alternative communication means to compensate their inefficiency in verbal language. For example, Braddock and colleagues (2008) reported an adult with Broca's aphasia who learned to use the Simplified Sign System – a system composed of highly iconic gestures – and benefited from this system. By learning it, the participant was able to communicate action and affective information effectively. It has also been hypothesized that a gestural-oriented training programme, such as the Simplified Sign System, may be helpful in augmenting speech when words are not available, especially when it is treated in association with a linguistically-based training. Family members and caretakers can be trained easily in the use of this system, and the burden of daily life communication is therefore lessened (Morgenstern, Braddock, Bonvillian, Steele, & Loncke, 2009). Albeit the role of using gesture in aphasic communication holds potential, it is important to first understand the relationship between gesture and language in the aphasic population before proposing gestures as an alternative means of communication. The main goal of this study is to tackle the question - Does aphasia influence gesture production?

Non-verbal ability in aphasics

In 1861, Broca reported the patient “Tantan” as “being incapable of manifesting his ideas or his desires other than by movements of his left hand. He frequently made incomprehensible gestures” (Broca, 1861). Several years later in 1870, Finkelnburg proposed that aphasia influenced not only verbal abilities – such as word comprehension, reading, and writing - but also non-verbal functions. Therefore, non-verbal disorders like symbolic usage and gesturing could also be observed in aphasic patients. To support his argument, Finkelnburg introduced five detailed case studies of aphasic individuals who demonstrated a variety of verbal and non-verbal deficits. He documented that among these aphasic patients, there was one with jargon aphasia whose “gestures were remarkably awkward, and sometimes completely incongruent to what he wanted to express”. Finkelnburg termed this cross-modality inability as “asymbolia”. He further suggested that there was more than disruption of language in aphasia and that asymbolia would be a more correct term for linguistically-impaired patients who also manifested partial or total deficits in expressing concepts by means of acquired signs.

Following Finkelnburg, other clinicians and researchers also regarded aphasia as a disorder that extends beyond linguistic capacity. That is, aphasic individuals may demonstrate impairments in both gesture execution and language production, and the severity of aphasia is positively correlated with the degree of their gestural deficits (Duffy, Duffy, & Pearson, 1975; Duffy & Duffy 1981; Gainotti & Lemmo, 1976; Pickett 1974). The rationale was: if there were a central symbolic system in charge of both linguistic and motor ability, then aphasic individuals should have relatively compromised pantomime recognition skills in comparison to brain-damaged, non-aphasic counterparts and healthy speakers. To test the hypothesis, Duffy and colleagues (1975) examined pantomime recognition, verbal recognition and naming in a large group of subjects, including 44 aphasic patients, 30 right-hemisphere-damaged persons who did not show aphasic symptoms, 26 patients with subcortical damage (e.g., Parkinson's disease), and 30 normal controls. Consistently with their hypothesis, the aphasic group showed the most impaired performance on the tasks when compared with other groups. The investigators therefore confirmed the influence of the central symbolic organizer, and further concluded that aphasia impedes a general level of functioning, rather than changing the relationship between verbal and non-verbal modality. In the same vein, Pickett (1974) reported a high correlation between gestural and verbal performance in his aphasic subjects, and concluded that motor deficits and linguistic impairments are symptoms of a common underlying cognitive disorder subsequent to left hemisphere disturbance (see Christopoulou & Bonvillian, 1985 for a detailed review of the relevant studies).

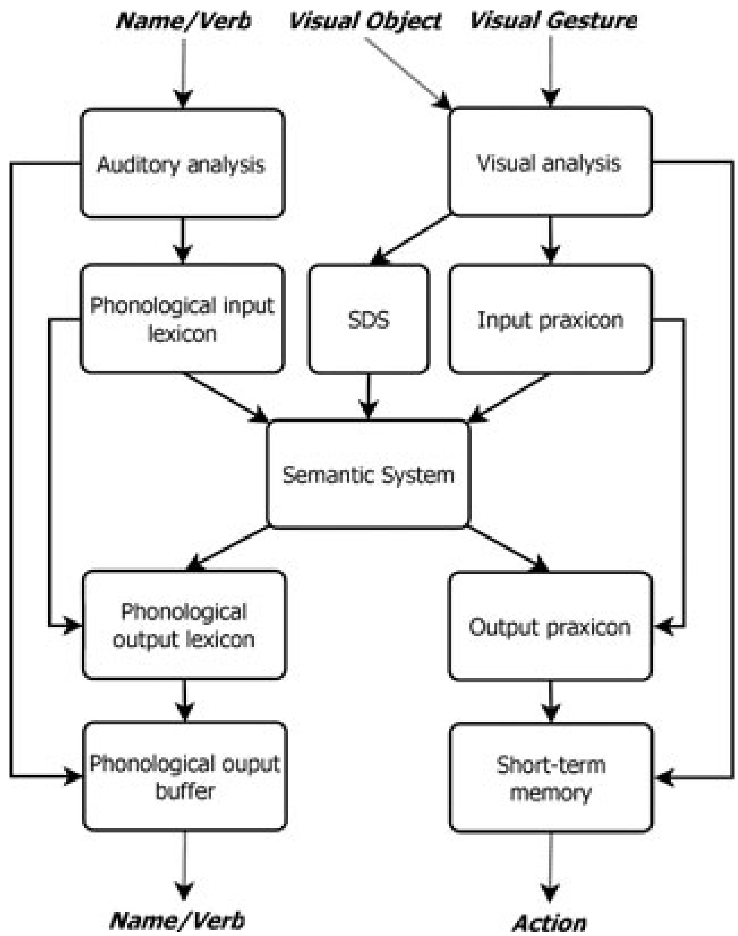
Limb praxis processing model

Liepmann (1900) approached linguistic-motoric impairments from another perspective. Based on a systematic examination of gestures on command in aphasic patients, Liepmann proposed a theory of gesture production that distinguishes between impairments in conceptualizing the idea of an action/a movement and deficits in executing the corresponding motor commands. The former impairment was termed ideational apraxia (IA), whereas the latter ideomotor apraxia (IMA). Ideationally impaired patients usually demonstrate deficits in using objects and tools; however, they are still capable of implementing the same gestures by imitation. On the contrary, patients with IMA present deficits in imitating actions and/or performing these movements following verbally or visually presented commands.

Noting a series of dissociations – for example, failing to comprehend visually presented gestures while preserving the capacity to imitate and execute gestures upon verbal instructions - in the performance of apraxic patients, Rothi and colleagues (1991) proposed a model of praxis which is akin to the model of language comprehension and production (Patterson & Shewell, 1987). This model specifically distinguishes a semantic and a non-semantic route for meaningful (familiar) and meaningless (non-familiar) gestures. That is, a gesture may be retrieved through the semantic route or via the non-semantic route. Within the semantic route, the semantic system - equivalent to the Conceptualizer in the language comprehension and production model - serves as a repertoire which contains learned gestures. This semantic system is a linkage between input praxicon and output praxicon. The input praxicon is responsible for recognizing familiar gestures, while the output praxicon for meaningful gesture production.

Rumiati, Papeo, and Corradi-Dell'Acqua (2010) further modified the model proposed by Rothi and colleagues by distinguishing different types of input, including visually and auditorily presented stimuli (e.g., visual gesture, object or action names, and visual objects) so that stimuli from two different modalities could be analysed under a perceptual framework (see Figure 1). Rumiati and colleagues tied their model to early perceptual operations: visual objects feed into the structure description system (SDS), whereas visual actions into input praxicon. The Semantic System serves as a conceptualizer, storing the knowledge pertaining to objects and actions which has already been acquired. The output praxicon functions as a supportive system for the implementation of both object-related and object unrelated actions.

Figure 1. The model of word and action production proposed by Rumiati et al. (2010)



In the model developed by Rumiati and colleagues, a prediction can be generated: deficits in producing a word should not influence one's ability to execute a gesture/action - for example hammering - either in imitation (bypassing the semantic route) or in using the actual object (a hammer), and vice versa. Some further predictions can be advanced: if the output lexicon and the output praxicon interact (e.g., via direct links), such that information from the praxicon can add to semantic knowledge and activate the target phonological entry in the output lexicon, whatever is activated in the praxicon may boost activation in the lexicon. Also, if the two components are independent, as assumed by

Rumiati and colleagues (2010), the entry activated in the output praxicon may re-enter the system at the structural description or at the input praxicon level, thus increasing the amount of information activated in the semantic system, which may more easily precipitate the correct response. Lastly, in the context of interactive models, information from the praxicon might feed back to semantics, from which it might contribute to the activation of the lexical entry of output.

Co-speech gestures in aphasic patients

In the late 1970s and the 1980s, researchers and clinicians narrowed down the investigation to focus on co-speech gesture abilities in aphasia. Unlike previous research, which employed exclusively clinical assessments of limb apraxia and pantomime to measure gestural ability, investigators in the 1980s sampled gesture performance in more natural and referential settings. To be more specific, in the former studies aphasic participants had to gesture or pantomime on request, based on an object, a picture, or a verbal command. Tests like these were usually carried out in a non-communicative context, for instance, "show me how you use a hammer" (see Rose, 2006 for review). Instead, the scope of studies implemented in natural and conversational settings was to look for finer-grained evidence for the communicative function of gestures (Cicone et al., 1979; Feyereisen, 1983; Glosser, Wiener, & Kaplan, 1986; LeMay, David, & Thomas, 1988). These investigators aimed to understand whether aphasic individuals could use gestures as a device to compensate for their verbal incapacity. Some studies reported that instead of being impeded by their linguistic deficits, the patient was actually more effective in using gestures to communicate with respect to control participants. For example, Le May and colleagues (1988) used informally structured 20-minute interviews to investigate gesture use in the spontaneous communication of aphasic speakers versus non-aphasic controls. Their results showed that patients - both Broca's and Wernicke's aphasics - used gestures that described physical movements significantly more often than the non-neuropsychologically impaired comparison group. It was also reported that Broca's aphasics demonstrated increased use of ideographic gestures which assisted them in maintaining their position in the conversation while searching for a word.

In a similar vein, Glosser, Wiener, and Kaplan (1986) compared gestural abilities in a group of patients (five mild and five moderate aphasics) and a group of five healthy controls, in two conditions: face-to-face informal dyadic conversation, and restricted visual access between speaker and listener. These investigators reported that in the condition of restricted visual access, gesture production was significantly reduced and there was an identifiable class of gestures used by aphasic individuals for the sake of efficient communication. As for the comparison on gesture production between aphasic and control groups, unlike the results presented by Le May and the colleagues (1988), Gloss's group (1986) showed that aphasic and control participants did not differ in the rate of gestural communication in the face-to-face interaction condition, and that gestural complexity showed a significant negative correlation with measures of linguistic impairment in aphasic patients.

Feyerisen (1983) also studied gesture production in 12 aphasic subjects and six normal controls in a setting of free conversations. Across-group analysis showed that aphasic subjects - though their verbal behaviour was impaired - produced more speech-related gestures than normals. Within-group analysis among the aphasic participants indicated that there was no difference as regards gesture frequency and gesture/word ratio between fluent and non-fluent patients, and that verbal fluency was not a critical predictor of gesture production. The author concluded that in aphasic individuals an increased gestural production serves as a cue for resolving verbal encoding difficulties.

Taken together, these divergent findings presented conflicting views on gesture abilities of aphasic patients. On one hand, some studies (*eg*, Saygin, Wilson, Dronkers & Bates, 2004) refute the notion of central symbolic dysfuntion, given that deficits in action comprehension and production found in aphasic patients do not closely correlate with their linguistic impairments. On the other hand, however, one cannot definitely hold that aphasia is a domain-specific disorder, because non-linguistic impairments are indeed found in this population (see Rumiati et al., 2010 for review), and sometimes these deficits correlate with language deficits (*eg*, Glosser et al., 1989). These findings lead to conclude that the relationship between linguistic (e.g., action/object naming and word comprehension) and non-linguistic (gesture execution and pantomime comprehension) abilities in the aphasic population still needs to be further explored. In addition, some methodological issues should be taken into consideration. That is, the previously mentioned studies which investigated aphasic patients' gestural competence sampled their data either from free conversation or from conversations on predefined topics. Although implementing an experiment in a natural context enables to elicit as many communicative gestures as possible, it also creates methodological variability which may later on yield confounding results. It is therefore difficult to generalize the reported findings and to interpret gestural ability found in the aphasic population at large.

In summary, aphasic individuals who have problems in communicating through language need an alternative communication strategy to help them with daily communicative needs. Research demonstrated that even if they receive linguistically-based treatments to remediate linguistic impairments, aphasic patients still encounter difficulty in daily communication (Rose, 2006). Several research groups and clinical aphasiologists proposed to encourage aphasic patients to employ gestures as an alternative means of communication, to compensate their inefficiency in verbal language. However, in order to be effective, the proposal of exploiting gesture use as an alternative communicative strategy to language presupposes a thorough understanding of the relation between gesture and language in the normal subjects and in the aphasic population.

Speech production is a cognitive demanding task (Levelt, 1989). Healthy speakers might encounter problems at any of these speech production stages, being interrupted with their utterances with hesitation, restarts, or fillers (Clark & Fox Tree, 2002; Schachter, Christenfeld, Ravina, & Bilous, 1991). It has been suggested that cognitively unimpaired subjects use gestures at junctures in their communicative activities when language information is less than optimal, and that they use different types of gestures under different circumstances. Kita and Özyürek (2003) showed that spatial deictic gestures deliver information which is difficult to be described by verbal language. Similarly, Hostetter, Alibali, and Kita (2001) reported that speakers gesture more when describing difficult-to-conceptualise information than when describing easy-to-conceptualise information. Krauss, Chen, and Chawla (1996) attributed gesture production as a result of lexical accessing difficulty. They hypothesised that iconic gestures - those convey referential characteristics of a to-be-named word - directly facilitate lexical retrieval processes. Gestures as such, according to the authors, originate in the processes that precede conceptualisation of the preverbal message. Producing gestures specifically activates spatially and dynamically related information which later on facilitates lexical research. If it is true that gestures are used to enhance communication when language is unavailable or not fully effective, and that verbal production and gesture production are two independent channels, one could predict that aphasic subjects - given that they are limited by their verbal production impairments - would produce more representational co-speech gestures than normal subjects to assist themselves in verbal language production. One step further, one could expect to observe correct or at least appropriate representational gestures time-locked to difficult-to-name words, being used to compensate or facilitate word retrieval in aphasic subjects.

To test our hypothesis, two groups of participants were recruited: four patients in the aphasic group and four healthy speakers in the control group. They were asked to watch eight short film clips adapted from the cartoon "Tweety and Sylvester" and then retell what they had seen. Both their verbal and non-verbal production were recorded and analysed. A detailed description of the experimental setting, of the clinical and linguistic profile of each subject, of data analysis techniques and of the study results is reported in the following chapter.

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3. Study One: The Co-speech Gesture Study

This chapter reports the co-speech gesture study in aphasic patients and in healthy speakers. The gestural ability of aphasic patients in comparison with healthy controls was examined by a story-retelling task. Qualitative and quantitative analyses of representational and non-representational gestures co-occurring with verbal production were conducted. A detailed description of the experimental setting, of the clinical and linguistic profile of each subject, of data analysis techniques and of the study results are provided. This study shows that there are no significant qualitative/quantitative differences between aphasic and non-aphasic participants in terms of either representational and non-representational gestures in the story retelling task.

Methods

This study was approved by the ethical committee of University of Trento and is in compliance with the Helsinki Declaration. Consent forms of participation were signed by patients and their family members before the study initiated.

Participants

Four aphasic patients (three females, one male) and four age-matched healthy speakers (three female, one male) participated in this project. The aphasic participants were those who enrolled in logopedic and physical therapies at our Neurocognitive Rehabilitation Center (CeRiN) and were invited to participate this study as volunteers after they had completed their clinical treatment. All aphasic participants met the following inclusion and exclusion criteria: all of them are aphasic in a chronic stage; they sustain left hemisphere stroke(s) at least 12 months prior to the study; all of them demonstrate word-finding difficulty caused by an impairment at the phonological level or the semantic level; they reported to be right-handed pre-morbidly; Italian is the primary language. Summarized demographic information and synthesized clinical data are presented in Table 1.

Four healthy speakers with no record of neurological or psychiatric illness formed the comparison group (age range 52-76). All of them are right-handed with Italian as their primary language.

Table 1. Demographic data and synthesized initial clinical data

	SYH	MAD	PAS	FIP
gender	female	female	male	female
age	66	61	60	78
handedness	right	right	right	right
years of education	13	13	11	10
etiology	ischemic CVAs	hemorragic CVA	ischemic CVA	ischemic CVA
months post onset	24	48	156	37
hemiparesis	right	right	right	NA
memory	at border	at border	under norm	under norm
attention	within norm	within norm	within norm	within norm
praxic ability	within norm	within norm	apraxic*	within norm

* PAS demonstrates buccofacial apraxia.

Procedure

Each participant was informed that they were participating in a story telling experiment. The focus of the experiment was story narration and that the study involved their performance on retelling the given cartoon stories after watching eight short cartoon episodes. She/he was instructed to watch the cartoon clips with attention and remember the stimuli as well as possible so that they would be able to narrate what happened in the given episodes to the experimenter with details. Gesture was not mentioned in the instruction. These episodes were shown on a computer monitor one after another intervened by the participant's story retelling right after she/he watched a given episode. Note that while listening to the participant retelling the story, the experimenter sat quietly next to the video camera. The experimenter only provided back-channel feedback (*eg*, nodding or saying "uh-huh") occasionally, without giving any cues or questions during the story-retelling task. The participant was also informed that the entire experimental session would be videotaped with a camera. All participants - including patients and normal controls - signed a consent form for the experimenters to use their data in the study.

Materials

The stimuli were composed of eight short film clips excerpted from the American cartoon "Tweety and Sylvester". The mean duration of the episodes was 47.6 seconds (range 35-76 sec.). In each episode, Silvester (a cat) attempted to catch Tweety Bird (a canary) in a different way. See the Appendix 1 for further details about the content of all episodes and McNeill (1992) for a scene-by-scene description of the cartoon.

Transcribing speech

The transcription method was adapted from Alibali and Heath's (2001) study. The participant's narration from all eight episodes was transcribed from the videotape. All their verbal production, including filled pauses (*eg*, "um"), word fragments, and repeated words were transcribed. As the speech was transcribed, the transcripts were divided into units. Each transcript unit was composed of a verb and its associated arguments and modifiers, with the exception that prepositional phrases were treated as separate units if they were set off from the main clause by a pause. Following are two examples to better explain the transcription procedure. Each example consists of two units, with the break between units marked by a slash:

(a) “the cat gets thrown out the window / and falls down to the street”

(b) “he’s back in his room (pause) / right across the way from Tweety”

Identifying and coding gestures

Similar to the speech transcription part, gesture identification and coding system was adapted from Alibali and Heath’s (2001) study. All the hand movements that each participant produced with each unit of the verbal transcript were identified from the videotape and later on coded. Each unit was viewed repeatedly in both regular and slow motion in order to identify the gestures. In the most cases, the hand(s) returned to rest position after each individual gesture. When successive gestures were produced without the hand(s) returning to rest position, the boundaries between gestures were determined according to changes in the hand-shape, motion, or placement of the hand(s). Each individual gesture was then classified either as a representational gesture or a non-representational one.

Gesture categorization

As mentioned above, each individual gesture was categorized either as a representational gesture or a non-representational one. Representational gestures include the following five sub-categories: (1) iconic gestures; (2) metaphoric gestures; (3) spatial deictic gestures; (4) literal deictic gestures; and (5) emblems. Non-representational gestures were sub-categorized into beats and self-touches. Most researchers are in concordance that deictic or pointing gestures - which identify real or abstract entities or locations in space - often contain communicative intention. Deictic gestures produced in lieu of speech or with deictic referring expressions such as "here" or "there" are especially uncontroversial (Melinger & Levelt, 2004). Iconic gestures - defined in McNeill (1992) - also known as lexical gestures. Gestures as such share a transparent relationship with some semantic aspect of the concurrent speech, often representing concrete or abstract entities, traits, or activities. Definitions of each subcategorized gestures and the examples are provided in Table 2.

Table 2. Definitions & examples of representational & non-representational gestures

Representational Gestures	
Iconic	Gestures that depict concrete referents (e.g., making climbing motions with the hands to convey "climb")
Metaphoric	Gestures that depict abstract referents metaphorically or indicate spatial locations to metaphorically refer to characters, locations, or parts of the story (e.g., gently waving the hand back and forth to represent "music" or pointing to the left to indicate Tweety and to the right to indicate Granny)
Spatial Deictic	Gestures that convey direction of movement (*e.g.*, pointing upward to covey upward movement)
Literal Deictic	Gestures that indicate concrete objects in order to refer to those objects or to similar ones (e.g., pointing to a wooden desk in order to indicate a piece of wood)
Emblem	Gestures that have a conventional form or meaning (e.g., holding up the index and middle fingers to mean "two")

Table 2. Definitions of representational & non-representational gestures (cont.)

	Non-Representational Gestures
Beat	Beats are motorically simple, rhythmic gestures that do not depict semantic content related to speech. Beat gestures have only up and down movement phrases, and most of them are produced using one hand in a loose, untensed handshape.
Self Touch	Gestures produced when the participant use hand(s) to touch other body parts or scratch

The recorded video registration from all participants was transcribed and coded by the experimenter right after data collection. Consequently, another trained rater went through the entire data independently. Only the agreed entries were used for data analysis. A third trained rater examined 25% of data randomly.

Data analysis

Behaviour measures including verbal measures and non-verbal measures were collected. Verbal measures include the words which participants articulated, and non-verbal measures include all gestures participant produced along their speech. Verbal measures were recorded according to the duration of the verbal productions in minutes. Number of words uttered by participants was counted. For normal controls, only lexical entries were considered as words. Fillers such as "hum" were not counted as words. For aphasic subjects, we considered both lexical entries and those "nearly misses", for instance, words containing phonemic errors but could be clearly identified as target words. Non-verbal measures included six types of gestures - iconic, spatial deictic, metaphoric, literal deictic, beat, and self touch. The frequency of gesture was measured by counting number of times per minute period. When the onset of one hand was observed during a gesture of the other hand, two gestures were counted (one per hand). For example, participant used his/her right hand to produce an iconic gesture to illustrate the shape of a long wooden board and his left hand to produce a spatial deictic gesture to illustrate the action "jump".

Case reports

Brief demographic and clinical profiles of the four aphasic participants of this study are presented in the following paragraphs.

Case 1: MAD

MAD is a 65-year-old right-handed female with 13 years of schooling. She suffered a cerebrovascular accident in September 2006. When she participated this project she was at 48 months post onset. MAD was anomic given by deficits at the phonological level. Her spontaneous verbal production was characterized by anomic pauses and sublexical errors. She had more difficulty in naming verbs respect to naming nouns.

Case 2: PAS

PAS is a 60-year-old right-handed male with 13 years of schooling. He suffered a cerebrovascular accident about 13 years ago. PAS demonstrated phonologically based naming impairment which was featured by long anomic pauses and segmented errors. Pre-treatment linguistic assessment results demonstrated that his comprehension ability on auditorially presented stimuli was within norm. In order to assess his semantically related word knowledge, Semantic Questionnaire designed by Laiacona and the colleagues (1993) was administered to further verify whether his naming deficit was caused primarily at the lexical or at the conceptual level of language production system. His performance on the Semantic Questionnaire was within norm.

Case 3: FIP

FIP is a 78-year-old right-handed female with 10 years of schooling. She suffered a cerebrovascular accident in August 2007. When she participated this project she was at 37 months post onset. FIP could speak fluently and was able to use rather complex syntactic structure. However, the information amount of her verbal production was limited given by word finding difficulty and constant use of semantically weak words (*e.g.*, light verbs, such as go and do). Her naming performance was featured by long anomic pauses and semantic errors. She had more difficulty in naming verbs respect to naming nouns. To further verify her semantic impairments, Laiacona and colleagues' (1993) Semantic Verbal Questionnaire was administered. Out of 480 items FIP made 69 errors in total, surpassing the pathological threshold (correct response <447).

Case 4: SYH

SYH is a 66-year-old right-handed female with 13 years of schooling. She suffered two cerebrovascular accidents in May and in July 2008, respectively. When she participated this project she was at 24 months post onset. SYH's verbal production was featured by a large amount of neologism and morphological errors. She had more difficulty in naming verbs respect to naming nouns. In terms of spontaneous language production, she was barely communicative given by frequent anomic pauses, numerous neologism, and fragmented errors. Her comprehension, however, was rather intact.

Results

The main scope of this study is to tackle the question: Does aphasia influence gesture production? To answer this question, two groups of participants were recruited, four patients in the aphasic group and four healthy speakers in the control group. They were asked to watch eight short cartoon clips and then retell what they had seen. Both their verbal and non-verbal production were recorded and analysed accordingly. We analysed and compared the non-verbal data at an individual level in the patient group and at a group level between the patient group and the control group from three perspectives: (1) the rate of representational gestures per 100 words versus the rate of non-representational gestures per 100 words; (2) the rate of representational gestures per minute versus the rate of non-representational gestures per minute; (3) gesture subtype analysis, teasing apart different types of co-speech gestures the participant produced in their narration task (spatial deictic, metaphoric, iconic, beat, etc. For the definitions of the gesture categories, see the previous section for details). We also conducted qualitative and individual analyses in aphasic subjects to examine whether gestures could facilitate or compensate when a target word was failed to be retrieved in the story-retelling task.

If as stated by the researchers supporting the stance that aphasia is not only a speech disorder but also extends beyond verbal comprehension and production (e.g., Duffy & Liles, 1979), aphasic individuals are expected to demonstrate similarly compromised output in gesture: that is, producing fewer number of gestures when compared with their normal counterparts or even unable to use gestural communication system. In contrast, if as other investigators suggested that the verbal and the non-verbal channels of communication are essentially separate and independent (*eg*, Feyereisen,

1983) and therefore using gesture might be an effective means to assist communication, there should not be difference between aphasic and normal subjects in terms of the number of gesture produced along their narration. Feyereisen (1983) further hypothesized that aphasic individuals should produce more gestures respect to non-aphasic ones, because gesture production has direct influence on verbal fluency: aphasic subjects may produce more gestures than normal subjects given that gesturing help them with verbal fluency when they encounter speech encoding difficulties.

Referring to previous studies which investigated co-speech gestures (*e.g.*, Alibali & Heath, 2011), the rate of gesture per minute of speech was used. Nevertheless, it is important to consider the appropriateness of using the rate of gesture per minute as the exclusive analysis, considering that in a normal situation, people already speak at different rate, and that in this study, especially, half of the subjects were aphasic individuals who have difficulty in producing verbal language and needs more time to find words when they were requested to fulfil the task. To avoid this interpretive difficulty, we chose to use the rate of gesture per 100 words as our primary dependent measure. However, we also report findings for gesture per minute in order to further verify whether the same pattern would be found with a different analysis method. Additionally, after examining the difference of gesture ability between aphasics and normal controls at a group level, we presented data points from each aphasic participant in contrast to the data from the normal controls as a group, considering each of the aphasic participants as a single case. In the following paragraphs, we will first report the rate of representational gestures per 100 words, and then the rate of non-representational gestures per 100 words. Following this, the rate of representational gestures and non-representational gestures per minute will be presented. In the end, qualitative analyses in aphasic individuals are reported.

Rate of representational gestures per 100 words

In this analysis, we calculated the number of representational gestures produced by each subject when they narrated each episode at a rate per 100 words. For the group analysis, we averaged the number of produced representational and non-representational gestures across eight episodes then across four subjects in each group in order to make a comparison between aphasic and non-aphasic subjects. The aphasic group produced higher cross-episode mean rate of representational gestures (N=326, cross-episode mean rate=8.39, SE=1.16) respect to the control group (N=165, cross-episode mean rate=4.50, SE=0.83). Two-way mixed factorial ANOVA was further used to analyse the data. No significant effect was found given by subject type ($F(1,6)=2.604$, $p=.158$).

Figure 2 reports the rate of representational gestures per 100 words in two groups. Table 3 and Figure 3 present mean rates and standard errors in each episode. Two way mixed factorial ANOVA showed that there was a significant effect caused by episode ($F(7,42)=5.664$, $p<.001$). Figure 4 illustrates individual performances of four aphasic patients in comparison to the group mean rate of non-aphasic counterpart.

Rate of non-representational gestures per 100 words

Similar to the analysis performed previously, we calculated the number of non-representational gestures produced by each subject while they retold the story of each episode. We then averaged the number of produced gestures across four subjects in each group in order to make a comparison between the aphasic and non-aphasic subjects. The aphasic group produced higher cross-episode mean rate of non-representational gestures (N=275, cross- episode mean rate=6.74, SE=0.70) respect to the non-aphasic group (N=161, cross-episode mean rate=4.18, SE=0.55). Two-way mixed factorial ANOVA was further used to analyse the data. No significant effect was found given by subject type ($F(1,6)=2.416$, $p=.171$).

Figure 5 presents the rate of non-representational gesture per 100 words in two groups. Table 4 and Figure 6 present mean rates and standard errors in each episode. Two-way factorial ANOVA showed that there was no significant difference across episodes ($F(7,42)= 1.267$, $p=.29$). Figure 7 illustrates individual performances of four aphasic patients in terms of non-representational gestures per 100 words in comparison to the group mean rate of non-aphasic counterpart.

To summarize, when we used per-100-word account to evaluate co-speech gesture performance, we found that there are no significant differences between aphasics and controls for either representational or non-representational gestures. Three out of four aphasics (PAS, FIP and SYH) produced more representational gestures than controls. Also, an episode effect was observed for representational gestures. This is however not the case in non-representational gestures.

Figure 2. Group comparison on the rate of representational gestures per 100 words

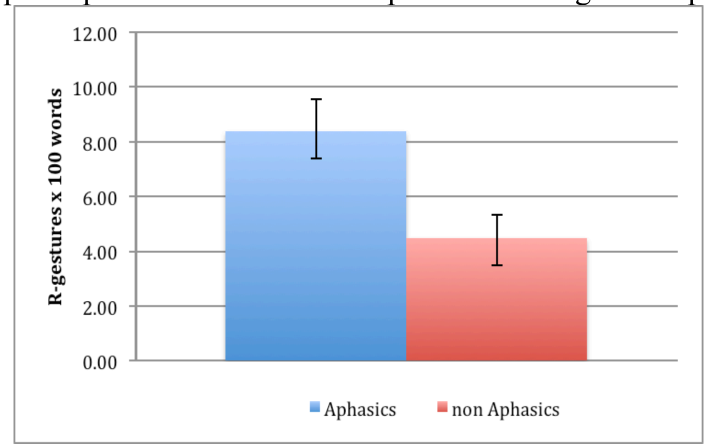

Figure 3. Rate of representational gestures per 100 words across 8 episodes

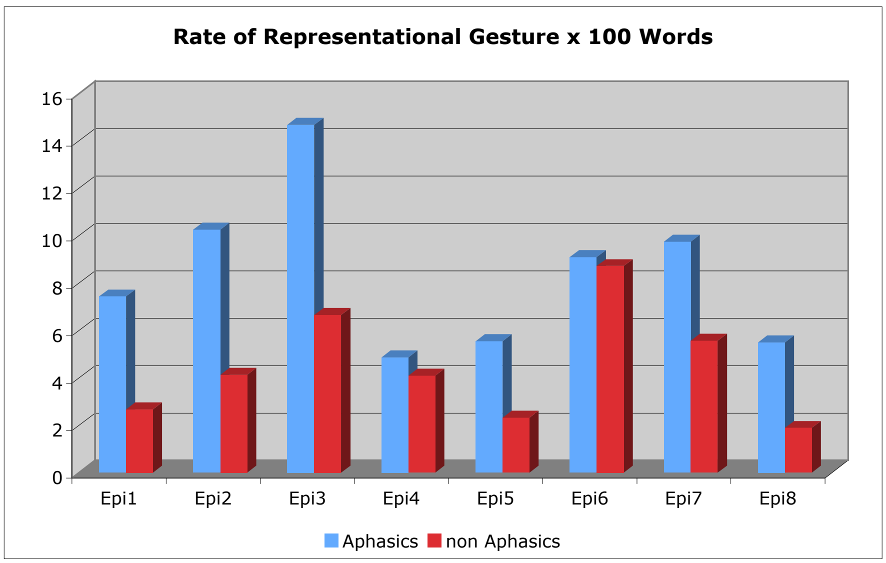

Figure 4. Individual performance of the aphasic group

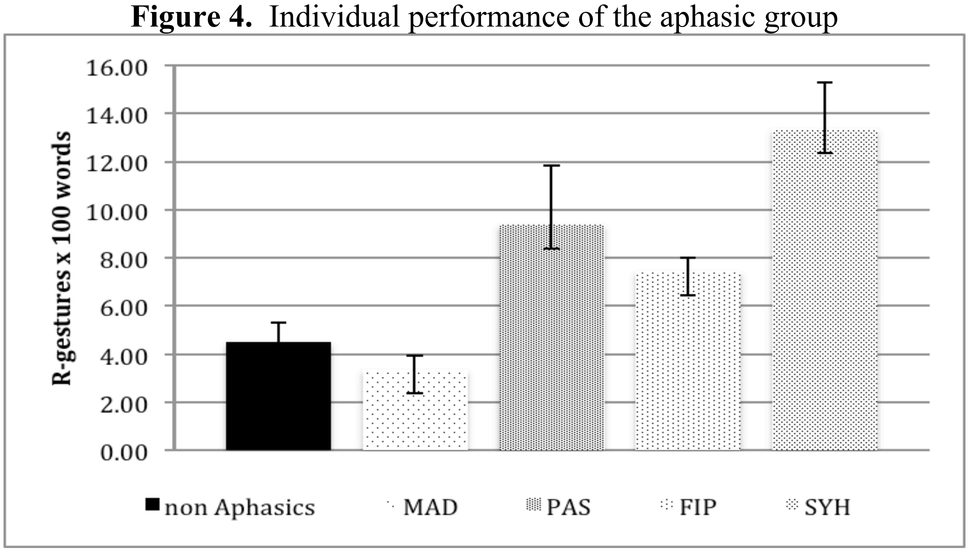

Figure 5. Group comparison on the rate of non-representational gestures per 100 Words

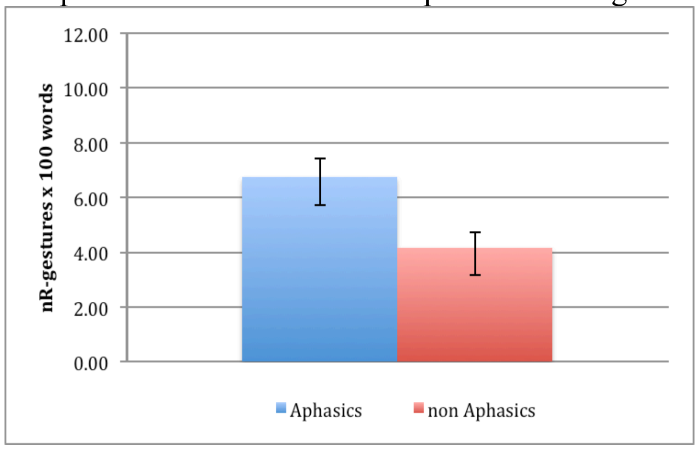

Figure 6. Rate of non-representational gestures per 100 words

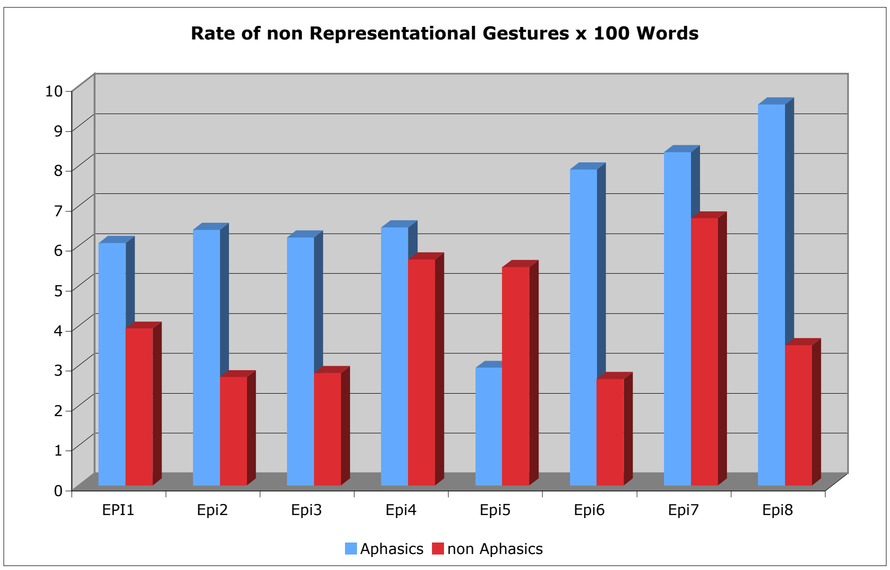

Figure 7. Individual performance of the aphasic group

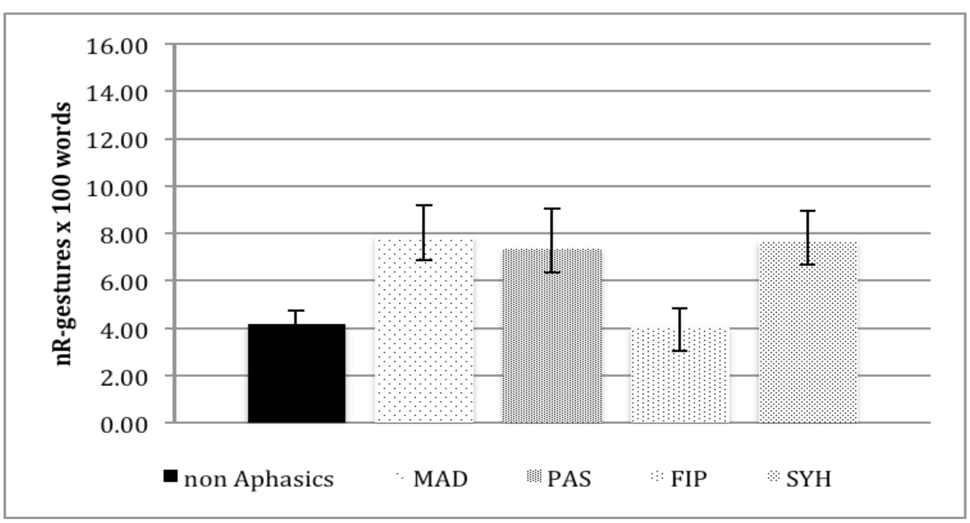

Table 3. Representational gestures produced per 100 words across 8 episodes

	Aphasics		Non-Aphasics	
	Mean	SE	Mean	SE
Episode 1	7.44	2.72	2.67	1.39
Episode 2	10.25	2.53	4.12	1.50
Episode 3	14.68	4.57	6.66	2.69
Episode 4	4.86	1.08	4.09	1.32
Episode 5	5.55	2.50	2.31	1.64
Episode 6	9.09	2.86	8.72	1.35
Episode 7	9.75	2.44	5.57	1.50
Episode 8	5.50	1.32	1.89	0.80

Table 4. Non-representational gestures produced per 100 words across 8 episodes

	Aphasics		non Aphasics	
	Mean	SE	Mean	SE
Episode 1	6.07	1.66	3.93	1.84
Episode 2	6.41	1.22	2.71	1.28
Episode 3	6.21	2.14	2.81	1.16
Episode 4	6.47	0.70	5.66	1.45
Episode 5	2.95	1.45	5.47	2.21
Episode 6	7.92	2.47	2.66	1.24
Episode 7	8.35	2.18	6.69	2.13
Episode 8	9.54	2.64	3.52	1.53

Rate of representational gestures per minute

To see whether the same pattern would be observed when data were analysed in terms of gesture per minute, we performed an identical procedure as in analysing gesture produced per 100 words, that is, calculating representational and non-representational gestures produced in each episode, respectively, and then averaging across episode to obtain mean rates of gesture per minute of each group. Respect to aphasic group (cross-episode mean rate=4.27, SE=0.35), non-aphasic group produced a higher cross-episode mean rate of representational gestures per minute (mean=5.95, SE=1.11). Two-way factorial ANOVA was performed. The result showed that there was no significant subject effect (F(1,6)=.587, *p*=.473/F(1,6)<1, *ns'*).

Figure 8 presents the rate of representational gestures per minute in two groups. Table 5 and figure 9 present mean rates and standard errors in each episode. A significant episode effect ($F(7, 42)=4.268$, $p=.001$) was found after two-way factorial ANOVA was performed. Figure 10 illustrates individual performances of four aphasic patients in terms of representational gestures per minute in comparison to the group mean rate of non-aphasic counterpart.

Rate of non-representational gestures per minute

Similar to the representational-gestures-per-minute analysis, we calculated the number of non-representational gestures produced by each subject while they retold the story of each episode at the per minute basis. We then averaged the number of produced gestures across four subjects in each group in order to make a comparison between aphasic and non-phasic subjects in terms of gestures per minute. When the comparison was made, it is observed that non-aphasic group produced higher cross-episode mean rate in terms of non-representational gestures per minute (mean=5.53, SE=0.71) respect to the aphasic group (mean=3.48, SE=0.32). Two-way factorial ANOVA showed that there was no significant subject effect ($F(1,6)=.855$, $p=.391$/$F(1,6)<1$, *ns'*).

Figure 11 presents the rate of non-representational gestures per minute in two groups. Table 6 and Figure 12 report mean rates and standard errors of non-representational gestures produced per minute in each episode. No significant episode effect ($F(7,42)=2.208$, $p=.053$) was observed when the data were analysed by two-way factorial ANOVA. Figure 13 illustrates individual performances of four aphasic patients in terms of non-representational gestures per minute in comparison to the group mean rate of non-aphasic counterpart.

To summarize, normal participants produced more representational gestures than aphasic ones when the analysis was performed on the basis of gestures per minute. However, no significant difference was shown between two groups when analysing representational gestures at a group level. An episode effect was noted, given that normal controls produced more representational gestures in certain episodes (*e.g.*, in Episodes - 3 and 4 and, marginally, 7). When non-representational gestures are analysed, there is a group effect, as controls produced more such gestures than aphasics, especially in Episodes-1, 4, 5, and 7).

Table 7 reports the total numbers and proportion of all observed gestures in two groups. All co-speech gestures are listed according to the categories (iconic, spatial deictic, beat etc.). Total numbers of produced gesture, the proportion of each gesture categorie, mean rates of representational and non-representational gesture per 100 words, and per minute of each type are reported here.

Figure 8. Group comparison on the rate of representational gestures per minute

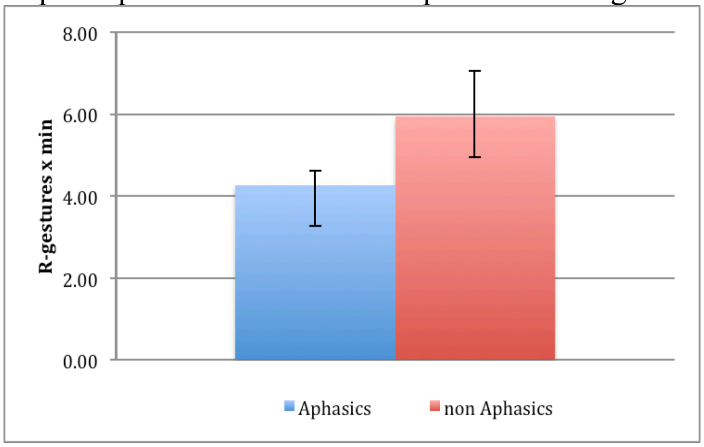

Figure 9. Rate of representational gestures per minute

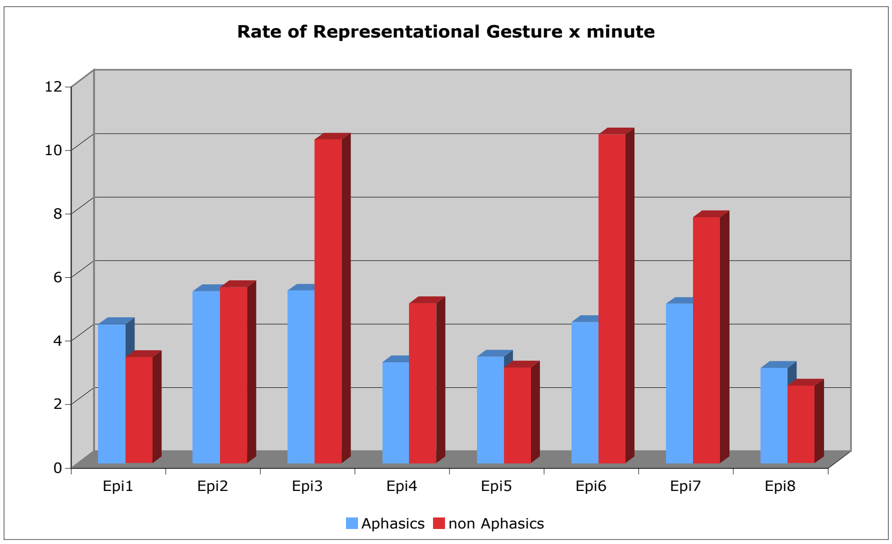

Figure 10. Individual performance of the aphasic group

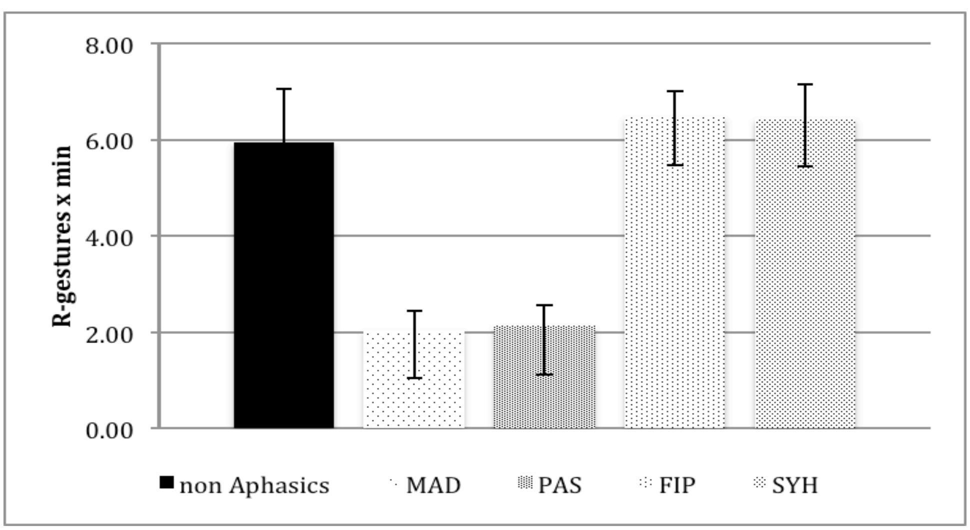

Figure 11. Group comparison on the rate of non-representational gestures per minute

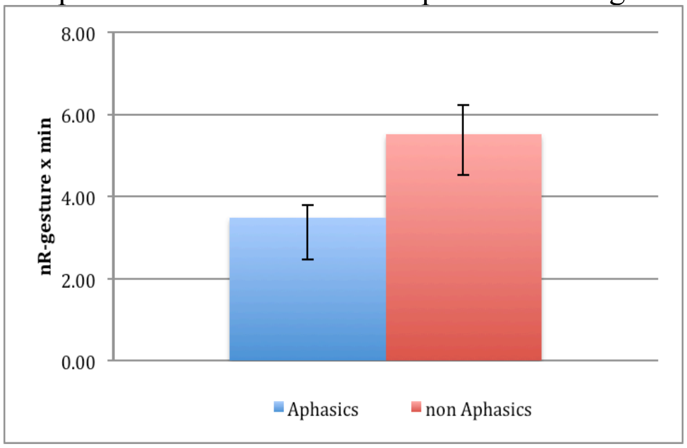

Figure 12. Rate of non-representational gesture per minute

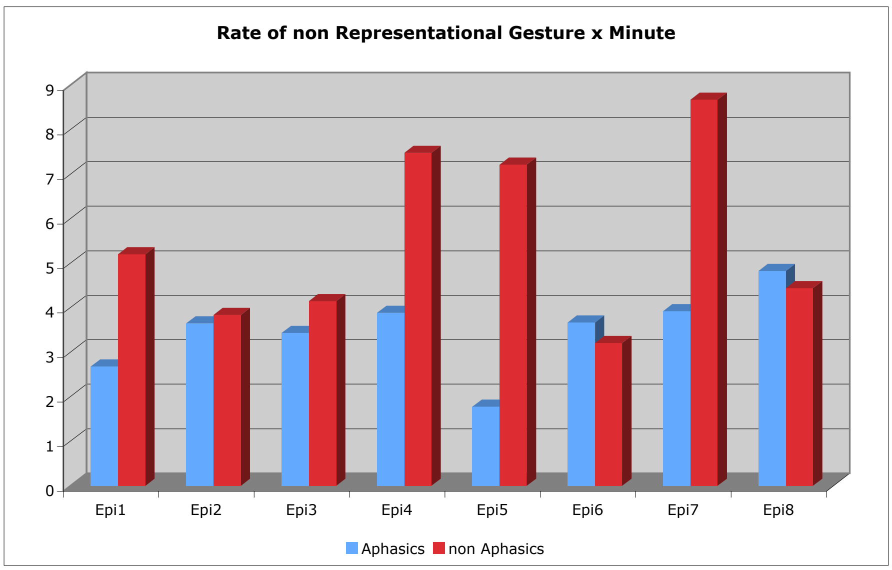

Figure 13. Individual performance of the aphasic group

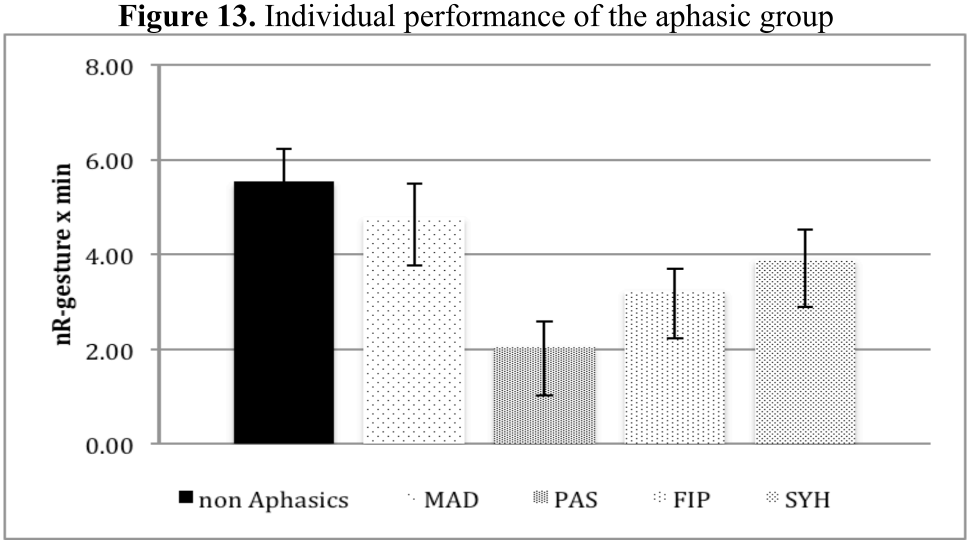

Table 5. Rate of representational gestures per minute

	Aphasics		Non-Aphasics	
	Mean	SE	Mean	SE
Episode 1	4.37	2.07	3.34	1.85
Episode 2	5.42	1.03	5.54	2.30
Episode 3	5.43	1.46	10.19	4.44
Episode 4	3.17	1.16	5.03	1.48
Episode 5	3.35	1.53	3.01	2.12
Episode 6	4.44	1.49	10.35	2.19
Episode 7	5.01	1.31	7.74	2.48
Episode 8	3.00	0.81	2.43	1.11

Table 6. Rate of non-representational gesture per minute

	Aphasics		Non-Aphasics	
	Mean	SE	Mean	SE
Episode 1	2.68	0.51	5.21	2.72
Episode 2	3.65	0.85	3.84	1.90
Episode 3	3.43	1.37	4.15	1.89
Episode 4	3.89	0.79	7.48	2.28
Episode 5	1.77	0.76	7.21	3.19
Episode 6	3.67	1.26	3.20	1.65
Episode 7	3.92	0.99	8.67	2.56
Episode 8	4.82	0.97	4.44	2.13

Table 7. Total numbers and proportion of all observed gestures

Frequency of Gestures	Aphasics		Non-aphasics	
	MEAN	SE	MEAN	SE
Iconic				
total number	119		57	
gersture per 100 words	2.69	0.36	1.57	0.29
gesture per minute	1.45	0.24	2.04	0.39
proportion of total gesture	**20%**		**18%**	
Spatial Deictic				
total number	132		74	
gersture per 100 words	3.91	0.65	1.99	0.32
gesture per minute	1.81	0.25	2.62	0.46
propotion of total gesture	**22%**		**23%**	
Metaphoric				
total number	69		34	
gersture per 100 words	1.66	0.27	0.94	0.18
gesture per minute	0.96	0.18	1.29	0.27
propotion of total gesture	**12%**		**10%**	
Literal Deictic				
total number	6		0	
gersture per 100 words	0.18	0.11	0	0
gesture per minute	0.07	0.04	0	0
propotion of total gesture	**1%**		**0%**	
Beat				
total number	169		127	
gersture per 100 words	4.13	0.47	3.24	0.51
gesture per minute	2.26	0.28	4.19	0.66
propotion of total gesture	**28%**		**39%**	
Self Touch				
total number	106		34	
gersture per 100 words	2.62	0.48	1.04	0.27
gesture per minute	1.20	0.21	1.46	0,39
propotion of total gesture	**18%**		**10%**	

Percentage of word finding difficulty solved by gestures

The results of our quantitative analyses showed that aphasic subjects could produce gestures, and that as a group, the gestures they produced are not different quantitatively from the normal controls. However, these results did not give us solid grounds to conclude that aphasics gesture like normal. For example, aphasics might produce the same number of gestures, but gestures may be all wrong, or may be used at an inappropriate juncture (*e.g.*, a self-touch when a metaphoric or iconic gesture would be appropriate). In order to be able to verify whether aphasics indeed use gestures like healthy speakers, not only in terms of quantity but also in terms of quality - as suggested by the researchers who proposed that aphasic patients produce gestures to facilitate the retrieval of phonological word forms from the mental lexicon during speaking (Hadar & Butterworth, 1997; Krauss, Chen, & Gottesmann, 2000) – we further performed a qualitative analysis by investigating individual performance of the participant who have word-finding difficulty in the aphasic group. The aim is to see how many representational and non-representational gestures were used as a substitute for difficult-to-be-named verbs or for nouns or as cues to assist word retrieval in the aphasic subjects. Table 8 reports total counts of word-finding difficulty (WFD) observed from each aphasic participant along the story-retelling task and how WFD was solved. To be more specific, total counts of WFD means the counts of patient's attempts to produce a word but with difficulty in retrieve it (*i.e.*, long anomic pauses, conduit d'approches etc.). The WFD solutions are categorised as following: total counts of WFD solved by correct representational gestures (+R) and the percentage (reported in parenthesis); solved by incorrect representational gestures (-R); solved by non-representational gestures (nR);

solved without gesture(s); substitute with +R; substitute with –R; substitute with nR; WFD not solved; and others, for example, using verbal circumlocution to replace for a given target word or “I don’t know”.

Table 8. Percentage of word-finding difficulty solved by gestures in aphasics

	MAD	PAS	FIP	SYH
Number of WFD	N= 59	N= 126	N= 50	N= 71
Solved by +R	11 (19%)	29 (23%)	19 (38%)	11 (15%)
Solved by -R	0 (0%)	0 (0%)	0 (0%)	1 (1%)
Solved by nR	39 (66%)	16 (13%)	4 (8%)	3 (4%)
Solved without gesture	6 (10%)	12 (9%)	6 (12%)	7 (10%)
Substitute with +R	0 (0%)	42 (33%)	18 (36%)	32 (45%)
Substitute with -R	0 (0%)	0 (0%)	1 (2%)	1 (1%)
Not solved	2 (3%)	19 (15%)	1 (2%)	14 (20%)
Others	1 (2%)	8 (6%)	1 (2%)	2 (3%)

By calculating how many representational and non-representational gestures were used as a substitute for difficult-to-be-named verbs or for nouns or as cues to assist word retrieval, we found that during the story-retelling task aphasic subjects tended to rely on either representational or non-representational gestures to solve their naming difficulty. In three out of four aphasic subjects, (PAS, FIP and SYH), more than 50% of their WFD was solved by correct representational gestures, either by using these gestures as cues or by substituting missing words with representational gestures directly. MAD is an exception. 66% of her WFD was solved by non-representational gestures, mainly self-touches. This is in correspondence with the cross-episode individual analyses on the performance of each aphasic subject: both on per-100-word and per-minute accounts, MAD is the subject who produced the highest rate of non-representational gestures (see Figure 7 and 13).

Discussion

The present study was designed to investigate the gesture ability of aphasic individuals in comparison to healthy speakers, hoping to tackle the question: whether aphasia influences only verbal channel of communication or it impedes also other non-verbal communicative functions, such as gestures. To address this question, we recruited two groups of participants - four linguistically deficit patients in the aphasic group and four healthy speakers in the control group. They were asked to watch eight short cartoon-clips and then retell what they had seen. Both their verbal and non-verbal production were recorded and analysed accordingly. We found that, quantitatively, there was no significant difference between aphasic and healthy participants in terms of producing representational and non-representational gestures in the story retelling tasks. When evaluating on the basis of gestures per100 words, the results show that first, there are no significant differences between aphasics and controls for either representational or non-representational gestures. However, aphasic participants produced more representational gestures than controls, especially PAS, FIP and SYH; secondly, an episode effect was observed for representational gestures, but not for non-representational gestures. When analyse the rate of gesture production on the per-minute basis, it seems that controls produced more or less the same rate of representational and non-representational gestures across measures, and that aphasics - as a group - produced more representational than non-representational gestures. In general, aphasics produced more gestures per 100 words and fewer gestures per minute than normal controls. When examining the percentage of WFD solved by gestures, we observed that representational gestures served as substitution or facilitation on word retrieval in three out of four patients (PAS, FIP and SYH). However, this is not the case for MAD, who tended to use non-representational gestures to solve her word retrieval difficulty.

Interpretation from methodological perspectives

If we consider the data from a group level instead of focusing on individual data, the per-100-words and the per-minute analyses do show some differences between aphasics and controls. To be more specific, participants from the control group made almost the same amount of representational and non-representational gestures, regardless of measure (rate: 4.5 representational and 4.18 non-representational gestures per100 words and 5.95 representational and 5.53 non-representational gestures per minute). Aphasics also produce similar numbers of representational and non-representational gestures in the per-minute count (rate: 4.27 representational and 3.48 non-representational gestures/minute). However, they differ in the per-100-words-count - in this case, they produced more higher rate of representational gestures (8.39/100 words) than non-representational gestures (6.74/100 words).

Based on this observation, a methodological should be discussed. Our study used both per-100-words and per-minute analyses and demonstrated that at a group level, normal controls made the same amount of representational and non-representational gestures, regardless of different methods of measurement. However, among aphasic subjects, per-minute count did not show the difference between the rates of representational and non-representation gestures, whereas per-100-words-count rendered the picture that our aphasic patients actually produced differentiated rates on representational and non-representational gestures. Could it be the case that per-100-words-count is a better and more appropriate measure of an aphasic's gestural ability?

Per-minute measure was frequently used (e.g., content units per minute, syllable per minute, concepts per minute etc.) in investigations relating to quantifying samples on linguistically related output in aphasic individuals in contrast to normal adults (e.g., Raymer et al., 2001; Yorkston & Beukelman, 1980). However, in our opinion, a timed measure might be too harsh for aphasics, especially when they are compared to a normal speaker. An aphasic person might be at a disadvantage in terms of verbally-based output because he/she speaks much more slowly given by word retrieval difficulty. Similarly with physical ability to perform certain hand-related movements: consider that many gestures normally require bimanual skills. This might entail either more difficulty in producing gestures in aphasics who are hemiparetic or hemiplegic or at least less spontaneity, because he/she is searching for an intended gesture to produce - much as making pauses to search for a difficult word. By contrast, a per-100-words measure might be preferable to examine the occurrence of specific gesture types. For example, the ability and appropriateness in producing representational gestures is best measured by the per 100 words method, as this allows to count how many words were produced, how many gestures in each category (*eg*, iconic, spatial deictic, metaphoric etc.) were produced to specifically compensate for measurable word finding pauses, and how many of these gestures were effective.

The relation between aphasia and gesture production

The results of the current study demonstrate that although aphasic subjects are impaired with verbal production, they are not necessarily compromised with gesture production. Instead, the observation on representational and non-representational gestures based in per-100-words-count and on how word finding difficulties were solved in individual patient suggests that verbally impaired subjects have greater reliance on representational gestures to compensate for word finding deficits. These findings do not support the notion (e.g., Cicone et al., 1979; Glosser et al., 1986) that there is a central organizer which controls both linguistic and non-linguistic communication modality, and that aphasic persons are impaired with both linguistic and gestural competence in communication. By contrast, our results are in line with previous studies which advanced that linguistic deficits do not necessarily influence gestural ability of aphasic individuals (Le May et al., 1988) and that aphasics though impaired with verbal production, they produce no less speech-related gestures than healthy speakers (Feyereisen, 1983).

Our findings enabled us to confirm uncorrelated verbal and non-verbal performance and dissociations between linguistic and non-linguistic deficits in population with acquired language disorders. This is in line with an array of previous neuropsychological documentations (*e.g.*, Bell, 1994; Goodglass &Kaplan, 1963; Kertesa et al., 1984; Papagno et al., 1993; Wang & Goodglass, 1992). For example, Goodglass and colleagues employed verbally prompted tests to investigate transitive and intransitive pantomime production as well as pantomime comprehension in aphasic persons. They reported that the two task performances were not correlated (Goodglass & Kaplan, 1963; Wang & Goodglass, 1992). More recently, Papeo and colleagues (2010) observed double dissociations between the ability to imitate pantomimes and the ability of action word comprehension and production. When patients' performances were analysed at the single-case level, they documented that a number of their patient participants demonstrated action naming impairment, while their action imitation remained relatively intact. At the group level, there was no correlation between action imitation and action word comprehension abilities in these patients.

Our results obtained from both quantitative and qualitative analyses help us explain how possibly gesture can cue naming, as mentioned in chapter two. This can be discussed under the model proposed by Rumiati and colleagues (2010) in which praxicon and lexicon are illustrated as two independent components and they interact both directly and indirectly. The first explanation is that activation in the praxicon (to produce gestures) can boost activation in the lexicon (to name a word) given that information from the praxicon can contribute weight to semantic knowledge and consequently activate the target phonological entry in the output lexicon. The second explanation is that correct naming response can be more easily precipitate given that the entry activated in output praxicon may re-enter the system either at the structure description level or at the input praxicon level to augment the information amount activated in the semantic system.

Episode effect in representational gestures

A significant episode effect was observed in representational gestures in aphasic and control groups in both analysis conditions (per 100 words and per minutes). In the aphasic group, when examining across all eight episodes, the higher representational gesture production mean rates were observed in the second, the third, the sixth, and the seventh episodes. An identical pattern was found in the non-aphasic group. In terms of the content (for details see Appendix 1), the above-mentioned episodes contain a certain amount of spatially related words. For example, Episode Six describes a scene in which

Sylvester sets up a catapult with a crate and a board right under Tweety's window and he tries throws the weight onto the other end of the board so that he is propelled into the air. In the end, Sylvester's landing on the board propels the weight on the other end into the air and the weight falls right on his head. Similarly, in Episode Seven, a handful words contain spatial information can be identified. The Cat Sylvester sets up a rope between his window at one side of the street and Tweety's window which is at the other side of the street. With this rope, Sylvester swings to Tweety's window in a Tarzan-style. Off he goes from his window ledge holding the rope. However, instead of arriving at the window ledge of Tweety's building, Sylvester smashes into the sidewall of the window, and falls down all the way to the ground. By contrast, those episodes (Episode - 1, -4, -5, -8) in which lower representational gesture mean rates contain much less spatially related information. Take Episode Four and Five or instance. Episode Four describes that Sylvester knocks down the monkey and desguises as a monkey to ask Granny for a penny in his cup. Sylvester tips his cap. In the end, Granny hits him on the head with an umbrella. Episode Five illustrates that Silvester disguises as a bellboy to help Granny with her bags and the covered birdcage. After he gets them, Sylvester throws away the luggage and escapes with the birdcage. In an alley he removes the cover of the birdcage and finds Granny hiding in the cage. Granny hits Sylvester badly on his head with an umbrella.

The observation - that higher rates of representational gestures were found in specific episodes with more spatial-motor related referents - can be explained by the fact that spatiodynamic action words – such as swing, catapult, wave, propel etc. - are rather abstract to describe and therefore elicited more representational gestures (eg, spatial deictic ones) during story telling. An array of research has already confirmed that speakers produce more representational gestures when describing spatially-related information which must be retrieved from memory respect to describing a spatial image that is visually present (de Ruiter, 2001; Morsella & Krauss, 2004). Evidence as such led to a conclusion that gestures may facilitate the retrieval of spatial information.

Function of gesture in aphasic communication

Various priming mechanisms have been identified in the literature pertaining to language production of healthy speakers. Depending on relationship between the prime and the target, such priming effects could be explained by a range of factors, for example, semantic priming (when the prime and the target share category membership), phonological priming (when phonological similarities are shared), and associative priming (when context of occurrence is shared). In our study, we observed that our aphasic subjects employed gestures, especially representational ones, to facilitate naming when they encountered word-finding. We explained this facilitation by activation in the praxicon which consequently boosts activation in the lexicon. Similar suggestion was also assumed by Hadar and Butterworth (1997) in their earlier study. In their model, conceptual processing enables the selection of a set of semantic features. Consequently, these features feed into both semantic lexicon and visual imagery subsystem as input to produce words and iconic gestures, respectively. In other words, according to these authors, conceptual representations are neutral in regard to sensory-motor modalities and can be seen as abstract, amodal, or propositional. In a similar vein, de Ruiter (2000) also proposed that gesture planning re-activates conceptual knowledge used for generating message.

Other cognitive neuropsychological studies also provided evidence from aphasic patients to support that gesture may facilitate lexical retrieval. Butterworth and colleagues (1981) demonstrated that a subject with jargon aphasia tended to gesture just prior to a word retrieval failure, proposing a potential role of gesture in aphasia word retrieval. Hadar and colleagues (Hadar, Burstein, Krauss & Soroker, 1998; Hadar & Krauss, 1999; Hadar, Wenkert-Olenik, Krauss & Soroker, 1998; Hadar & Yadlin-Gedassy, 1994) conducted a series of studies to investigate gesture use in aphasic persons and reported that individuals whose word retrieval failure arises from lexical-semantic and lexical-phonologic deficits use more gesture respect to patients with primarily conceptual impairments and patients of right hemisphere brain damage with visuospatial deficits, or normal controls. These investigators also reported that around 70% of gestures used by aphasic subjects occurred close to the hesitation pause caused by word-finding difficulty (Hadar, Wenkert-Olenik, Krauss & Soroker, 1998). Taken together, these studies indicated how aphasic individuals utilised gestures during word retrieval and suggested that gesture may play a role in lexical processing. If this is the case, would gestures - especially highly iconic ones - serve as effective treatment approach to improve naming performance in aphasic individuals?

Rose and Douglas (2001) studied facilitation effects given by four different types of cues on picture naming in six aphasic patients. Among these cue types - pointing (simple motor movements), gestures designed to cue articulation (complex motor movements), visual imagery processes, and iconic gestures - only iconic gestures brought in significant facilitation effect after training aphasic subjects to make iconic gestures of given objects during a picture naming task. Pointing, cued articulation, and visualisation processes did not significantly improve naming skills in these participants. The authors further proposed that gesture facilitates language production at the conceptualiser level. However, they also postulated an unsolved problem: if priming were occurred earlier in the gesture and word production process, facilitation should have been evident also with the use visualisation processes as cues, since imaging an object in mind or visualising an action associated with a given object involve in selecting and specifying spatial/dynamic features in the gesture and word production process.

Concluding remarks

In this study, we recruited four aphasic patients and four age-matched healthy speakers to perform a story-retelling task after watching eight short films from the cartoon "Tweety and Silvester". Both qualitative and quantitative analyses were performed to examine verbal and non-verbal production from the participant which was video-taped during the task. Group and individual performance on representational and non-representational gestures was analysed with per-100-word and per-minute measures. We found that in aphasic subjects, as a group, gestures were quantitatively indistinguishable from those produced by normal controls. Also, qualitative analyses demonstrated that the aphasic subjects tended to use representational gestures to cue difficult-to-name words. This supports the notion that gesture may cue naming and may be a potential treatment approach in aphasia rehabilitation. Our finding also stimulated us to further explore the potential role of gesture in comparison with two other treatment techniques used in aphasia rehabilitation. The following two chapters report the second study on the effects elicited by three types of aphasia treatments - the Gesture-based, the Language-based, and the Combined.

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4. On Aphasia Treatments

One commonly seen problem associated with aphasia given by left hemisphere stroke is word retrieval deficit. The source of breakdown leading to naming failure varies across individuals. Breakdown at the semantic level leads to impairment on word comprehension and retrieval; whereas lexical-phonological impairment entails difficulty in word retrieval with preserved comprehension abilities (Lambon Ralph, Moriarty, & Sage, 2002). Due to the pervasiveness of word retrieval deficit, a broad array of studies has investigated treatments aimed at ameliorating these impairments.

In some cases, aphasic speakers presenting with loss of language skills are able to produce meaningful gestures (Carlomagno & Cristilli, 2006). In addition, it has been claimed that gesture training can facilitate word naming (Pashek, 1997; Marangolo et al., 2010). Logopedic treatment aiming to reconstruct concepts and restore phonological information on difficult-to-name words has been widely studied; while the therapeutic role played by gesture in language recovery has been rarely considered. On top of this, it has been reported that neural networks for retrieving nouns & verbs diverge (Miceli, Silveri, Villa, & Caramazza, 1984; Druks, 2002), and the patients' response to different treatment approaches in noun and verb naming remains unclear. This study aims to compare and contrast the effects of three treatment approaches: gestural approach (G), logopedic approach (L), and combined (G+L) approach, on noun & verb naming accuracy in aphasic patients with phonological and/or semantic deficit.

Logopedic approach

The aim of the logopedic approach to aphasia treatment is to implement semantic and phonological activities to reconstruct lexical abilities in a way compatible with the normal process of word retrieval (Nickels, 2002). For example, Wambaugh and the colleagues (2001) reported that both semantic and phonological cueing treatments improve naming performance on trained words in persons with semantic, phonological, and mixed anomia. Antonucci (2009) investigated the effect elicited by Semantic Feature Analysis (SFA) - a lexical retrieval treatment which provides semantic information about concepts to facilitate access to specific word forms - in three aphasic individuals, and reported that SFA improved word retrieval abilities during discourse. Leonard, Rochon, and Laird (2008) proposed a novel phonologically-based treatment - Phonological Components Analysis (PCA) - to recover naming deficits in aphasic. During treatment, the participant was trained to identify five phonological features of the target item (i.e., rhymes with, first sound, first sound associate, final sound, number of syllables). These investigators demonstrated positive treatment outcome and suggested that PCA was useful in strengthening activation within the lexical system with a long-term effect.

Gestural approach

Treatments as such aim at either compensation or restoration of linguistic dysfunction. Gesture-based approach mainly focuses on enhancing production abilities. From a compensatory point of view, gesture may constitute an effective alternative to word retrieval failures for aphasic individuals (Rose, 2006). Skelly (1979) compiled the results from a broad array of literature pertaining to using gestures or manual signs (e.g., American-Ind sign communication system) as a treatment approach to individuals with aphasia or other severe communication disorders. This review indicated that most aphasic participants were able to learn at least a limited number of gestures and signs to express their basic needs, and that consequently, the communicative quality of their daily life was improved. Recently, Daumüller and Goldenberg (2010) implemented a therapy composed of 24 communicative gestures referring to actions (i.e., drinking, writing, opening etc.) and objects (i.e., glass, key, pencil etc.) with 23 severe aphasics. Therapy focused on familiarizing patients with the communicative functions of gestures, in order to ameliorate their daily communication. Results showed that patients with severe aphasia were able to acquire intelligible gestures to replace their impaired verbal expression. From the facilitative point of view, gesture is used in aphasic treatment as a cue to prompt or pre-stimulate (Rose & Douglas, 2001; Rose, Douglas, & Matyas, 2002) word retrieval or comprehension. In Rose and Douglas' (2001) study, five types of cues, including pointing, visualizing object, visualizing object use, cued articulation, and producing iconic gestures, were examined to explore the effect on eliciting object naming in six aphasics with word finding difficulty. Among all cue types, producing an iconic gesture was the most effective facilitator, while other types of cue did not show significant positive effects.

Combined approach

Gestural approach paired with logopedic approach in treatment resulted in significant naming improvements in some aphasic individuals (Pashek, 1997; Raymer et al., 2006; Rose & Douglas, 2001; Rose et al., 2002). The abovementioned studies documented that treatment results are greatest when gesture and verbal production are combined in training. In a case study, Pashek (1997) investigated gesture facilitation on noun and verb retrieval in an aphasic male. The investigator concluded that cued naming was most effective when the patient's training on verbal skills was accompanied by producing iconic gestures. This strategy is close to the framework of intersystemic reorganization proposed by Luria (1970): an intact modality (gesture) is paired with an impaired modality (speech) in order to facilitate improvement of the latter. In the same vein, Raymer and the colleagues (2006) examined the effects of a gesture combined with verbal treatment on single word retrieval in nine aphasic patients subsequent to left hemisphere stoke. They reported that this treatment resulted in significant improvements on naming verbs and nouns. These investigators proposed the combined treatment as a potential means to improve aphasic communication when word retrieval fails.

Verb v.s. noun retrieval

Aphasic patients with selective deficits for noun and verb naming has been reported by a broad body of neuropsychological studies (e.g., Berndt, Mitchum, Haendiges, & Sandson, 1997; Caramazza & Hillis, 1991; Laiacona & Caramazza, 2004). However, whether there are differentiated neural substrates subserving verbs and nouns is still under debate. Results from the two PET studies conducted by Tyler and the colleagues (2001) manifested that nouns and verbs were represented within an undifferentiated and neural networks; nevertheless, other studies (e.g., Shapiro & Caramazza. 2003a; Shapiro & Caramazza, 2003b; Shapiro, Moo, & Caramazza, 2006) demonstrated that neural networks diverge according to grammatical word class. Even though many aphasic patients show impairments of both noun and verb retrieval, empirical evidence indicates that dissociated performance on noun and verb naming which may be caused by fundamental representational and/or processing differences between the two word types (see Druks, 2002 for review). For instance, several studies reported that fluent aphasics with lesions of the left inferior temporal cortex show greater difficulty on naming nouns than verbs, whereas non-fluent aphasiacs with damage to the left inferior frontal cortex demonstrate greater deficit of verb than of noun retrieval (e.g., Miceli et al., 1984; Tranel Adolphs, Damasio, & Damasio, 2001). If this is the case, gesture-related treatment when contextualized in verb naming and in noun naming condition, respectively, might result in different treatment outcomes. Marshall (1999) reported an aphasia therapy programme which employed gesture/word mappings and successfully facilitated verb retrieval of patient EM. Based on empirical evidence from patient EM, Marshall further maintained that selectivity - that is, using gesture to impose a degree of constraint over the to-be-produced message - is essential for verb production, and that using a single gesture helps aphasic persons to be selective in formulating a constrained representation which can be subsequently mapped onto a verb. Druks (2002) suggested that networks involved in verb and action knowledge are closely linked. In the same vein, Bird and the colleagues (2000) hypothesized that a particular threshold of activation must be reached to attain production of a given word. In other words, a particular number of semantic representation must be activated to achieve word retrieval. These researchers further claimed that verbs, compared to nouns, are richer in functional features in concepts and are less imaginable. Following this logic, producing representational gestures may help concretize specific spatio-motoric or functional features and subsequently facilitates verb retrieval. Taken together, considering the close relationship between gestures, actions, and verbs, gesture-based treatment may be especially effective for verb naming.

Problems unsolved

Even it has been reported that multi-modal treatment elicited positive treatment outcome (see Rose, 2006 for review), it is still unclear whether the gesture or the language approach in isolation, or the combined gesture-language approach would be most effective in improving verb and noun retrieval. If the position taken by Pulvermüller and Berthier (2008) is true, i.e., that in aphasia therapy it is advantageous to train language in relevant contexts - the approach combing logopedic and gestural training should result in a summed-up treatment effect. This prediction, however, was not met in previous studies (e.g., Rodriguez, Raymer, & Rothi, 2006; Rose & Sussmilch, 2008). Further, how gesture facilitation might result in diverging outcomes for noun and verb naming remains to be understood. So far, most of the studies on the effects of gesture-based and language-based treatment on naming accuracy focused on nouns. Only a couple of studies investigated treatment outcome on verb naming or on both verb and noun naming (e.g., Rodriguez et al., 2006; Raymer et al., 2006). Another open question that needs to be addressed is the relation between the cognitive damage responsible for word retrieval failures and the outcome of the gesture-based approach. Rose and the colleagues (Rose & Douglas, 2001; Rose et al., 2002) showed that gestural treatment yielded different results in aphasic individuals whose naming difficulty was primarily caused by deficits at the lexical-phonological level and in subjects with semantically-based word finding impairment. Nevertheless, this differentiation was less clear in other studies (e.g., Rodriguez et al., 2006; Morgenstern et al., 2009).

Taken together, this study aimed to investigate the following questions: (1) Among gestural, logopedic, and combined approaches, which one is most effective in improve verb and noun naming accuracy? (2) How gestural facilitation might diverge for nouns and verbs? (3) What's the relation between type of cognitive damage and response to the gestural approach?

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5. Study Two: Three Treatment Approaches and Their Effects

This chapter reports the second study. The treatment study used a single-subject, multiple-baseline design to investigate the effects of three types of treatment approaches - gesture-based, language-based, and combined - on word naming, with both verbs and nouns. Four chronic aphasic patients with word-finding difficulty were recruited for this study. It was hypothesized that gesture-based and language-based treatments alone would yield positive effects, and that a combined treatment would result in the largest improvement of word naming. Treatment design, the materials used for treatment, and data analysis methods are described in detail. Results are presented in a *small group, single-case* format. Clinical profile and response to each treatment technique are individually examined and reported on. A summary of the treatment results observed in the four subjects as a group is also provided. All types of treatment, as hypothesized, led to significant, item-specific improvement on both verb and noun naming. Three out of four subjects showed the largest recovery following the combined treatment, especially for verbs. This suggests that gesture, when combined with logopedic treatment, can boost naming skills. At the end of the chapter, how gesture production interacts with word processing is discussed.

Method

This study was approved by the ethical committee of University of Trento and is in compliance with the Helsinki Declaration. Consent forms were signed by patients and their family members before the study initiated.

Participants

Four aphasic patients (two female, two male) participated in this project. These patients were enrolled in logopedic and physical therapies at the Neurocognitive Rehabilitation Center (CeRiN), and volunteered to participate in this study after completing their clinical treatment cycle. All participants met the following inclusion and exclusion criteria: they were in the chronic stage; they had sustained a left hemisphere stroke at least 12 months prior to the study; they demonstrated word-finding difficulty caused by lexical-phonological or semantic damage; they reported to be right-handed pre-morbidly; Italian was their primary language. Depending on the underlying impairment leading to word-finding difficulty, patients were further divided into two groups: deficit at the conceptual level (Con-D) and deficit at the lexical-phonological level (Phon-D). According to this criterion, three patients (SYH, CAC, and PAS) were assigned to the Phon-D group and one to Con-D group (FIP). Demographic and clinical information on these subjects is summarized in Table 9.

Table 9. Demographic data and synthesized initial clinical data

	SYH	CAC	PAS	FIP
gender	female	male	male	female
age at time of study	66	51	60	78
handedness	right	right	right	right
years of education	13	10	11	10
etiology	2 CVAs	cerebral hemorrage,	CVA	CVA
months post onset	24	36	156	37
group	Phon-D	Phon -D	Phon -D	Con-D

Study design

The study used a single-subject, multiple-baseline design and consists of five sequential phases: (1) pre-treatment evaluation; (2) collection of baseline data; (3) treatment; (4) maintenance; (5) post-treatment evaluation. The same design was used with all participants.

Pre- and post-treatment evaluation. The pre-treatment phase aimed to outline the linguistic and neuropsychological abilities in each patient. Table 10 provides a complete list of the all the tests. Only selected tasks related to linguistic ability were administered during the post-treatment evaluation, to see whether generalization to untrained language abilities was elicited by the treatment.

Table 10. A list of the neuropsychological and linguistic tests

	TEST
Cognitive impairment screening	Mini Mental State Examination (Folstein et al., 1975)
Memory	Verbal digital span (Orsini et al., 1987)
	Spatial span: Corsi Block Task (Spinnler & Tognoni, 1987)
	The Auditory Verbal Learning Test (Carlesimo et al., 1996)
	The Rey-Osterrieth Complex Figure Test (Caffarra et al., 2002a)
Attention and Visuo-spatial analysis	The Stroop Task (Caffarra et al., 2002b)
	Attentive Matrices (Spinnler & Tognoni, 1987)
Visuo-spatial & frontal assessment	Clock Drawing Test (Mondini et al., 2003)
	Frontal Assessment Battery (Consoli et al., 2002)
Logic reasoning	Raven's Progressive Matrices (Basso et al., 1987)
Praxis assessment	Buccofacial praxia (De Renzi & Faglioni, 1996)
	Ideomotor praxia (De Renzi et al., 1980)
Language assessment	Neuropsychological Exam for aphasia (Capasso & Miceli, 2001)
	Battery for Analysis of Aphasic Deficits (Miceli et al, 2004)

Baseline. The aim of baseline data collection was threefold - to target stable naming performance, to construct word lists to be used in the three types of treatment for each patient, and to serve as reference to compare performance in the maintenance phase.

All participants were asked to complete naming task that required the production of single words (verbs and nouns) for three times, without receiving cues or feedback other than general encouragement from the examiner. The items which patients systematically failed to name were later used to construct word lists for the treatment phase.

Treatment. Three types of treatment were proposed – Gesture-based (G), Language-based (L), and Combined (G+L). All treatment sessions were conducted by the first author at CeRiN. In each treatment session, the three types of training were given in a fixed order for all subjects. That is, each session started with the gesture-based approach, followed by the language-based approach and the combined approach. A treatment session lasted approximately one hour; two or three sessions per week were administered. Each patient completed eight treatment sessions for verbs and another eight for nouns.

Maintenance. Three consecutive sessions were arranged immediately after the treatment phase to see if the effect of training was maintained. In the maintenance phase, patients were asked to name the word lists used in the treatment phase without receiving any feedback. Table 11 outlines the study design in time sequence from left to right.

Table 11. Study design

NO. sessions	3	8	3	8	3	
Pre-evaluation	Baseline	Treatment verbs	Main-tenance	Treatment nouns	Main-tenance	Post-evaluation

Materials

Pre- and post-treatment evaluation. For the pre-treatment evaluation, the computerized version of the B.A.D.A. (Battery for Analysis of Aphasic Deficits, Miceli, Laudanna, Burani, & Capass, 2004) was used to assess linguistic breakdown of each patient. Various other tests, for example, Corsi Block Task (Spinnler & Tognoni, 1987), Attentive Matrices (Spinnler & Tognoni, 1987), and Gesture Imitation (De Renzi, Motti, & Nichelli, 1980), were administered to evaluate patients' neuropsychological performance on memory, attention, and praxis tasks. Table 10 provides a complete list of the tests which were used in this stage. For post-treatment evaluation, a series of single-word processing tasks from B.A.D.A. (e.g., naming verbs and nouns, comprehension of verbs and nouns) were administered to see whether the effects of the just-completed treatment resulted in generalized improvement.

Baseline. A databank containing nouns of manipulable objects (n=100) and verbs of hand-related actions (n=80) in black-and-white line drawing was used for baseline collection. Psycholinguistic variables - such as frequency, word length, number of syllables, and familiarity - of all to-be-named items were controlled *a priori*. These stimuli were presented three times for oral naming. Items that each patient systematically failed to name were collected. Of these, 60 verbs and 60 nouns were selected to construct individually tailored word lists for the treatment phase. Each 60-word list was further divided into three sets: 20 items for gesture-oriented training; 20 for language-oriented training; 20 for combined training. In each set, 10 items underwent training and the other 10 remained untrained and served as the control set. Words in each set were balanced according to each patient's baseline naming error rate. The psycholinguistic variables (e.g., frequency, word length, syllables etc.) that may influence naming performance were also considered. An identical selection criterion was applied to the noun and to the verb lists.

Treatment. Three types of treatment were carried out in the context of single-word naming tasks. Color pictures were used as stimuli to elicit oral naming. Note that the color pictures used in the treatment phase were different from those used during the baseline and maintenance phases. In Gesture-based treatment, patients were trained to produce a gesture that can be mapped onto a corresponding target word. In Language-based treatment, Semantic Feature Analysis (SFA) was used for the patient in the Con-D group and Phonological Component Analysis (PCA) was administered to patients in the Phon-D group. The combined treatment includes the same materials used in the gesture-based and language-based treatments, but materials were alternated across sessions.

For Gesture-based treatment, a protocol adapted from Rose and Douglas (2006) was used. The patient was presented a picture and was requested to produce its name, by producing a noun or a verb. The instructions "tell me what is happening in this picture with one word" in the verb condition and "tell me what is the object in this picture with one word" in the noun condition were given to elicit responses from each patient.

For Language-based treatment, Phonological Component Analysis (PCA) was administered to Phon-D group whereas Semantic Feature Analysis to Con-D group. A PCA chart was used following the protocol developed by Leonard et al. (2008). The target picture was presented at the center of the chart and the participant was asked to name it. Irrespective of his/her ability to name the target, the patient was asked to identify five phonological properties of the target item such as rhyme, first sound, associated first sound, final sound and number of syllables. An example PCA chart is provided in Appendix two. For SFA, a protocol adapted from the study conducted by Coelho and the colleagues (2000). A picture was placed at the center of the SFA chart and the patient was asked to name it. Regardless of whether the response was correct or incorrect, the patient was guided in verbalizing the semantic features of a given target with the aid of the chart and of cues from the examiner. Note that the verb and noun treatment order was interchanged among patients (i.e., SYH and PAS were trained first on nouns, then on verbs; a reversed sequence was used for CAC and FIP). Example SFA charts for object and action naming can be found in Appendix three and four, respectively.

To sum up, in a 60-minute session, each patient received three treatments: Language-based, Gesture-based, and Combine treatments. Language-based treatment relied on two techniques - SFA, which targets semantic representations; and PCA, which targets lexical representations. Gesture-based treatment relied on one technique - producing a gesture that corresponds to a target word. Combined treatment is a combination of the Language- and Gesture-based treatments with an alternated order across session.

Maintenance. Stimuli used in baseline data collection were used in the maintenance phase to assess each patient's naming performance. The object and action naming task was administered three times. No cues or feedbacks other than general encouragement from the examiner were provided.

Data analysis

All the responses produced by each patient were transcribed and coded as correct or incorrect. Only accurate response was regarded correct. With permission from the patients, all sessions were videotaped or registered for later transcription and analyses. An independent judge was invited to view and rate patients' responses from 10% of randomly selected treatment sessions. Cohen's Kappa (1960) was used as a measure of agreement and indicated that the two judges concurred above 95% for each patient. In order to estimate the effect elicited by each type of treatment, effect size (*d*) was calculated using the method suggested by Beeson and Robey (2006) for a single-subject, multiple-baseline experimental design (mean maintenance phase – mean baseline phase / standard deviation baseline phase). According to the benchmarks suggested by Robey and Beeson (2005), treatment effect sizes with values of 4.0, 7.0, and 10.1 correspond to small, medium, and large effect sizes, respectively. These effect sizes were used to evaluate the primary results of the study. Secondary results (generalization) were evaluated by comparing pre- and post-treatment neuropsychological assessment scores.

Case reports

In this section, data collected from the four patients will be presented individually in a *small group, single-case* format. Each case initiates with patient's neuropsychological and linguistic profile. Following the clinic background, patient's baseline performance, treatment materials used in his/her case, and treatment results are reported in order. Treatment outcomes were calculated by effect size (*d*), as suggested at the end of the previous section. A summary of the primary treatment results and the secondary results observed in the four subjects as a group is provided as well.

Case 1: SYH

Neuropsychological and linguistic profile. SYH is a 66-year-old right-handed female with 13 years of schooling. She suffered two cerebrovascular accidents in May and in July 2008, respectively. When she participated this project she was at 24 months post onset. Her memory, attention and praxic abilities were within norm. SYH's verbal production was featured by a large amount of neologism and morphological errors. She had more difficulty in naming verbs respect to naming nouns. In terms of spontaneous language production, she was barely communicative given by frequent anomic pauses, numerous neologism, and fragmented errors. Her comprehension, however, was rather intact.

Baseline performance. Corresponding to her performance in pre-treatment linguistic assessment, SYH's baseline performance was more impaired on verb naming than noun naming. Errors of incorrect noun responses included neologism and fragmentation. Incorrect verb naming mainly composed of morphological errors. The percentages of semantic errors were much lower respect to other phonologically related errors, showing that her comprehension was rather intact. Her detailed baseline performance is provided in Table 12.

Treatment. Given that SYH's comprehension ability was rather preserved and her incorrect responses mainly resulted in phonologically/lexically related errors, PCA was used for of Language-based treatment. In her case, verbs were trained before nouns. She was assigned to the Phon-D group.

Results. In SYH, all approaches led to a significant improvement of naming accuracy in both the noun and the verb condition. In the verb condition, the gestural and the combined approach led to big effect sizes (G: *d*=11.48; G+L: *d*=13.2), while the logopedic approach resulted in a medium-sized effect (*d*=9.75) on trained items. A limited effect was observed on untrained items. In the noun condition, all three approaches yielded large effect sizes for trained items (G: *d*=11.55; L: *d*=12.63; G+L: *d*= 12.06), while some generalization effect was observed in untrained items (G: *d*=8.05; L: *d*=5.17). The secondary results showed that SYH made improvement on verb naming (error rate from 78.6% to 57.1%); however, the rest remained rather unchanged. See Tables 13 and 14 for a summary on effect sizes elicited by three treatment approaches, and Figure 14 for the recovery curves in each condition. Table 15 provides secondary results obtained by a comparison between pre- and post-treatment linguistic assessments.

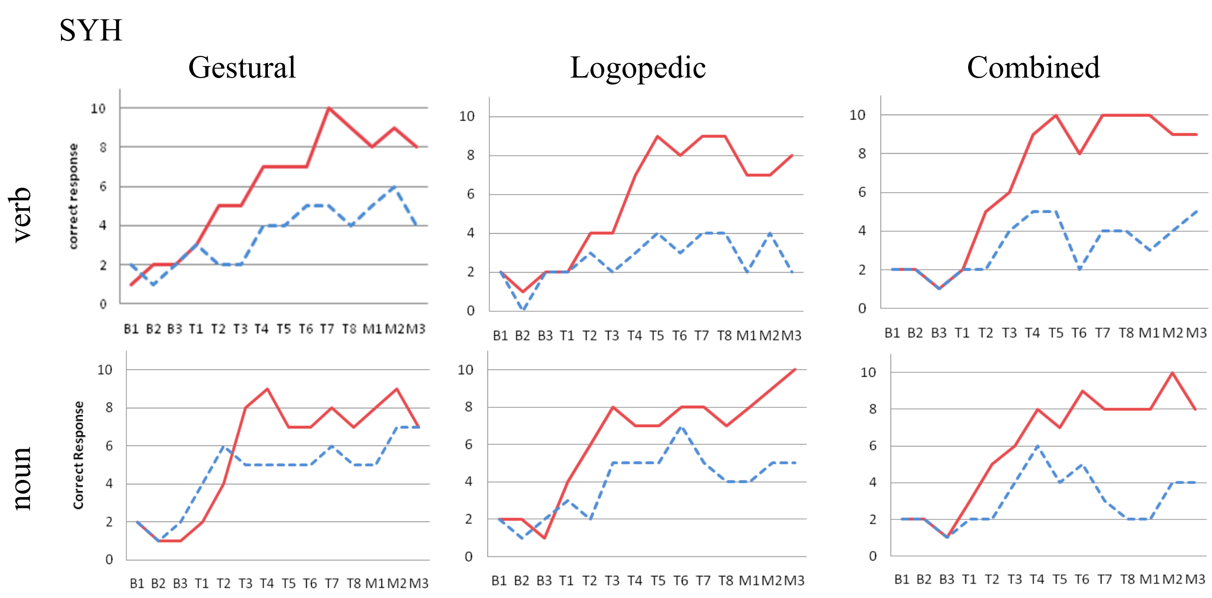

Figure 14. Recovering curves in verbs and nouns elicited by three types of treatment obtained from SYH who was trained first with verb sets (— trained, ------ untrained).

Table 12. SYH's performance on baseline naming (verbs n=80, nouns n=100)

	1° baseline		2° baseline		3° baseline	
	Verbs	Nouns	Verbs	Nouns	Verbs	Nouns
Correct	12 (15.0)	29 (29.0)	10 (12.5)	23 (23.0)	11 (13.7)	21 (21.0)
Omission	10 (12.5)	12 (12.0)	13 (12.5)	15 (15.0)	12 (15.0)	14 (14.0)
Circumlocution	25 (31.2)	4 (4.0)	24 (33.7)	9 (9.0)	21 (26.2)	10 (10.0)
Neologism	18 (22.5)	28 (28.0)	24 (30,0)	30 (30.0)	20 (25.0)	27 (27.0)
Morphological	1 (1.2)	14 (14.0)	2 (1)	10 (10.0)	3 (3.7)	13 (13.0)
Nominalization	4 (5.0)	--	2 (5)	--	3 (3.7)	--
Verbalization	--	1 (1.0)	--	3 (3.0)	--	1 (1.0)
Fragments	7 (8.7)	10 (10.0)	3 (9)	10 (10.0)	10 (12.5)	13 (13.0)
Semantic	3 (3.7)	2 (2.0)	2 (4)	0(0)	0 (0)	1 (1.0)

Note. Percentages are in parentheses

Table 13. SYH's performance on verb naming

	Gesture-based			Language-based			Combined		
	Before		After	Before		After	Before		After
trained set	1.67	treatment	8.33	1.67	treatment	9.33	1.67	treatment	7.33
untrained set	1.67		5	1.67		4	1.33		2.67

Table 14. SYH's performance on noun naming

	Gesture-based			Language-based			Combined		
	Before		After	Before		After	Before		After
trained set	1.33	treatment	8	1.67	treatment	9	1.67	treatment	8.67
untrained set	1.67		6.33	1.67		4.67	1.67		3.33

Table 15. Secondary results from SYH

		Pre-treatment		Post-treatment	
	n	errors	%	errors	%
Lexical decision	40	6	15	3	7.5
Transcodification	22	22	100	21	95.4
Comprehension (nouns)	20	1	5	2	10
Comprehension (verbs)	10	0	0	1	10
Word naming (nouns)	15	9	60	10	66.7
Word naming (verbs)	15	11	78.6	8	57.1
Naming according to description	8	6	75	6	75

Case 2: CAC

Neuropsychological and linguistic profile. CAC is 51-year-old right-handed male with 10 years of schooling. He suffered a left subcortical haemorrhage in May 2007. His performances on memory and attention tests were within norm. CAC did not demonstrate any ideomotor impairment; however, he is buccofacially apraxic. CAC was anomic given by deficits at the phonological level. His spontaneous verbal production was characterized by long anomic pauses and circumlocution. Pro-treatment linguistic assessment results showed that he was more impaired with verb than noun naming.

Baseline performance. Corresponding to his performance in pre-treatment linguistic assessment, CAC demonstrated impaired performance both on verb and noun naming. Errors of incorrect noun responses included omissions with long anomic pause, semantically correct circumlocutions (lipstick: "something small for woman, red", and he pantomimed the way to apply a lipstick on his lips), and conduit d'approches. CAC had more difficult in naming actions respect to naming objects. In his baseline naming, errors were composed of total anomic response and semantically correct circumlocutions (to iron: the thing that woman does). His detailed baseline performance is provided in Table 16.

Treatment. Given that CAC's comprehension ability was well preserved and his naming errors are composed by majorly by omission and semantically correct circumlocutions, PCA was used for of Language-based treatment. In his case, nouns were trained before verbs. He was assigned to the Phon-D group.

Results. For CAC, the gestural approach was the most effective one in the noun condition, yielding a medium-sized effect (*d*=8), while the logopedic and the combined approach resulted in a small-sized effect (L: *d*=4.67; G+L: *d*=5.33). With comparison to trained items, no improvement was observed on untrained items. In the verb condition, the combined approach elicited a close-to-large size effect (*d*=9.20). The gestural and the logopedic approach (G: *d*=5.76; L: *d*=4.60) resulted in a mild improvement with medium-sized effect. According to the secondary results, CAC's verb and noun naming was slightly improved (verb naming error rate from 85.7% to 71.4%; noun naming error rate: 26.7% to 20%). See Tables 17 and 18 for a summary on effect sizes elicited by three treatment approaches, and Figure 15 for the recovery curves in each condition. Table 19 provides secondary results obtained by a comparison between pre- and post-treatment linguistic assessments.

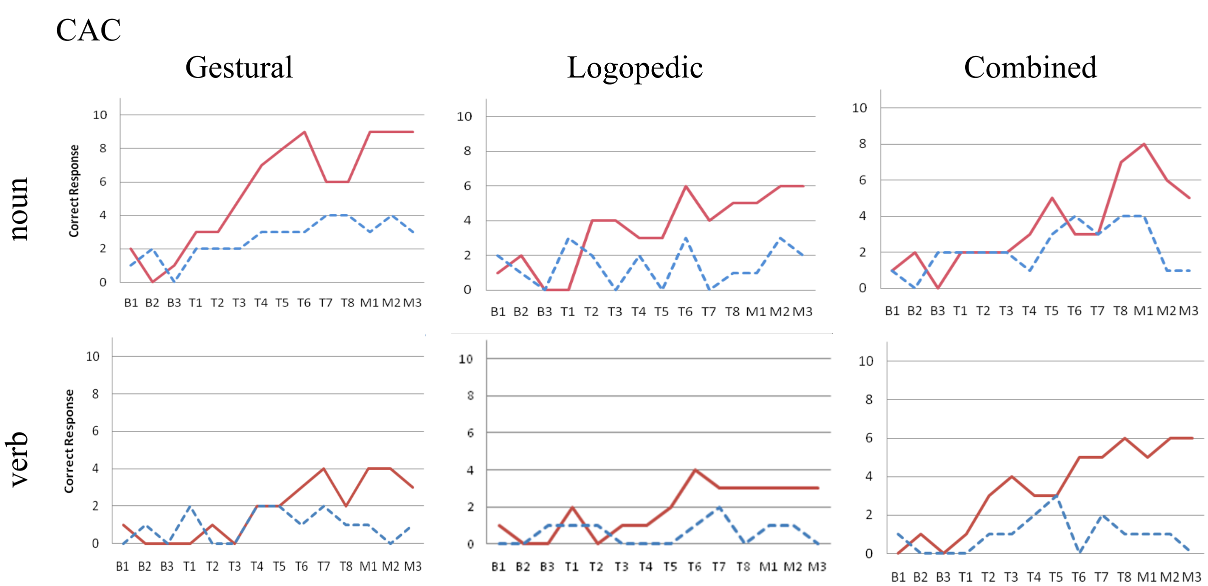

Figure 15. Recovering curves of in verbs and nouns elicited by three types of treatment obtained from CAC who was trained first with noun sets (— trained, ----- untrained).

Table 16. CAC's performance on baseline naming (verbs n=80, nouns n=100)

	1° baseline		2° baseline		3° baseline	
	Verbs	Nouns	Verbs	Nouns	Verbs	Nouns
Correct	7 (8.7)	25 (20)	13 (16.2)	12 (12)	10 (12.5)	22 (22)
Omission	14 (17.5)	34 (34)	5 (6.2)	40 (40)	22 (27.5)	47 (47)
Conduite d'approche	-	10 (10)	-	32 (32)	-	9 (9)
Circumlocution	59 (73.7)	29 (29)	62 (77.5)	15 (15)	48 (60)	21 (21)
Others*	-	1 (1)	-	1 (1)	-	1 (1)

*CAC responded the target item in dialect ("braghe" instead of "pantaloni").

Table 17. CAC's performance on noun naming

	Gesture-based			Language-based			Combined		
	Before		After	Before		After	Before		After
trained set	1	treatment	9.00	1	treatment	5.67	1	treatment	6.33
untrained set	1		3.33	1		2	1		2

Table 18. CAC's performance on verb naming

	Gesture-based			Language-based			Combined		
	Before		After	Before		After	Before		After
trained set	0.33	treatment	3.67	0.33	treatment	3	0.33	treatment	5.67
untrained set	0.33		0.67	0.33		0.67	0.33		0.67

Table 19. Secondary results from CAC

		Pre-treatment		Post-treatment	
	n	errors	%	errors	%
Lexical decision	40	4	10.0	3	7.5
Transcodification	22	3	13.0	1	4.3
Comprehension (nouns)	20	0	0	2	10.0
Comprehension (verbs)	10	0	0	0	0
Word naming (nouns)	15	4	26.7	3	20.0
Word naming (verbs)	15	12	85.7	10	71.4
Naming according to descroption	8	1	12.5	5	62.5

Case 3: PAS

Neuropsychological and linguistic profile. PAS is a 60-year-old right-handed male with 13 years of schooling. He suffered a cerebrovascular accident about 13 years ago. His performances on memory related tasks were at border. Though lack of attention when assessments were administered, his performances on attention related tasks were within norm. PAS is buccofacially apraxic, but his ability in ideomotor praxis is well preserved. PAS demonstrated phonologically based naming impairment which was featured long anomic pauses and segmented errors. Pre-treatment linguistic assessment results demonstrated that his comprehension ability on auditorially presented stimuli was within norm. In order to assess his semantically related word knowledge, Laiacona et al's (1993) Semantic Questionnaire was administered to further verify whether his naming deficit was caused primarily at the lexical or at the conceptual level of language production system. His performance was within norm.

Baseline performance. Pre-treatment linguistic assessment and the baseline naming performance demonstrated that PAS had deficits on naming both verbs and nouns, with slightly more difficulty in verb naming. In his baseline naming, errors were composed of total anomic response, omissions, semantically correct circumlocutions (e.g., switch: something to turn off the light) or negation (fork: not spoon…). His detailed baseline performance is provided in Table 20.

Treatment. Given that PAS's comprehension ability was preserved and his naming errors are composed by majorly by omission and semantically correct circumlocutions, PCA was used for of Language-based treatment. In his case, nouns were trained before verbs. He was assigned to the Phon-D group.

Results. In PAS' case, gestural and logopedic approaches resulted in medium-sized improvement in the noun condition (G: *d*=6.89; L: *d*=7.48). However, this subject did not respond to the combined approach (*d*=2). His naming accuracy was significantly improved in the verb condition, with gestural and combined approaches eliciting large-sized effects (G: *d*=10.34; G+L: *d*=10.93), and the logopedic approach resulting in a medium-sized effect (*d*=9.2). In the verb condition, some generalization effect was observed in untrained items (G: *d*= 7.48; L: *d*= 5.75; G+L: *d*= 6.89). According to the secondary results, PAS's verb and noun naming was substantially improved (verb naming error rate from 50% to 28.5%; noun naming error rate: 46.7% to 26.6%). See Tables 21 and 22 for a summary on effect sizes elicited by three treatment approaches, and Figure 16 for the recovery curves in each condition. Table 23 provides secondary results obtained by a comparison between pre- and post-treatment linguistic assessments.

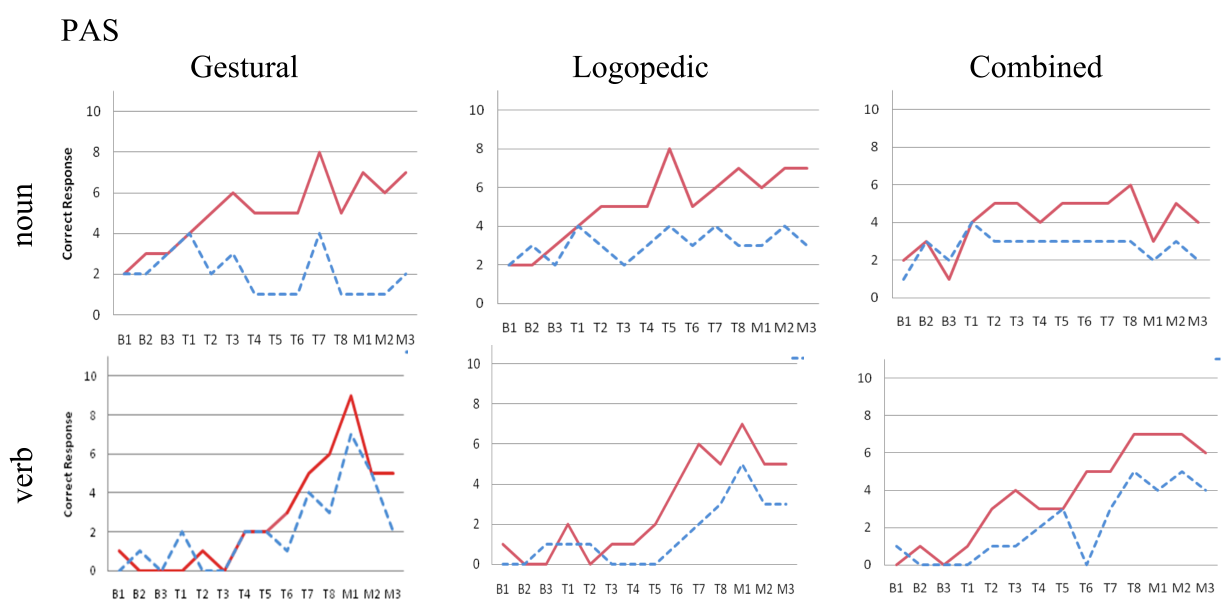

Figure 16. Recovering curves in verbs and nouns elicited by three types of treatment obtained from PAS who was trained first with noun sets (— trained, ------ untrained)

Table 20. PAS's performance on baseline naming (verbs n=80, nouns n=100)

	1° baseline		2° baseline		3° baseline	
	Verbs	Nouns	Verbs	Nouns	Verbs	Nouns
Correct	17 (21.2)	26 (26)	14 (17.5)	18 (18)	19 (23.7)	23 (23)
Omission	32 (40)	39 (39)	25 (31.2)	44 (44)	34 (42.5)	30 (30)
Morphological	-	1 (1)	-	-	-	-
Circumlocution	31 (38.7)	30 (30)	40 (50)	37 (37)	27 (33.7)	42 (42)
Semantic	-	3 (3)	-	1 (1)	-	5 (5)
Neologism	-	1 (1)	-	-	-	-
Other*	-	-	1 (1.2)	-	-	-

Note. Percentages are in parentheses

Table 21. PAS's performance on noun naming

	Gesture-based			Language-based			Combined		
	Before		After	Before		After	Before		Afte r
trained set	2.67	treatment	6.67	2.33	treatment	6.67	2	treatment	4
untrained set	2.33		1.33	2.33		3.33	2		2.33

Table 22. PAS's performance on verb naming

	Gesture-based			Language-based			Combined		
	Before		After	Before		After	Before		After
trained set	0.33	treatment	6.33	0.33	treatment	5.67	0.33	treatment	6.67
untrained set	0.33		4.67	0.33		3.67	0.33		4.33

Table 23. Secondary results from PAS

		Pre-treatment		Post-treatment	
	n	errors	%	errors	%
Lexical decision	40	3	7.5	3	7.5
Transcodification	22	0	0	0	0
Comprehension (nouns)	20	1	5	0	0
Comprehension (verbs)	10	1	5	0	0
Word naming (nouns)	15	7	46.7	4	26.6
Word naming (verbs)	14	7	50	4	28.5
Naming according to descroption	8	3	37.5	3	37.5

Case 4: FIP

Neuropsychological and linguistic profile. FIP is a 78-year-old right-handed female with 10 years of schooling. She suffered a cerebrovascular accident in August 2007. When she participated this project she was at 37 months post onset. Results of neuropsychological assessments showed that her abilities in memory, attention and praxis were within norm. FIP could speak fluently and was able to use rather complex syntactic structure. However, information amount of her verbal production was limited given by word finding difficulty and her constant use of semantically weak words (e.g., light verbs, such as go and do). Her naming performance was featured by long anomic pauses and semantic errors. She had more difficulty in naming verbs respect to naming nouns.

Baseline performance. FIP's baseline naming performance was in line with the pre-treatment linguistic diagnosis. That is, single word oral naming ability was generally impaired with more difficulty in naming verbs than nouns. In baseline action naming, most frequently occurred errors were circumlocution and semantic ones; whereas in object naming most notable error types were anomic and semantic ones. FIP tended to use light verbs (e.g., take and do) to substitute specific verb targets and made bypassing description on a given picture. Most errors from her object naming were resulted in omissions, circumlocutions (racket: "something you use to play tennis"). She also made notable percentage of with-in category semantic errors (e.g., "saw" instead of "hammer"; "trumpet" instead of "saxophone"). To further verify her semantic impairments, Laiacona et al's (1993) Semantic Verbal Questionnaire was administered. Out of 480 items FIP made 69 errors in total, surpassing the pathological threshold (correct response <447). Her detailed baseline performance is provided in Table 24.

Treatment. Given her naming deficit resulted by impairments at conceptual level, SFA was proposed as materials used in Language-based treatment. In FIP's case, nouns were treated before verbs. She was assigned to the Con-D group.

Results. For FIP, all three approaches yielded a medium-sized improvement of trained nouns (G: *d*= 8.62; L: *d*= 9.75; G+L: *d*= 8.62); while in the verb condition, the gestural and the combined approach resulted in medium-sized effects (G: *d*=4.33; G+L: *d*=6.31). By contrast, the logopedic approach did not lead to any significantly positive change (*d*=1.53). According to the secondary results, FIP's verb and noun naming was slightly improved (verb naming error rate from 57.1% to 42.9%; noun naming error rate: 20% to 13.3%). See Tables 25 and 26 for a summary on effect sizes elicited by three treatment approaches, and Figure 17 for the recovery curves in each condition. Table 27 provides secondary results obtained by a comparison between pre- and post-treatment linguistic assessments.

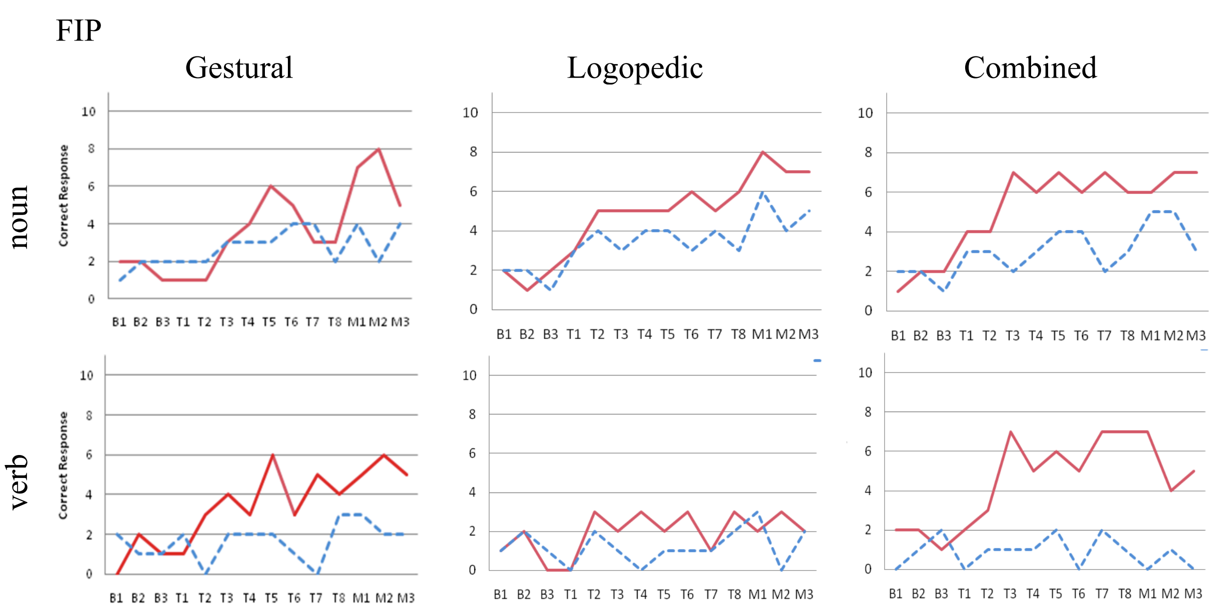

Figure 17. Recovering curves in verbs and nouns elicited by three types of treatment obtained from FIP who was trained first with noun sets (— trained, ----- untrained).

Table 24. FIP's performance on baseline naming (verbs n=80, nouns n=100)

	1° baseline		2° baseline		3° baseline	
	Verbs	Nouns	Verbs	Nouns	Verbs	Nouns
Correct	13 (16.2)	31 (31.0)	12 (15.0)	20 (20.0)	15 (18.7)	24 (24.0)
Omission	3 (3.7)	29 (29.0)	1 (1.2)	24 (24.0)	3 (3.7)	26 (26.0)
Circumlocution	38 (47.5)	9 (9.0)	40 (50.0)	17 (17.0)	34 (42.5)	15 (15.0)
Neologism	2 (2.5)	6 (6.0)	1 (1.2)	8 (8.0)	1 (1.2)	8 (8.0)
Morphological	-	-	1 (1.2)	-	3 (3.7)	-
Nominalization	4 (5.0)	-	2 (2.5)	-	1 (1.2)	-
Verbalization	-	1 (1.0)	-	3 (3.0)	-	-
Fragments	1 (1.2)	4 (4.0)	5 (6.2)	6 (6.0)	3 (3.7)	1 (1.0)
Semantic	19 (23.7)	20 (20.0)	18 (22.5)	22 (22.0)	20 (25.0)	26 (26.0)

Note. Percentages are in parentheses

Table 25. FIP's performance on noun naming

	Gesture-based			Language-based			Combined		
	Before		After	Before		After	Before		After
trained set	1.67	treatment	6.67	1.67	treatment	7.33	1.67	treatment	6.67
untrained set	1.67		3.33	1.67		5	1.67		4.33

Table 26. FIP's performance on verb naming

	Gesture-based			Language-based			Combined		
	Before		After	Before		After	Before		After
trained set	1	treatment	5.33	1	treatment	2.33	1.67	treatment	5.33
untrained set	1.33		2.33	1.33		1.67	1		0.33

Table 27. Secondary results from FIP

		Pre-treatment		Post-treatment	
	n	errors	%	errors	%
Lexical decision	40	8	20	10	25
Transcodification	22	0	0	0	0
Comprehension (nouns)	20	0	0	1	5
Comprehension (verbs)	10	1	1	2	20
Word naming (nouns)	15	3	20	2	13.3
Word naming (verbs)	14	8	57.1	6	42.9
Naming according to descroption	8	5	62.5	4	50

Summarized results from Individual cases

When examining primary results by comparing naming performance in the baseline stage with that in the maintenance stage, item-specific improvement was observed in all patients. As for the untrained items, there was limited treatment outcome. Although all three treatment approaches elicited positive effects in both verb and noun conditions, differentiate improvement patterns were observed across patients. Tables 28 to 31 summarize outcomes - presented by effect sizes - for trained and untrained stimuli elicited by three approaches in the verb and in the noun condition. As mentioned in the method session, according to the benchmarks suggested by Robey and Beeson (2005), treatment effect sizes with values of 4.0, 7.0, and 10.1 correspond to small, medium, and large effect sizes, respectively. As can be seen, in the verb condition, for all subjects the combined approach resulted in the largest treatment effect, followed by the gestural approach. In the noun condition, the logopedic approach was the most effective in three out of four cases, whereas the response to the logopedic and the combined approach varied across participants.

Generalization

When examining across each patient on treatment gain, no significant improvement was noted on untrained items in both the verb and the noun conditions across all approaches, except for SYH and for PAS. SYH showed mild generalization in the noun sets treated by the gestural and the logopedic approach and in the verb set treated by the gestural approach, while PAS demonstrated slight generalization in the verb sets treated by all three approaches. Secondary results were evaluated by comparing the performance on the language tasks (B.A.D.A.) that were administered before and after treatment. Table 32 provides all the test results collected before and after treatment. As can be seen from the table, in terms of word naming, slight generalization in naming nouns can be observed from the case PAS; mild generalization in naming verbs can be noted from the cases of SYH and PAS. Performances on the rest of the tasks, however, remained rather unchanged.

Table 28. Summary of treatment gains on trained verbs

	SYH			CAC			PAS			FIP		
	Mb	Mm	*d*	Mb	Mm	*d*	Mb	Mm	*d*	Mb	Mm	*d*
G	1.67	8.33	**11.48*****	0.33	3.67	**5.76***	0.33	6.33	**10.34*****	1	5.33	**4.33***
L	1.67	9.33	**9.75****	0.33	3	**4.60***	0.33	5.67	**9.2****	1	2.33	**1.53**
G+L	1.67	7.33	**13.2*****	0.33	5.67	**9.20****	0.33	6.67	**10.93*****	1.67	5.33	**6.31***

Mean numbers of correct responses in trained verb sets (each set n=10) in baseline and maintenance phases in three types of treatment. Mb: mean of baseline phase. Mm: mean of maintenance phase. *d*: effect size. (*d*: >10.1= large***; >7.0= medium**; >4= small*)

Table 29. Summary of treatment gains on untrained verbs

	SYH			CAC			PAS			FIP		
	Mb	Mm	*d*	Mb	Mm	*d*	Mb	Mm	*d*	Mb	Mm	*d*
G	1.67	5	**5.74***	0.33	0.67	**0.58**	0.33	4.67	**7.48****	1.33	2.33	**1.72**
L	1.67	4	**1.16**	0.33	0.67	**0.58**	0.33	3.67	**5.75***	1.33	1.67	**0.58**
G+L	1.33	2.67	**4.01***	0.33	0.67	**0.58**	0.33	4.33	**6.89***	1	0.33	**0.67**

Table 30. Summary of treatment gains on trained nouns

	SYH			CAC			PAS			FIP		
	Mb	Mm	*d*	Mb	Mm	*d*	Mb	Mm	*d*	Mb	Mm	*d*
G	1.33	8	**11.55*****	1	9	**8****	2.67	6.67	**6.89***	1.67	6.67	**8.62****
L	1.67	9	**12.63*****	1	5.67	**4.67***	2.33	6.67	**7.48****	1.67	7.33	**9.75****
G+L	1.67	8.67	**12.06*****	1	6.33	**5.33***	2	4	**2**	1.67	6.67	**8.62****

Mean numbers of correct responses in trained noun sets (each set n=10) in baseline and maintenance phases in three types of treatment. Mb: mean of baseline phase. Mm: mean of maintenance phase. *d*: effect size (*d* >10.1= large***; >7.0= medium**; >4= small*).

Table 31. Summary of treatment gains on untrained nouns

	SYH			CAC			PAS			FIP		
	Mb	Mm	*d*	Mb	Mm	*d*	Mb	Mm	*d*	Mb	Mm	*d*
G	1.67	6.33	**8.05****	1	3.33	**2.33**	2.33	1.33	**1.72**	1.67	3.33	**2.86**
L	1.67	4.67	**5.17***	1	2	**1**	2.33	3.33	**1.72**	1.67	5	**5.74***
G+L	1.67	3.33	**2.87**	1	2	**1**	2	2.33	**0.33**	1.67	4.33	**4.58***

Table 32. Secondary results across four patients

		SYH		CAC		PAS		FIP	
		Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
	n.	error%		error%		error %		error %	
Lex decision	40	15	7.5	10.0	7.5	7.5	7.5	20	25
Transcodification	22	100	95.4	13.0	4.3	0	0	0	0
Comprehension (n)	20	5	10	0	10.0	5	0	0	5
Comprehension (v)	10	0	10	0	0	5	0	1	20
Word naming (n)	15	60	66.7	26.7	20.0	46.7	26.6	20	13.3
Word naming (v)	14	78.6	57.1	85.7	71.4	50	28.5	57.1	42.9
Naming on description	8	75	75	12.5	62.5	37.5	37.5	62.5	50

Discussion

This study explored effects given by three types of treatment – gesture-based, language-based, and combined, on the retrieval of nouns and verbs. Four chronic aphasics with word-finding difficulty participated in this study. In gesture-based treatment, patients were trained to produce a gesture that can be mapped onto a corresponding word. In language-based treatment, Semantic Feature Analysis and Phonological Component Analysis were used. Combined treatment includes the same materials used in the gesture-based and language-based treatments, but materials were alternated across sessions. Training materials included verbs of hand-related actions and nouns of manipulable objects. All types of treatment led to significant item-specific improvement on both verb and noun naming. Three out of four subjects showed the largest recovery following combined treatment, especially on verbs. Even though this pattern was less clear in the noun condition, the three approaches still yielded positive effects on word retrieval.

This study aimed to answer the following research questions: (1) Among gestural, logopedic, and combined approaches, which one is most effective in improve naming accuracy? (2) How gestural facilitation might diverge for nouns and verbs? (3) What's the relation between patient type and its response to gestural approach? In this section, these questions are going be addressed accordingly.

Treatment efficacy

An item-specific training effect was observed. Only limited improvement was noted for untrained items. However, the patterns of improvement varied across subjects: in the verb condition, for all participants the treatment gain was greater for the combined and the gesture-based approaches than for the language-based approach; whereas in the noun condition, this pattern is less clear. It is difficult to pinpoint which approach was the most effective in the noun condition, since each participant seemed to react rather idyosyncratically. However, it is important to note that our participants - who demonstrated more severe retrieval difficulty in verbs than nouns shown by pre-treatment and baseline linguistic assessment - benefited most from the combined approach and gestural approach in verb condition. A family member of PAS reported that after the treatment, he continuously used gesture as a strategy to express his needs and to self-help his daily life communication which was originally hindered by his impaired verbal ability. This observation suggests that gesture use not only may cue naming and thus be a viable means for aphasic rehabilitation, but may also provide the patient with a compensatory strategy in a daily conversational setting. This is in line with Marshall's proposal (2006): by pairing an iconic gesture with its corresponding word the therapist can help aphasics foster their spoken language. Constant application of the gesture mapping onto verbs treatment was also proposed for the purpose of developing a close, one-to-one correspondence between a specific gesture and its corresponding lexical-phonological target, and therefore of anchoring the facilitative effect of gesture.

Albeit gesture has been claimed to have a potential role in aphasic communcation, one issue should be further considered in terms of its clinical usefulness. The present project and previous studies investigating gesture-based treatment employed a template in which there is a strict, single-word-to-single-gesture correspondence. However, how to extend the trained outcome to natural conversation contexts needs to be further studied. McNeill (1992) pointed out a close relation between gesture and sentence at the discourse level. Indeed, production of a verb phrase may be modulated by training aphasic patients on the emblematic or pantomimic use of gestures (Daumüller and Goldenberg, 2010). Nevertheless, evidence about gesture-based treatment in sentence and grammatic level is still lacking. More research is needed to establish whether gesture training is only indicated in the remediation of word retrieval deficits, or it can ameliorate communicative abilities in a natural conversation setting also in subjects with different language impairments (eg, "agrammatic" speech).

Gesture facilitates naming and its interaction with language

In our study, the gesture-based and the combined treatment yielded large-sized effects in both the verb and the noun condition in all participants except PAS, who did not respond to the combined approach in the noun condition. Our results are consistent with those reported by Raymer and her colleagues (2006). These authors demonstrated that gesture-based training, when accompanied by logopedic training, yielded significant improvement in both classes of words. However, these investigators also admitted that their results did not help to establish whether gesture-based training differentially facilitates verb and noun naming. Our results showed that in the verb condition, for all participants the treatment gain was greater for the combined and the gesture-based approaches than for the language-based approach. On top of this observation, we try to further discuss why the combined and gesture-based treatment, compared with the language-based one, elicited larger effects in the verb condition by considering the fact that all the verb stimuli used in the study involve upper arm/hand actions, and that in the combined and gesture-based treatment, the gestural component revolves around truly iconic gestures. Referring back to the model proposed by Rumiati and colleagues (2010) in which object/action names and gestures are produced in two separate but interactive linear systems (see Figure 1 in chapter one), the iconic upper arm/hand gestures may facilitate naming in three ways: first, if the output lexicon and the "output praxicon" interact, such that information from the praxicon can add to semantic knowledge and activate the target phonological entry in the output lexicon, whatever is activated in the praxicon may boost activation in the lexicon. Secondly, if the two components are independent, the entry activated in the output praxicon may re-enter the system at the structural description or at the input praxicon level, thus increasing the amount of information activated in the semantic system, which may more easily precipitate the correct response. Thirdly, in the context of interactive models, information from the praxicon might feed back to semantics, from which it might contribute to the activation of the lexical entry of output.

Levelt's (1989) linear speech production system has been frequently used as a background reference for the development of gesture-language interaction models (*eg*, Butterworth & Hadar, 1989; Hadar & Butterworth, 1997; Kita, 2000; Kita & Özyürek, 2003; Krauss et al., 1996, 2000; de Ruiter, 1998, 2000). Under this framework, four processing subsystems are involved in the cross-modal gesture-language interaction. A Conceptualizer generates pre-verbal messages to be fed into the linguistic formulation module; a Gesture Planner is in charge of gesture production; a Formulator is responsible for linguistic production; and a Multi-component working memory maintains mental images active (Feyereisen, 2006). These models share the assumption that gestures - and especially representational ones - help speech production, and that the production of gestures as such closely relates to the activation of visuo-spatial images in working memory (*eg*, imagining a curved trajectory from one position to another while expressing the concept of "to swing").

Three main hypotheses were proposed by the abovementioned investigators: the Free Imagery Hypothesis, the Lexical Semantics Hypothesis, and the Interface Hypothesis. According to the Free Imagery Hypothesis, gestures are generated from mental imagery in working memory, and most importantly, are planned prelinguistically. For instance, de Ruiter (1998, 2000) proposed that representational gestures stem from the Conceptualizer which generates prelinguistic information relating to both gesture and speech. Krauss et al., (1996, 2000) further suggested that representational gestures derive from spatial imagery in working memory which is closely connected with the Conceptualizer and are activated at the moment of speaking. The Lexical Semantics Hypothesis, on the other hand, maintains that representational gestures are formulated after the "selection of the lexical items in abstract form from a semantically organized lexicon" (Butterworth & Hadar, 1989, p.172). In other words, a selected lexical item – as a result of the computational stage in speech production – supplies the related semantic features of a given gesture which is affiliated with it. The third hypothesis, the Interface Hypothesis proposed by Kita and Özyürek (2003), maintains that gestures originate at an interface representation between speaking and spatial thinking. Such interface representation contains spatio-motoric information. Hence, producing a gesture helps encode non-linguistic spatio-motoric properties of a referent, packing the information about the referent which is compatibile with linguistic encoding possibilities.

Our results are at variance with some predictions of these hypotheses. According to the Free Imagery Hypothesis, gestures do not facilitate word form retrieval. To the contrary, they assist preverbal conceptual processing. If this is the case, the Con-D participant in our study should have benefited from the gestural approach more than the Phon-D subjects. However, this was not the case. On the other hand, the Lexical Semantics Hypothesis maintains that gestures are formulated through a post-semantic route (Hadar and Butterworth, 1997). It cannot explain how gesture can prime a target word sublexically, since gestures lack phonological and grammatical properties. Overall, our results favor the Interface Hypothesis, according to which the role of gestures is to maintain related conceptual properties active – especially those spatial-dynamic features which may not be expressed in speech. Producing gestures consequently helps word representations to reach threshold during lexical retrieval.

Aphasia type and utilising gesture

For the sake of treatment efficacy, it is important to determine which type of aphasia benefits most from the gesture-based approach. In her detailed review, Rose (2006) reported that "for individuals with primary phonological level deficits, iconic gesture is likely to facilitate word production and may be a useful self-generated cueing strategy" (p.96). This claim was supported by empirical evidence from the studies conducted by Rose and colleagues (Rose & Douglas, 2001; Rose et al., 2002) and Rodriguez and colleagues (2006). Rodriguez and cohorts (2006) reported that individuals with a semantically-based naming deficit responded to gesture-facilitated spoken naming in a limited fashion. In our study, the Phon-D patients (SYH, CAC, and PAS) indeed demonstrated improved verb and noun retrieval following training with the gestural approach. However, the effect was only marginally greater than that observed in the Con-D subject FIP, especially in noun condition. This finding is consistent with the results obtained from Raymer and colleauges' study (2006): that patients with primarily semantic deficits also show a positive response to such training. Given that our results report contrasting evidence, the question of which aphasia type would benefit more from gesture-based treatment has not yet been answered. Further research and more case studies are needed to clarify this issue.

Some limitations of the study

One may argue that in the current study each technique trained in each session was in a fixed order, and that each subject underwent all treatments at the same time might rule out the possibility to see training effects elicited by three individual techniques. Indeed, to some extend, this concern prevented us to *strongly* infer *the* account of the role played by gesture in word retrieval facilitation. Putting aside practical and ethical considerations, one of course could design a precisely balanced experimental setting to investigate training outcomes elicited by a certain amount of treatment techniques randomly assigned cross a certain amount of aphasic subjects using individually tailored and never repeated stimuli, and even assigning patient participants to a control group. This is, however, not an easy task for aphasia research. As has been pointed out, the traditional experiment setting and statistic analysis have some disadvantages when applied to aphasia research, especially in the arena of treatment research (Thompson, 2006). In our study, all techniques were trained in each session, the reported across-subject differences may truly indicate “personal preference” in terms of treatment type: one technique is specifically more effective in one subject than in another and a patient may be in favour of certain techniques respect to others. This consequently gives us clues for clinical references: the task for the future is to understand in advance - may it be based on behavioural pre-treatment indices or observation - which treatment is more likely to be successful to a given patient.

One may also argue that the low number of participants from the current study makes it difficult to draw an inference that generalizes the architecture of cognitive system across people and that there was only one participant in the Con-D group creates an out-of-balanced experimental design. It is undeniable that more participants with a breakdown in conceptual knowledge should have been recruited to make the current study more complete. However, note that this study is exploratory in nature, further research involving a larger number of participants is surely needed to yield in more profound understanding toward the relation between gesture and language in aphasic population. Also, one has to take into consideration that it is practically difficult in the field of aphasic research to run experiments with a large number of subjects in an extremely controlled setting. Buxbaum (2006) observed the individuality of neuropsychologically impaired patients and noted that “nearly every possible fractionation has been reported, raising the possibility that each patient may be as unique as a snowflake”. Based on this observation, Caramazza and Coltheart (2006) clarified why aphasic researchers study symptoms instead of syndromes and carry out single case studies rather than group studies. As the authors stated, even every single patient is essentially unique, generalizable knowledge can still be obtained by studying them and that "in any field of cognition where cognitive neuropsychology is underdeveloped, starting with small group studies of symptom collections (syndromes) might prove to be a useful ground-clearing exercise" (p.7).

Concluding remarks

In conclusion, this study demonstrated that all treatment approaches led to significant, item-specific improvement on both verb and noun naming. Three out of four patients showed the largest recovery following combined treatment, especially on verbs. Even though this pattern was less clear in the noun condition, the three approaches still yielded positive effects on word retrieval. This suggests that gesture, when combined with logopedic treatment, can boost naming skills, and may play a facilitative role in ameliorating impaired naming performance of aphasic persons. It is also important to note that gesture can serve as a compensatory strategy to solve daily communication difficulty. One step further to investigate the priming effect given by gestures at phonological and syntactic level is may further shed light on the potential role played by gesture in aphasic rehabilitation.

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6. Conclusions and Future Directions

Conclusions

Can gesturing help aphasic individuals communicate and serve as a treatment device for aphasia? Not much research attention has been drawn to investigate this issue due to complicate nature of aphasia research (subject inhomogeneity; long research time; ethical concerns etc.) and methodological challenges, such as difficulty to define and code gestures and to disentangle its relationship with language production. In this thesis, we have presented two studies to address this issue. In the first study, methodologically, we explored two different measures - per-100-word and per-minute - to conduct quantitative analysis on aphasic verbal and gestural production in comparison with normal controls. We also conducted in-depth qualitative analysis to pinpoint how word-finding difficulties were solved in aphasic subjects. We found that aphasic patients and normal controls do not gesture at differentiated rates along narratives, and that aphasics not only employed gestures - especially representational ones - to assist themselves in finding words but also employ these gestures as substitutes for absent words when word retrieval fails. On one hand, the evidence refutes the notion of "asymbolia" - impaired performance does not necessarily correlate to gesture production, and on the other hand, it also supports the compensatory and facilitative role played by gesture. We can therefore conclude that gesture could be a potential solution for communication problems in aphasic population and could be encouraged for daily conversational use. Thus, these patients may re-acquire an active role in natural communication settings instead of merely receiving information passively or being totally dependent on cues given by others. The results obtained from the first study gave us a firmer ground to propose a treatment device based on gesture. In the second study, we investigated this device in comparison with two other devices, the language-based and the combined, to understand how aphasic patients might respond to them and which one of these devices is most effect in improving naming nouns and verbs. Treatment outcomes on naming objects and actions elicited by language-based therapies have been reported by a broad array of aphasiological studies. By contrast, effects given by gesture-based treatment or by treatments integrating gesture-based and language-based techniques on verb and noun naming were less known. We used a single-subject-multiple-baseline design to tackle this issue. It was observed that all types of treatment brought in significant item-specific improvement in both verb and noun naming. Combined treatment in the verb condition elicited the largest recovering in three out of four patients. We conclude that a gesture-based technique, when combined with language-based treatment, can boost naming skills.

Future directions

Following issues should be further explored in order to be able to devise a set of guidelines for gesture-based therapies in real clinical use. First, although in the first study we observed that representational gestures were used to substitute missing words and to solve word-finding difficulties, however, this is not the case for *all* patients. Some issues needs to be specifically considered before the gesture-based treatment is given. For example, in-depth observation on individual preference of using representational/non-representational gestures in a naturalistic and conversational setting with their close others should be made in advance. The correlation between gesture using preference and outcomes of gesture-based treatment needs to be further investigated. This may serve as a predictor for treatment outcome elicit by gesture-based technique. Secondly, Bartolo, Cubelli, Della Salla and Drei (2003) pointed out that working memory plays a crucial role in patients' ability in producing pantomimes. The rationale is that in order to process pantomimes, an essential mechanism is required to integrate and synthesise perceptual inputs and object/action semantics and their relevant procedural programmes. Working memory is such a locus for performing integration and synthesis as such. Fillingham, Sage, and Lambon Ralph (2005) also suggested cognitive processes in general serves as vital predictor of treatment efficacy. In our study, we did not observe pathological performance on memory-related tasks in the aphasic subjects. For future studies, this issue must be taken into consideration when recruiting subjects. Thirdly, a mid-term follow-up monitoring (i.e., six-month post-treatment control) on changes in gestures and verbal production in aphasic persons after they complete their experimental treatment cycle will enable us to understand the carry-over effect elicited by gesture-based training and its interaction with linguistically-related improvement in a natural, conversational setting. Lastly, it may be sensible to further develop a tool-kit which contains the highly iconic gesture stimuli used in the second study and newly added pseudo-emblematic or pantomimic gestures that correspond to single words or short phrases frequently used in daily life. As a consequence, the tool-kit can be served as a reference for family members and care-takers of patients to understand the word-gesture correspondence with which aphasic individuals are trained in the clinical treatment.

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7. Appendices

Appendix 1 - Description of Cartoon Episodes

Episode 1: Binocular

With binoculars, Cat Sylvester spies Canary Tweety who is at the window of a building across the street. Silvester goes into the main entrance of Tweety's building, but he is driven out in a pile of garbage.

Episode 2: Drainpipe

Tweety sings happily in the cage without noticing that Sylvester climbs along the drainpipe close to the window, intending to catch her. When Tweety realizes that the cat is there to get her, she flies away to ask for help. Granny comes out from the apartment and beats up Sylvester with an umbrella. Silvester again is thrown out of the windown.

Episode 3: Bowling Ball

Sylvester tries to approach Tweety's window to get her by climbing up the drainpile next the to window. But next time, he climbs up inside the drainpipe. Tweety brings over a bowling ball and throws it down from the upper opening of the drainpipe. Sylvester swallows the bowling ball, being dragged down by the weight in his belling. After getting out from the pipe, he keeps rolling on a street and eventually into a bowling alley.

Episode 4: Monkey

A organ grinder and his monkey perform at a street. Sylvester knocks down the monkey and steals his outfit. Disguised as a monkey, Sylvester climbs up along the drainpipe next to Tweety's windown and tries to approach the window. In the apartment, Sylvester keeps searching for Tweety everywhere. Granny saw the "monkey" and offers him a penny in his cup. Sylvester tips his cap, and Granny hits him on the head with an umbrella.

Episode 5: Bellboy

Sylvester is hiding in a mailbox at the front desk of a hotel where Tweety and Granny stay. Granny calls the bellboy at the front desk to inform him that she is checking out and that they need a bellboy to carry her bags and bird. Disguised as a bellboy, Sylvester shows up at the door of Granny's room. Granny hands him her bags and the covered birdcage. Sylvester throws away the luggage and escapes with the birdcage. In an alley he removes the cover of the birdcage and finds Granny hiding in the cage. Granny hits Sylvester badly on his head with an umbrella.

Episode 6: Catapult

Sylvester sets up a catapult with a crate and a board right under Tweety's window. He then stands on one end of the catapult with a 500-pound weight in hand. He throws the weight onto the other end of the board so that he is propelled into the air. As soon as he arrives Tweety's window, he grabs Tweety. Later on he lands on the board with Tweety held in hand. Sylvester's landing on the board propels the weight on the other end into the air. Sylvester runs off, however, as he does so, the weight falls right on his head. The weight flattens his head. Tweety escapes from his grasp.

Episode 7: Swing

Sylvester is in front of a graphic desk to study how to reach the window of Tweety. Based on his study, Sylvester sets up a rope between his window at one side of the street and Tweety's window which is at the other side of the street. With this rope, Sylvester swings to Tweety's window in a Tarzan-style. Off he goes from his window ledge holding the rope. However, instead of arriving at the window ledge of Tweety's building, Sylvester smashes into the sidewall of the window, and falls down all the way to the ground.

Episode 8: Trolley Car

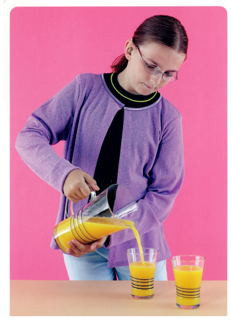
Sylvester climbs up an electricity pole and reaches the overhead trolley wires. While he walks on the wires, a trolley car approaches him, ringing the bell. Sylvester runs and the trolley car chases after him. When Sylvester reaches the connecting points of the wires, he gets electrical shocks. Every time when Sylvester receives a shock, he jumps up as if exploding. The same scenario repeats. After getting several shocks, the camera pans to a view of the trolley driver. It is actually Tweety driving the trolley car and the Granny rings the bell.

Appendix 2 - Phonological Components Analysis (PCA)

Rhyme This word rhyme with?	**Pronunciation** The first letter of this word is?

(Object Stimulus)

OR



(Action Stimulus)

ASSOCIATION Tell me some words that start with the same letter!	**PRONUNCIATION** The last letter of this word is?	**SYLLABLE** How many syllables are there in this word?

Appendix 3 - Semantic Feature Analysis (SFA) for Objects

CATEGORY

What category does it belong to?

UTILISATION

What's the function of it?

DESCRIPTION

Describe the composition of it!

LOCATION

Where is it usually used?

ASSOCIATION

What is the first thing you associate to when you see it?

Appendix 4 - Semantic Feature Analysis (SFA) for Actions

UTILISATION

What is this action for??

DESCRIPTION

When you do this action, is there any object that you use?

LOCATION

Where do you usually do this action?

ASSOCIATION

What is the first thing you think about when you do this action?