Research Article

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Gesture, prosody and verbal content in non-fluent aphasic speech

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Abstract: Non-fluent aphasia is characterized by frequent word search and a much slower speech rate than non-aphasic speech. For patients with this type of aphasia, communication with those around them is therefore made difficult and is often severely impaired. One of the therapeutic proposals to improve the quality of life of these patients is to re-educate them with more multimodal alternatives. This of course assumes that gestures represent possible alternative means of communication for patients, and that their gestures are not affected in the same way as their speech. This article therefore proposes to study the gestures of 4 aphasic people and to compare them to the gestures performed by non-aphasic people, but also to establish correspondences between those gestures, intonation contours and the way people with aphasia develop their discourse. Results show that although gesture rate is not different in the two groups of participants, the gesture-to-speech ratio is higher for people with aphasia (PWA) than for non-aphasic people (NAP). Considering the fact that PWA also gesture more than NAP during silent pauses, which are longer but not more frequent than in NAP's speech, and the fact that their gestures coincide less often with a lexical word, we believe that PWA use their gestures as compensation strategies for deficient speech. Yet, their speech impairment is also reflected in their gesturing: more gestures are prepared but abandoned before the stroke in this group and pre-stroke holds are longer, which means that PWA hold their gestures in the hope that they will better coincide with the word they are supposed to accompany and which takes more time to be uttered than in non-pathological speech. Their gestures are also less linked to each other than in the NAP group which goes hand in hand with the fact that they tend to utter independent syntactic phrases with no cohesive marker between them. This is also reflected in their less frequent use of flat and rising tones in intonation, which generally indicate that two sentence parts are dependent one upon the other, as well as their less frequent use of gestures showing discourse organization. In terms of gesture types, the PWA in this study perform many rhythmic beats and rely much on conventional gestures to compensate for their speech impairment rather than on their own creativity. Globally, this means that if multimodal therapies may benefit PWA to improve their communication with other people, speech therapists nevertheless need to be aware that life-long habits of gesture-speech alignment and synchronization may not be so easy to overcome for patients.

Keywords: gesture; non-fluent aphasia; prosody

1 Introduction

Aphasia is a language disorder caused by brain damage, most often due to stroke, that can affect written and oral language production and/or speech comprehension (Dipper et al. 2015). Neuronal lesions affect specific language functions, with disorders that may reveal phonological, syntactic, lexical, and semantic impairments

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(Preisig et al. 2015). Aphasia can be fluent or non-fluent: among the fluent types, we count Wernicke's, transcortical sensory, conduction and anomic aphasia, in which people may be fluent but may not be coherent or may have problems finding specific words. With the non-fluent types of aphasia, Broca's aphasia, transcortical motor aphasia and global aphasia, people encounter difficulties in speech production and/or comprehension. Non-fluent aphasic speech is mainly characterized by high speech efforts related to frequent lexical searches, difficult sound articulation, and syntax based primarily on the production of noun phrases (Macauley and Handley 2005). Aphasia has serious psycho-social consequences for people with aphasia (PWA) because of the communication difficulties it causes (Blom Johansson 2012; Nyström 2006). Most of the time, it means:
– Loss of employment,
– Isolation of PWA and degradation of family and social relationships,
– Loss of self-esteem in the face of a feeling of linguistic incompetence that can lead to depression.

It is therefore of the utmost importance to fully understand aphasic communication in its globality to be able to help these people in their ordinary life. In order to improve patients' quality of life, therapists and researchers are questioning the appropriateness of multimodal aphasia therapy (M-MAT: Multimodal Aphasia Therapy) in comparison with a therapy focused solely on speech (CIAT: Constraint-Induced Aphasia Therapy) that used to be prevalent in rehabilitation practices. The results of studies conducted on the progress of patients who have undergone either therapy are mixed (Rose et al. 2015): the effects of multimodal therapy depend on the communication situation and the severity of the patients' aphasia. The effectiveness of multimodal therapy also presupposes that the patients' gestures are not affected to the same extent as speech and can compensate for the deficient speech or at least facilitate access to the lexicon. Although work on the gestures produced – spontaneously or at the request of therapists – by PWA has multiplied over the last 10 years, we are still far from knowing the similarities and differences between the gestures of PWA and non-aphasic people (NAP), nor the potentially compensatory or facilitating role of the gestures performed by PWA (Pritchard et al. 2015). Moreover, most existing studies are based on specific speech corpora that can have a great influence on spontaneous gesture production (narrations from images, production of procedural speech, …), or on qualitative studies of gesture production by PWA in uncontrolled corpora (interactions in the family environment). Indeed, de Beer et al. (2019) have shown that we find more iconic gestures and pantomines in cartoon narration tasks, but more metaphorics, deictics and emblems in conversations.

The objective of this paper is therefore to present a prosodic study of the gestures of PWA in comparison with those of NAP in conversations since this discourse genre is more revealing of discourse coherence than image description or procedural discourse. Our working hypothesis was that since gesture and speech are tightly linked to each other in non-pathological discourse (McNeill 2005), there might be similar breakdowns in the two modalities for PWA that therapists need to be aware of before launching into multimodal rehabilitation without any previous knowledge of the possible shortcomings they might have to face. Reversely, speech and gesture are also different semiotic modes of expression and the speech impairment in PWA might encourage them to spontaneously rely more on the gestural semiotic mode, a tendency which can then be encouraged by speech therapists.

2 Theoretical background

In Broca's aphasics, words uttered in the initial group position are longer than words produced in the final position, in contrast to non-aphasic speech rhythm (Danly and Shapiro 1982), and nonfinal syllables are also longer than final syllables (Louis 2003). In particular, non-fluent PWA show difficulties in initiating word production (Kurowski and Blumstein 2016), with more frequent phonological errors at the beginning of a word (Tuller 1984). Non-fluent PWA also suffer from numerous paraphasias: metathesis (sound inversion), epenthesis (sound addition), substitutions and deletions of sound(s) in words, assimilations and word confusions. These paraphasias generate numerous self-corrections in PWA in contrast with non-aphasic speech.

The literature on the gestures of PWA sometimes reveals contradictory results. According to Cicone et al. (1979) and Feyereisen (1983), non-fluent PWA are no more fluent in gesture than they are in speech. They produce fewer gestures than non-aphasic speakers, with speech rate being directly correlated to gesture frequency and the gesture-to-word ratio. In contrast, other studies have found that most PWA tend to use non-verbal communication to compensate for impaired speech (de Beer et al. 2017; Hogrefe et al. 2013). These differences in the results obtained for the gesture rate of PWA are largely explained, however, by the fact that the calculations were not carried out on the same speech units (Cocks et al. 2013): while some studies choose the gesture-to-word ratio or the syntactic clause to calculate the number of gestures performed by PWA, others choose a temporal unit (number of gestures per second or minute). Among the works that report a possible compensation of speech by gesture, the results are also contradictory. While Smith (1987), cited in (Ahlsén 1991), finds that more severely affected PWA compensate more than less severely affected people, Mol et al. (2013) find that more severely affected PWA gesture less easily than NAP to compensate for speech. More recently, De Beer at al. (2020) also find that whereas PWA use iconic gestures to compensate for their deficient speech in narration tasks, these gestures are rather used in a redundant way by NAP in the same task. In this respect, they therefore confirm results found in earlier studies where PWA were reported to rely heavily on iconic gestures to compensate for their language impairment (Akhavan et al. 2018) and may benefit from the multimodal information provided by co-speech gestures. Preisig et al. (2018) found that patients with more severe aphasia and reduced speech fluency produced more 'meaning-laden' gestures to compensate for the problems they meet in speech.

Finally, it is not yet clear what role gesturing plays for PWA: while some authors such as those already mentioned in the previous paragraph believe that gesturing can be used by PWA to compensate for deficient speech, others believe that gesturing facilitates the recovery of the correct phonological form of words in lexical searches without substituting speech (de Ruiter 2006), while still others attribute both functions to gestures in this population (Kroenke et al. 2013). As Ahlsén (2015) notes, linguistic gesture and speech are closely related, but also have a certain independence from each other, which would explain these apparently contradictory results. It should also be noted that, in conversations, PWA perform gestures different from those produced by NAP. While PWA perform an equivalent amount of emphatic gestures, more word-search-related gestures are observed as well as more referential gestures (Macauley and Handley 2005), which means that PWA perform more iconic gestures when they are searching for their words than when speech is more fluid (Sekine et al. 2013). In addition, most PWA use gestures that draw or trace shapes rather than gestures that mimic an action (Mol et al. 2013).

In terms of the information conveyed by the gestures performed by PWA, different authors note that the most severely affected PWA perform less informative and less understandable gestures than those of the less severely affected PWA or those of NAP (Mol et al. 2013; Pritchard et al. 2015; van Nispen 2016). More than 70% of the gestures performed by PWA contain redundant information to that of speech, and gestures that contain additional information are produced preferentially during speech, not during pauses (van Nispen 2016), which goes against a compensatory role of gestures. On the other hand, the less fluent the PWA are, the more essential their gestures become to communication (Goodwin 1995, 2000; Rose et al. 2017).

The effects of multimodal therapies are also contrasted: while they are effective for some patients, they are not effective for others (Beeke et al. 2015), as they often involve conversational strategies implemented between PWA and a conversational partner (most often the husband or wife). To be effective, such a strategy therefore involves changes of conversational habits that can be deeply rooted if the PWA has been suffering from the disorder for several years. The impact of these multimodal strategies also depends on the type of aphasia people suffer from (Hanlon et al. 1990) and the severity of aphasia (Marshall et al. 2012). Preisig et al. (2018:10) conclude their study stating that “rehabilitation professionals should increase the awareness of potential interlocutors for the gestures produced by people with aphasia”, and we believe this to be true. We also believe that speech therapists themselves should be fully aware of the implications of multimodal therapies in their advantages as well as in their shortcomings, and it is precisely the objective of this paper to present a preliminary study in linguistics on the prosody[1] of aphasic speech and gestures which although it is now based on a limited sample of aphasic patients, will probably increase its sample size in the future.

3 Data and methodology

Most of the studies mentioned in the previous section have examined gesture-speech relationships in experiments based on descriptions of images or actions that encourage the production of iconic or pointing gestures, while other types of gestures have been largely ignored, although gestures like beats or pragmatic gestures that reveal the organization of discourse are of a central interest in prosodic studies. Besides, we know little about the gestural production of PWA in less constrained environments compared to the gestures of NAP. This is what this paper will focus on: when not constrained by the iconic nature of a response or its link to an image, are the gestures of PWA similar to those of NAP? Furthermore, is the internal structure of the gestures produced by PWA similar to that of NAP? For example, what happens to gestures when words are difficult to express? Are they maintained, repeated or abandoned?

3.1 Corpus

In order to answer these questions, I used some video files from AphasiaBank (MacWhinney et al. 2011), a multimedia database of aphasic and non-aphasic speakers of several languages, recorded using the same protocol. The protocol tasks include four genres: personal narratives elicited by very similar questions in PWA and NAP, image descriptions, storytelling and procedural discourse, but only personal narratives were used for this study of aphasic speech in English. In order to elicit these personal narratives, the patients were asked to answer the following questions:

- How do you think your speech is these days?
- Do you remember when you had your stroke?
- What kinds of things have you done to try to get better since your stroke?
- Thinking back, can you tell me a story about something important that happened to you in your life? It could be happy or sad or from any time – from when you were a kid or more recently.

From the database, I selected 4 PWA (2 women and 2 men) and 4 NAP (3 women and 1 man), all speakers of American English. Among the PWA, 2 patients suffer from Broca’s aphasia and the other 2 suffer from transcortical motor aphasia. The aphasia of the four PWA is moderated according to the WAB (Western Aphasia Battery) score they obtained on a series of hospital-based oral and written language comprehension and production tests, the results of which are included in the database. Including people with lower WAB scores would make it difficult to study the relationships between speech and gesture as they probably would be too limited in speech for such a study, which is one of the reasons why relatively few patients were included in this study. Another reason is that the gestures had to be fully visible and the sound quality good enough for the prosodic analysis of speech. Information on the four PWA in the study is given in Table 1.

1 The term encompasses the study of pauses, speech rate, intensity, rhythm and voice pitch/tones. It can apply to both speech and gesture.

Table 1: Description of the PWA selected in AphasiaBank for the study (information concerning the duration of aphasia and age of the participants is given in relation to the date the recording took place).

Participants	Gender	Duration of aphasia	Date of recording	Age	Aphasia	WAB score
ACWT01a	F	11 y 8 m	2012	69,9	Broca	63,9
ACWT02a	F	3 y 30 m	2012	53,1	TCM	74,6
adler18a	H	5 y 75 d	2010	71,5	TCM	59,8
elman03a	H	11 y	2009	55,2	Broca	66,2

3.2 Data processing

The nature of the corpus raises the question of the units chosen to adequately compare the speech of PWA and NAP, as prosodic or syntactic units traditionally adopted for transcription in multimodal studies may prove problematic. For example, Inter-Pausal Units (which correspond to pauses between two speech chunks) are difficult to adopt here because of the recurrent presence of long silent pauses – sometimes even in the middle of a word – in PWA during their frequent lexical searches. These frequent and sometimes quite long pauses, as well as the presence of numerous word truncations, also make it difficult to detect intonation phrases. Finally, the agrammaticality of the speech of Broca's aphasics (notably the recurrent absence of verbs and the substitution of certain syntactic groups by onomatopoeias, for example) excludes a transcription of syntactic clauses or even sentences. Knowing that phonemes are not suitable units for multimodal analysis because they don't have the same granularity as gestures, breath groups have been chosen here for a verbatim transcription of the corpus using PRAAT (Boersma and Weenink 2009). The advantage of choosing breath groups is that this unit is independent from any theory of speech. Besides, although inspiration is affected by aphasia, expiratory muscle strength is not (Mustafaoglu et al. 2017), which means that breathing patterns should not be different for PWA than those for NAP and the speech units in breath groups should be comparable in the two groups of speakers. Each breath group was delineated by an audible breathing and/or a change in speech turn. 224 breath groups were counted for PWA versus 324 for NAP. The corpus was then transcribed into words that were also aligned with the speech signal (694 words for PWA vs. 2899 words for NAP). These transcriptions included silent and filled pauses (silent pauses were counted without any duration threshold and filled pauses were vocalized with items like 'um', 'uh' or 'er'), as well as truncated words, laughter, etc. In two separate tracks, I noted the number of syllables in each breath group – without noting the transcription of each syllable – as well as the intonation contours on highly-stressed syllables. Those included the following tones: fall, rise, flat, as well as complex tones like the rise-fall and the fall-rise.

Using the ELAN multimedia file annotation software (Sloetjes and Wittenburg 2008), all hand gestures performed by PWA and NAP in the 8 personal narratives were coded. The annotation counted 430 gestures for PWA versus 291 for NAP, for a total of 721 gestures. The gestures were categorized into referential gestures (gestures that refer to a concrete object or action or an abstract concept) and non-referential gestures. The referential category followed McNeill's classification (2005) and included iconics (gestures that represent objects or mime actions), metaphorics (gestures that represent abstract concepts like moving the two extended hands up and down to represent equality), emblems (conventional gestures, for instance gestures to say goodbye, no, etc.) and pointing gestures. Non-referential gestures included gestures that do not refer to an object, action or concept, such as gestures related to word-search, as for example a circular movement of the hand that represents the thinking process, gestures that express some modality — also called modal gestures by A. Kendon (2004), like the opening of the hands to express uncertainty — or are related to the organization of discourse, for instance the opening of the right hand to accompany or replace a phrase like 'on the one hand' followed by the opening of the left hand to express 'on the other hand', as well as beats, i.e. rhythmic biphasic gestures. In total, NAP performed 132 referential versus 159 non-referential gestures, and PWA performed 162 referential versus 268 non-referential gestures. The finer categorization described above was adopted in a second round of coding with the notation of gesture dimensions such as iconics, metaphorics, emblems, beats and points as described by McNeill (2005). The categories were also adapted to correspond more closely to the gesture performance of PWA. Dimensions such as 'word search', 'discourse organization' and 'truncations' were added to the typology.

Still using ELAN, the different gesture phases (Kendon, op. cit.) were coded. Among these phases is the preparation, i.e. the placement of the hands for the gesture. The stroke is the communicative part of the gesture, and the retraction corresponds to the release of the hands (here, either accompanied by a total withdrawal to the resting position, e.g. hands placed on the table, or accompanied by a partial withdrawal, e.g. relaxing of the hands without withdrawal of the arm for instance). Two other phases were also noted: a possible pre-stroke or post-stroke hold during which the hand(s) pause(s) before or after the stroke, while keeping the manual configuration established during preparation or during the gesture itself. Gesture apex (i.e. point of maximal extension) was also noted as this reference point is used in the analysis of synchronous events in speech with a different granularity.

Finally, all the annotations made with PRAAT (speech transcription, number of syllables in breath groups, intonation contours) were imported in the ELAN annotation file in order to study the synchrony of gesture and speech events.

4 Analysis

In order to answer the questions posed in Section 2 and repeated below for the sake of clarity, the differences between PWA and NAP were tested using Generalized Linear Mixed Models (GLMM) (Bates et al. 2014) with the R 3.4.0 statistical analysis program (R Core Team 2012). Speakers were included as a random factor to account for inter-speaker variability. Some examples are also included in the description whenever possible to illustrate some of the results of the quantitative analysis. Our research questions were the following:

- When not constrained by the iconic nature of a response or its link to an image, are the gestures of PWA similar to those of NAP?
- Is the internal structure of the gestures performed by PWA similar to that of NAP? For example, what happens to gestures when words are difficult to express? Are they maintained, repeated or abandoned?
- Is discourse coherence expressed in the same way (i.e. by means of intonation strategies or specific gesture performance) in the two groups of speakers?
- Can gesture compensate for speech deficiency in PWA?

4.1 Duration

Speech rate: Although Mustafaoglu et al. (2017) reveal no difference in expiratory muscle strength for the two groups of speakers, we found a significant difference between participants (PWA vs. NAP) over the duration of the breath groups ($\beta = 1061.4$, SE = 431.2, $p < 0.05$), with a mean duration of 4.029 s for PWA and 2.839 s for NAP. There was also a significant difference between the two groups of participants in terms of articulation speed (no. of syll/s in the breath groups excluding pause times) with an average of 2.5 syll/s for PWA versus 4.1 syll/s for NAP ($\beta = -2.14$, SE = 0.28, $p < 0.001$). The speech rate (no. of syll/s counting pauses) is also significantly different between the two groups ($\beta = -2.3$, SE = 0.24, $p < 0.001$) with an average rate of 1.5 syll/s for PWA versus 3.8 syll/s for NAP as shown in Figure 1.

Duration of pauses in speech: The different speech rates in the two groups can't be explained by a longer duration of filled pauses which is not significantly different between the two groups ($\beta = -65.4$, SE = 32.4, $p = 0.09$), with a mean duration of 0.584 s for the filled pauses of PWA versus 0.513 s for NAP. On the other hand, it is the duration of silent pauses within the breath groups that is significantly different between the two

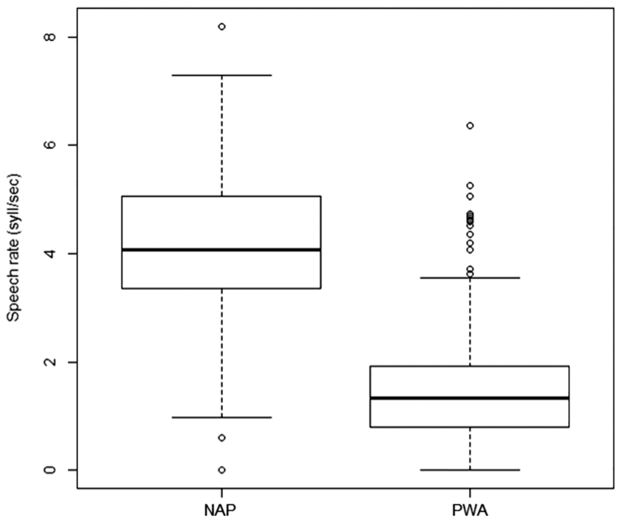

Figure 1: Speech rate of NAP and PWA in breath groups.

populations (β = –290.5, SE = 83.5, p = 0.01), with a mean duration of silent pauses of 0.682 s for PWA versus 0.371 s for NAP as shown in Figure 2. This can be explained by the frequent word searches in PWA's discourse that favor the appearance of sometimes long silent pauses.

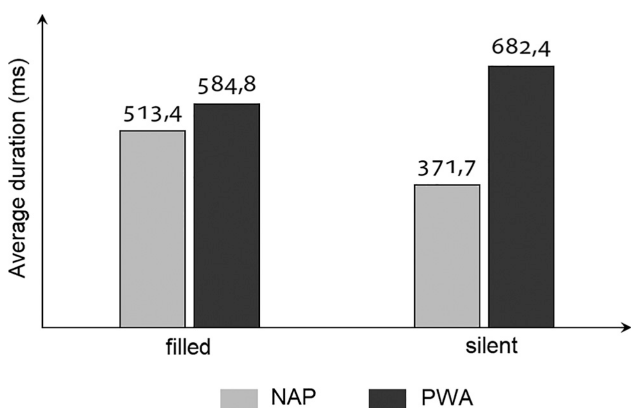

Figure 2: Average duration of filled and silent pauses for NAP and PWA.

This is illustrated in example (1), where the speaker answers "New Dear's day two thousand" (with a substitution of 'year' for 'dear') to the therapist's question about the date of her stroke. In this breath group with a total duration of 4.27 s, there are two relatively long silent pauses of 0.6 and 0.7 s respectively. In example (2), the speaker searches for the term 'remember', but initially confuses it with 'November', which is very close phonetically, and is close to the correct form in its second formulation, with the addition of /f/ at the beginning of the word. She then produces two breath groups separated by an audible breathing. The first group contains two fairly short silent pauses, but the second one is a little longer.

(1) New (0,6) Dear's day (0.7) two thousand.
(2) I don't nomember (0.1) ah (0.06) mm (h) I (0.3) don't fremember.

Gesture duration: No significant difference in the overall duration of gestures between PWA and NAP was found globally in this corpus (β = –98.7, SE = 188.4, p = 0.61), and this is true for referential gestures (β = 433, SE = 342, p = 0.25) as well as non-referential ones (β = –363.1, SE = 227.8, p = 0.16).

Duration of gesture phases: The main differences between PWA and NAP lie in the internal structure of gestures, either in the duration of a gesture phase as shown in this paragraph and summarized in Figure 3, or in the proportional number of phases as shown in the next section. The difference in the duration of preparations is not significant between the two groups (β = 120.8, SE = 54, p = 0.06). However, pre-stroke holds are significantly longer for PWA than for NAP (β = 79.8, SE = 30.4, p = 0.03). This is the only gesture phase that has a longer duration for PWA than for NAP since gesture strokes are not significantly different in length between the two groups (β = –12.4, SE = 58.3, p = 0.83), and neither are post-stroke holds (β = –243.7, SE = 170, p = 0.2) or retractions (β = –49.7, SE = 54.9, p = 0.4). The lack of significance in the duration of post-stroke holds despite the difference in average duration for this phase as shown in Figure 3 below is undoubtedly explained by the great variability of these holds in PWA.

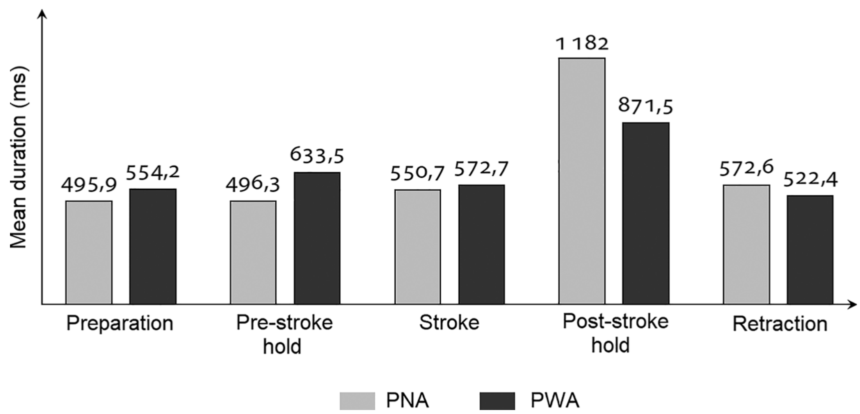

Figure 3: Mean duration of gesture phases for PNA and PWA.

The longer duration of pre-stroke holds in PWA is illustrated in example (3) below. Following a question from the therapist (TH): "Do you remember when you had your stroke?", the PWA responds that she had her stroke "three years ago" and initiates an emblem (number 'three') during the relatively long silent pause (1.6 s) following the question. During this pause, she places her fingers at (1) in the configuration for number 'three' (the end of the preparation corresponds to Figure 4a). She then keeps her hand in this precise configuration for a long hold (corresponding to the notation (2) in the example) until the end of the silent pause. In (3), she begins the stroke of her gesture, the climax of which is shown in Figure 4b. Finally, when pronouncing 'ago', she retracts her hand to rest it on her lap, which corresponds to notation (4) in the example.

```
(3)   TH:    Do you  remember  when  you  had your  stroke?
      PWA:   (1,6)  uh  (0,1) three  th-  years  (0,1)  ago.
             |-|--|-----------------------------------|-----|
              1  2                  3                     4
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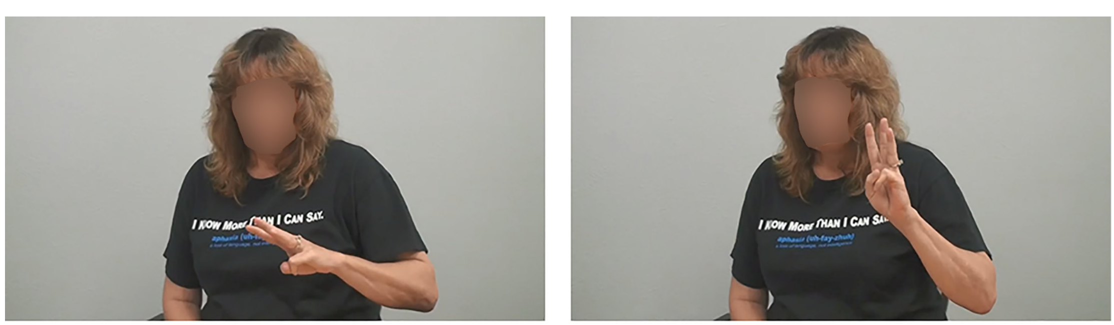

(a) (b)

Figure 4: Preparation phase (a) and stroke (b) of the emblem performed by the PWA in example (3).

4.2 Number of occurrences

Number of pauses: The difference in speech rate observed in the previous section is not related to a higher number of filled pauses within the breath groups for PWA (β = 0.63, SE = 0.29, p = 0.27) or silent pauses (β = 1.40, SE = 0.33, p = 0.14).

One may wonder why the number of silent pauses is not higher in PWA than in NAP. The explanation is that NAP produces breath groups that often count several syntactic clauses. These clauses are very commonly delimited by silent pauses (but not as long on average as those of PWA). Thus, example (4) is produced by a NAP. The breath group has a total duration of 7.2 s, within which four syntactic clauses are separated by three silent pauses.

(4) I had a cold (0,06) I couldn't lift my head up (0,3) I mommy I've got two small children (0,9) but my aunt was there.

In contrast to NAP, PWA produce breath groups which usually have a single syntactic clause, but the groups of words that form that clause can be separated by pauses, as in examples (1) and (2).

Distribution of tones: As far as melodic tones are concerned, there are also differences between the two groups of participants, as shown in Figure 5 below. In order to be able to carry out statistical tests, rising-falling tones and simple falls were grouped together, as well as falling-rising tones and simple rises, because there was not enough data in these two sub-categories of tones to allow for the processing of the statistics. The linear model reveals a statistical difference between the two groups for falling tones (β = 0.004, SE = 0, p < 0.01), which are proportionally more prevalent in PWA than in NAP, as shown in Figure 5 (65.4% for PWA vs. 56.7% for NAP). In contrast, PWA produce proportionally fewer flat tones than NAP (β = –0.004, SE = 0, p < 0.01); flat tones make up 20.2% of PWA's versus 24.5% of NAP's tones respectively. Finally, the difference in the use of rising tones is also significant (β = –0.013, SE = 0, p < 0.01). The rising tones constitute only 14.4% of the tones for PWA as opposed to 18.8% of the tones for NAP.

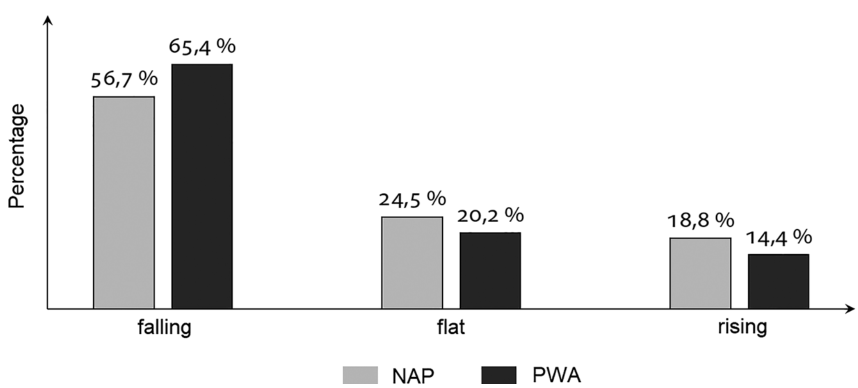

Figure 5: Proportion of falling, flat and rising tones compared with the total number of tones for PWA and NAP.

The large proportion of falling tones in PWA (which also include rising-falling tones) is shown in Figure 6. The speaker talks about a trip to China that she found 'just amazing', an emotion she expresses by repeating the whole statement 'oh, just amazing'. The two interjections are strongly stressed and pronounced in a falling tone. The first mention of 'amazing' is uttered with an emphatic rising-falling tone, but the second mention has a slightly falling tone. The four intonation phrases are uttered in a single breath group, but there is no rising tone to express any dependency between the intonation phrases, whereas we would have expected a flat or rising tone on both interjections at least, and even possibly on the first occurrence of 'amazing' in non-pathological speech.

This difference in the use of tones between the two groups of participants can be explained by differences in the structure of the statements: rising and flat tones are used primarily in English in this type of discourse to mark the incompleteness of a statement or an oral paragraph in NAP (Wells 2006). PWA, whose discourse may consist of

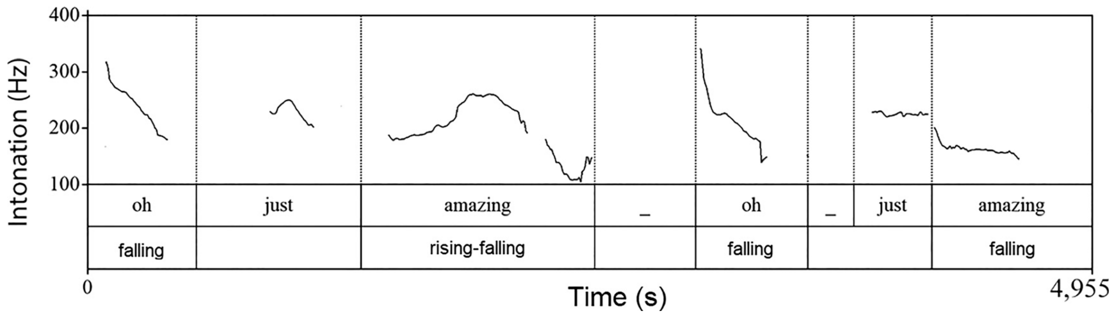

Figure 6: PRAAT intonation curve of independent intonation phrases uttered by a PWA.

independent syntactic phrases, do not compensate for absences of syntactic or discursive links between phrases by tones that might help express relationships between statements. More statements are therefore formulated as complete and independent, thus forming a discourse in which clauses are less chained to each other. In the following section, we will see that this prosodic characteristic resonates with the types of gestures performed by PWA.

Gesture rate: With regard to gesture rate (number of gestures per second for all gesture types), no significant difference was observed between the two groups ($\beta = 0.16$, SE = 0.07, $p = 0.06$) with an average gesture rate of 0.38 gestures/s for PWA versus 0.24 gestures/s for NAP. This lack of significance for gesture rate applies in the same way to non-referential ($\beta = 0.102$, SE = 0.05, $p = 0.10$) and referential ($\beta = 0.06$, SE = 0.05, $p = 0.24$) gestures. On the total number of gestures performed by the two groups of speakers, the gesture-to-word ratio is therefore 0.6 for PWA against 0.1 for NAP. If we do not count truncated gestures and gestures related to word search, the proportion remains the same between the two groups with 0.5 gestures per word for PWA versus 0.09 gestures per word for NAP. However, a significant difference between the two groups is noted if we take into account the number of gestures as a function of articulation time ($\beta = 0.35$, SE = 0.06, $p < 0.005$).

Gesture phases: In terms of gesture phases, PWA perform significantly more preparations than NAP ($\beta = 0.7$, SE = 0.23, $p = 0.01$). This is not the case of pre-stroke holds, since PWA do not perform more holds than NAP ($\beta = 1.4$, SE = 0.6, $p = 0.08$). Although gesture strokes are not significantly different in length between the two groups, as shown in the previous section, there are fewer strokes in PWA than in NAP ($\beta = -2.9$, SE = 6, $p = 0.02$). Post-stroke holds are not more numerous in one group than in another ($\beta = -0.07$, SE = 0.32, $p = 0.8$). The same observation can be made for retractions that are not more numerous in one group than in the other either ($\beta = -0.29$, SE = 0.42, $p = 0.5$).

The overall results on gesture phases are shown in Figure 7, which indicates the percentage of each phase as a function of the total number of gestures performed in each group. The lack of significance in the number of pre-stroke holds between the two groups is explained by the very small number of this type of phase in NAP, which is in itself revealing.

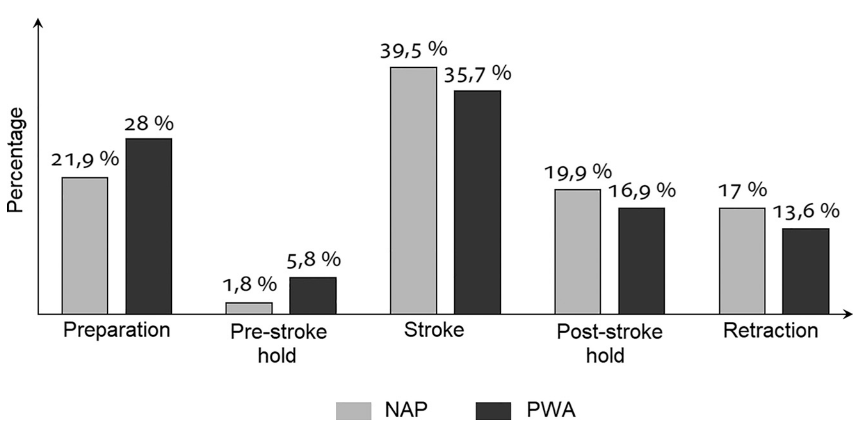

Figure 7: Percentages of occurrence of gesture phases as a function of total number of gestures for NAP and PWA.

4.3 Can the gestures of aphasics compensate for impaired speech?

To assess whether there is compensation for speech deficiency by gesture in PWA, two hypotheses can be made. The first hypothesis is that if the gestures of PWA do not compensate for impaired speech, a higher proportion of gestures should accompany lexical rather than grammatical words. If, on the contrary, PWA's gestures allow them to compensate for deficient speech, a higher proportion of gestures should be performed during pauses since, in this situation, gestures are substitutes for words.

The results show that PWA perform more gestures during pauses than NAP ($\beta = 0.13$, SE = 0, $p < 0.01$), but also that a larger number of gestures are produced during word truncations, and nonwords ($\beta = 16.22$, SE = 0, $p < 0.01$). On the other hand, PWA perform fewer gestures with gesture climaxes coinciding with lexical words than NAP ($\beta = -0.01$, SE = 0, $p < 0.01$). The number of gestures that coincide with grammatical words is not significantly different between the two populations ($\beta = -0.03$, SE = 5.78, $p = 0.99$). All of these results support a role for compensation of gestures in PWA, a role reinforced by the fact that gesture pre-stroke holds are longer to better match the words they accompany, as was shown in Section 3.1. If the word doesn't come despite the lengthening, the gesture will probably be carried out during a pause or a truncated word.

These results are shown in Figure 8, which indicates that while the percentage of gesture peaks coinciding with grammatical words is similar in the two groups (19.2% in PWA vs. 18.7% in NAP), the percentage of gesture peaks coinciding with lexical words is much higher in NAP (69.5%) than in PWA (40.8%).

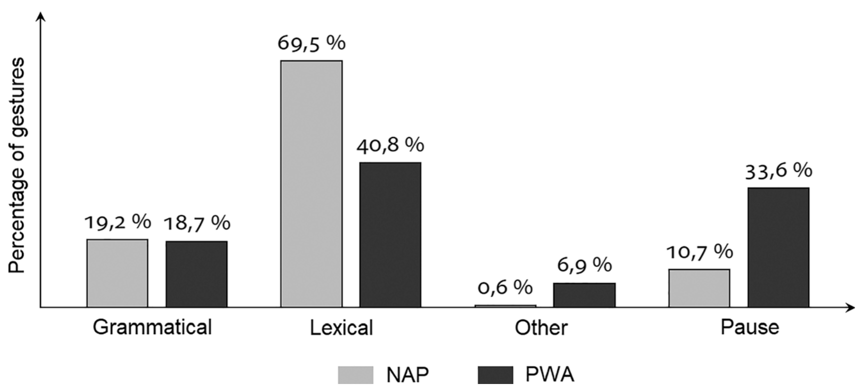

Figure 8: Percentages of gestures performed together with grammatical words, lexical words, non-words and pauses in NAP and PWA.

Gesture peaks that coincide with a nonword (coded 'other' in the figure) are not very numerous but are nevertheless more abundant in PWA (6.9%) than in NAP, where this pattern is virtually absent (0.6%). Finally, the percentage of gesture climaxes performed during a pause is three times higher in PWA (33.6%) than in NAP (10.7%).

With regard to the types of gestures performed by the two groups, first of all, we note a lack of significance in terms of the proportion of referential and non-referential gestures of PWA and NAP ($\beta = -0.01$, SE = 3.99, $p = 0.99$). PWA performs 54.6% of non-referential gestures for 45.3% of referential gestures. These proportions are indeed very close for NAP, who perform 62.2% of non-referential gestures versus 37.7% of referential gestures.

Going into more detail about gesture dimensions, Table 2 below shows the number of gestures performed by each group of participants, as well as the Chi-squared estimated values for the gestures. These values show that a χ^2 approximation is appropriate and a Pearson's Chi-squared test showed that there is a highly significant relationship between the two categorical variables – pathology versus gesture type (X-squared = 113.68, df = 7, p-value < 2.2e-16). Table 3, which is provided in annex at the end of this paper, gives the detail of gesture performance for each speaker in the corpus. It shows that speakers are quite similar in the proportions of gesture dimensions they perform apart from a few differences: the proportion of beats is the same in three PWA except Broca 1 who performs less beats, but proportionately more emblems and points. TMC 2 also performs proportionally more gestures linked to discourse organization. Other gesture proportions are not different if we consider individual speakers but we note that the total number of gestures performed is very much speaker-dependent in the two groups of participants.

Table 2: Number of gestures and expected Chi-squared frequencies for PWA and NAP.

Gestures	PWA	NAP		PWA	NAP
Aborted	23	2	Aborted	14.90985	10.09015
Beats	146	58	Beats	121.66436	82.33564
Discourse	73	97	Discourse	101.38696	68.61304
Emblems	49	4	Emblems	31.60888	21.39112
Iconics	40	55	Iconics	56.65742	38.34258
Metaphorics	12	36	Metaphorics	28.62691	19.37309
Pointings	61	36	Pointings	57.85021	39.14979
Word Search	26	3	Word Search	17.29542	11.70458

Figure 9 below shows the proportion of each gesture type performed by the two groups of participants. One notes that the difficulties experienced by PWA in initiating word production are not only reflected in the existence of many truncated words, but in their gestures as well, as they also perform a higher percentage of truncated gestures (gestures that contain a preparation possibly followed by a hold, but which do not contain any stroke) than do NAP, for whom gesture truncations are rare (6.2% for PWA vs. 1.1% for NAP).

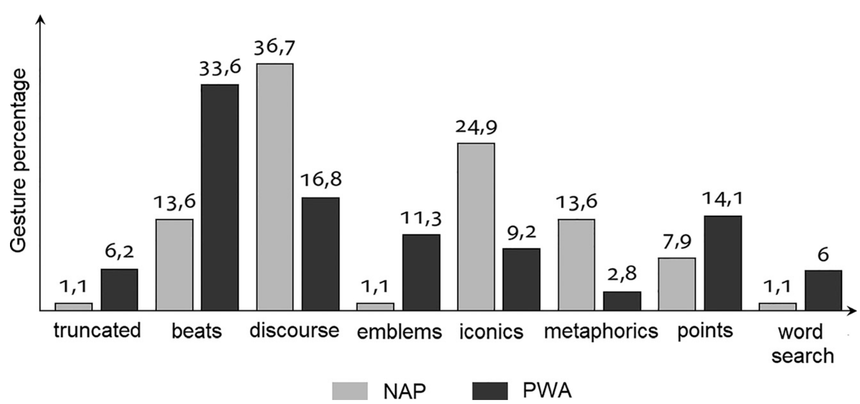

Figure 9: Distribution of gesture types for NAP and PWA.

Among referential gestures, PWA perform many more emblems (conventional gestures) than NAP (11.3 vs. 1.1%) and almost twice as many pointing gestures (14.1 vs. 7.9%), which share a greater degree of conventionalism with emblems than other gesture types. In contrast, PWA perform proportionally fewer iconic gestures than NAP (9.2 vs. 24.9%) and fewer metaphorics as well (2.8 vs. 13.6%). Both of these gestures happen to be much more idiosyncratic than emblems and pointing gestures. This means that if PWA use gestures to compensate for their speech in this type of interaction, these are based primarily on conventional gestures rather than on their personal creativity in this study. PWA's greater use of emblems (which are, in this context, often linked to the expression of numbers) and pointing gestures can be related to the pointing gestures of young children learning to count (Graham 1999). In the context of PWA, points provide a physical record of what has been stated in the discourse and provide a link to what is to be stated next, and emblems provide a link between a concrete physical realization and the abstract symbolic naming of numbers, thus providing a cognitive underpinning of some abstract notion (Goldin-Meadow 2017). These two types of gestures are illustrated in example (5).

(5)	Truncated gesture, pointing gesture and emblem:	
1 Speech:	p- u	[h (3,7) okay (1,2) five w- [w@l] weeks (0,8)
2 Gesture:		[truncation] [point] [emblem]
3 Speech:	um (0,3) I went to the home	

A particularly interesting point here is the gestural performance on the beginning of this participant's statement (actions performed towards the end of the statement are not noted here). The speaker answers the question of the therapist, who asked her what therapy she had taken after her stroke. The content of the response is that for five weeks she went to a special institute. The statement begins with a truncated word "p-" immediately followed by a pause filled with 'uh'. Towards the middle of this filled pause, she begins the gesture illustrated in Figure 10a while gazing at her hand.

PWA have particular difficulties with the expression of numbers and numerals, and one can imagine that here the gesture initiated was an attempt to find the number of fingers necessary for the gestural expression of the number 'five' that comes later in the statement. The filled pause is immediately followed by a long silent pause (3.7 s), during which the initiated gesture turns into the point shown in Figure 10b. This point is only accompanying the silent pause and therefore does not correspond to any verbally expressed referent. The speaker then goes on to directly perform the emblem of the number 'five', the climax of which coincides with the beginning of the word 'five' after a pre-stroke hold, a gesture that is held throughout the first part of the statement, until the end of the pause of 0.8 s that follows the word search. Here, the difficulties of formulation appear to cover the entire noun phrase 'five weeks', since 'five' is articulated after a new discursive start marked by 'okay' and a 1.2-s long silent pause, but 'weeks' is also difficult to pronounce. It is first primed with w-, then the speaker produces the paraphasia [w@l][2] with a confusion of two phonemes before she manages to utter 'weeks'.

Among the non-referential gestures, we have just mentioned truncated gestures, but we note that PWA also perform many more beats than NAP (33.6 vs. 13.6%). The impression that emerges from the corpus is that of the four PWA, three participants in particular – suffering from Broca's aphasia and transcortical motor aphasia respectively – perform a very large number of beats, evenly spaced in their speech. These beats do not

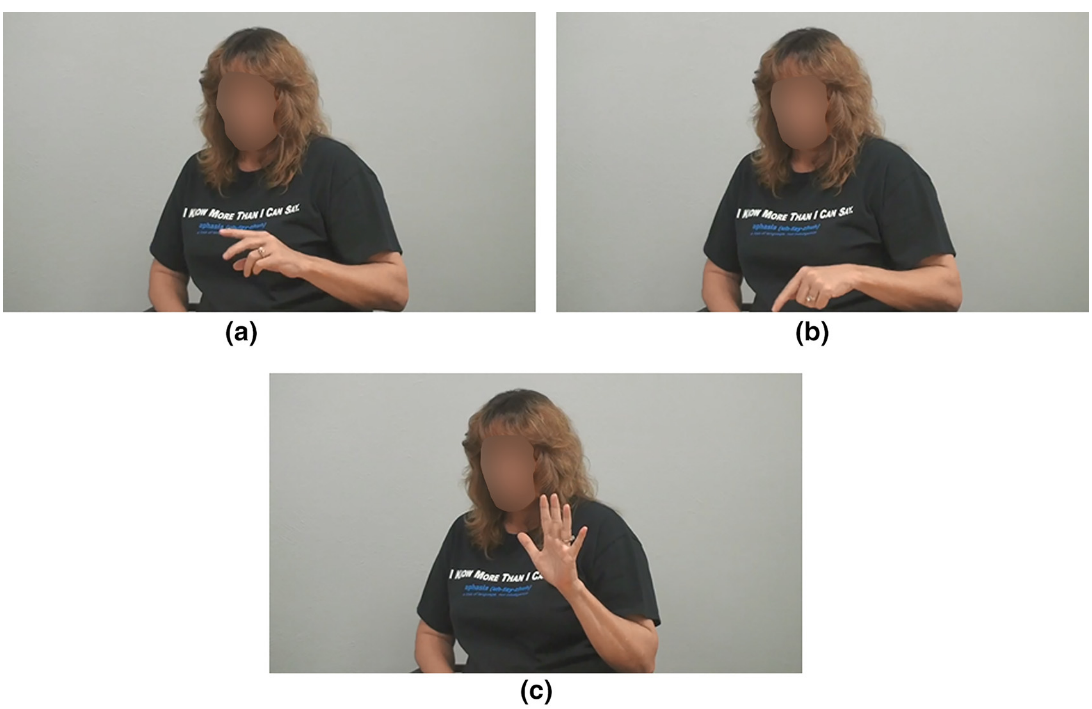

Figure 10: Truncated gesture (a), pointing gesture (b) and emblem (c) in a PWA's discourse.

2 Speech paraphasias were transcribed in SAMPA (Wells 1997) rather than the IPA, a transcription convention that is more adapted to direct phonetic transcription in speech analysis software.

have an emphasis function at all as could have been expected from other studies (Ferré 2011; Krahmer and Swerts 2007; Ruth-Hirrel and Wilcox 2018; Shattuck-Hufnagel and Ren 2018), but are used by PWA to set the pace of speech and thus create a rhythmic effect of entrainment that can facilitate lexical access. Orgassa (2005) finds similar results for a patient with anomic aphasia. In addition, PWA also perform more gestures expressing word search than NAP (6 vs. 1.1%) in phases where speech is less fluid. Finally, PWA perform significantly fewer gestures related to discourse organization or grammar than NAP (16.8 vs. 36.7%). This observation corroborates what has been noted about the prosodic contours of both groups insofar as it highlights two points. On the one hand, PWA chain their syntactic statements much less than NAP and their discourse often consists of syntactic phrases which are usually not connected to each other. On the other hand, the absence of certain grammatical words such as conjunctions, punctuation markers and tags, etc., especially in PWA with Broca's aphasia, are not compensated for by gestures that may indicate grammatical and discursive relationships which are not verbally expressed.

Example (6) illustrates the use of beats and gestures related to the expression of lexical search by a PWA. The shape of the beats and gestures related to the word search is also visible in Figure 11: the speaker performs several beats on the table with his middle and ring fingers (images 11a and b show the preparation and stroke of a beat, respectively, and image 11c shows the climax of a word-search gesture).

(6)	Beats and gestures related to word search:
Speech:	I used to be (0,1) a player (0,5) that uh (0,8) X (0,9)
Gesture:	[beat] [beat] [beat][word search . . . .]
Speech:	uh (0,7) done something (0,3) w- uh (0,7) something wrong
Gesture:	[point] [beat . . . .] [word search] [beat] [beat]

In example (6), the speaker begins his utterance by performing three successive beats on 'I', 'used' and 'to be'. To execute them, he raises his hand slightly from the table and performs the beat on the table itself. Then he performs a gesture expressing his word search while the rest of the utterance becomes more problematic, with many silent pauses, a full pause and an incomprehensible syllable (noted X in the transcription of the example). The gesture itself consists of raising the hand above the table by waving the fingers while making a

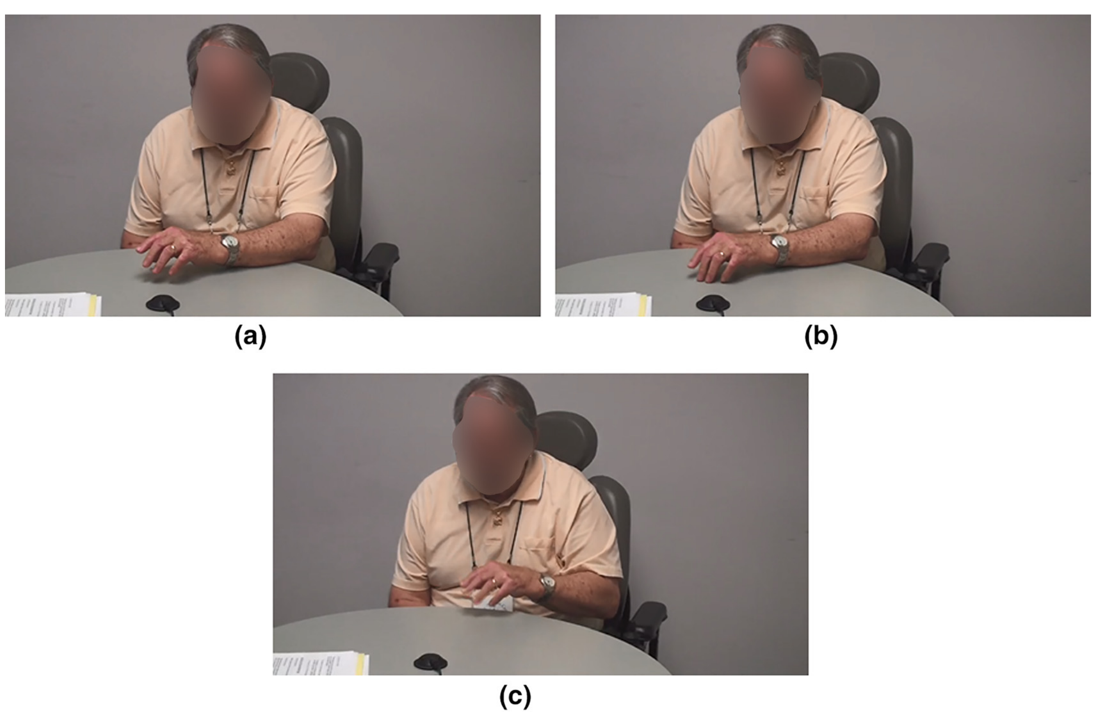

Figure 11: Beat (a, b) and word search gesture (c) in the discourse of a PWA.

horizontal circular movement. The gesture is used to show that after 'player', which is at a turn transition relevance place (Sacks et al. 1974) where the therapist could take the turn to speak, the speaker has not yet finished his utterance but needs more time to formulate the rest of it. While uttering another filled pause, 'uh', the speaker points to himself, which serves as the subject for the following verb phrase 'done something', itself uttered with a beat after the silent pause of 0.7 s. He then resumes his word-search gesture during the new formulation difficulties that follow, as he searches for the word 'wrong', which is first initiated and abandoned. After this, he rephrases 'something' with a beat and performs a new beat on the lexical item 'wrong' that is found as the speaker reaches the end of his utterance. We can see here that, in a statement that constitutes the equivalent of only one syntactic sentence, the speaker performs six beats and two gestures related to his expression difficulties, which are performed to prevent the therapist from intervening when his statement is not complete. We also see that the beats performed in a statement that is difficult to put into words do not have the emphatic role of beats shown in Ferré (2011) for parliamentary discourse.

5 Conclusion

The study presented in this paper was conducted on 4 aphasic people selected in the AphasiaBank database (McWhinney et al. 2011), two of whom were affected by Broca's aphasia whereas the other two suffered from Transcortical Motor aphasia. The speech and gesture performance of these four people were compared with those of four non-aphasic speakers recorded in the same database, following the same protocol. The aim of the paper was to answer a certain number of questions: do PWA perform the same types of gestures in the same proportion than NAP? Are PWA's gestures different or similar in their internal structure or do PWA's deficiencies in speech have an impact on the way they gesture? Do PWA use gestures to compensate for speech deficiencies? Although the sample of patients is of limited size, the results yielded by the study are nevertheless interesting and the study itself could be extended to a larger group of patients in the future.

Not surprisingly, this article showed that the speech rate and articulation speed of people with aphasia (PWA) is much slower than that of non-aphasic people (NAP) in personal narratives, and that this is due not only to difficulties in word articulation and many verbal truncations, but also to the presence of longer silent pauses than in NAP's speech, but not necessarily more. Filled pauses are not significantly different in the two groups of participants. As shown by Swerts (1998), filled pauses primarily play a role in structuring discourse, unlike silent pauses, which help to deal with more local difficulties and are in line with the extensive lexical search that aphasia can generate.

Gesture rate (number of gestures per second) is therefore not different in the two groups of speakers, whether it be for referential or non-referential gestures. But of course, as the flow of PWA's speech is slower than that of NAP, PWA perform more gestures per number of words than NAP, which confirms the studies of Feyereisen (1983) and Cocks et al. (2013). These results are also consistent with work that find that PWA are more gestural than NAP and are based mainly on the ratio of gestures to the number of words. The gesture-to-word ratio is still higher for PWA than for NAP when truncated gestures and gestures expressing ongoing word search are not included in the count.

The fact that PWA produce proportionally fewer gesture strokes than NAP shows that the way they gesture is related to their speech difficulties: just as PWA produce many more word truncations than NAP, they have more gesture truncations too. They may prepare a gesture and then retract their hands without the gesture having been performed. It can therefore be said that gestural abandonment goes hand in hand with verbal truncation. PWA also produce more preparation phases than NAP, and again, this pattern corresponds to their verbal production: since people with Broca's aphasia express themselves mainly in noun phrases with fewer syntactic links between groups, their gestures are less chained. Finally, the longer duration of their pre-stroke holds also shows that PWA take longer pauses before performing their gestures, until their lexical search is resolved. This is consistent with what had already been observed in stuttering by Mayberry and Jaques (2000), namely that the gesture is suspended – rather than abandoned – until the word can be produced when the initial syllable is longer. Discussing gesture theories and the different gesture-speech models which have been presented in the literature is much beyond the scope of this paper, which is based on a rather small sample size, but the changes observed in the gestures performed when speech is disfluent rather support the *Interface Model* (Kita and Özyürek 2003, 2007) in which some interactions are possible between gestures and speech at later stages than the initial conception of a notion, which is what happens when PWA abandon some initiated gesture during word search, or lengthen the beginning of a gesture so that its stroke is better aligned with the corresponding word in speech.

Finally, the type of gesture performed is related to the agrammatic (in Broca's aphasics) and dysprosodic structure of PWA: they perform fewer gestures expressing discourse organization and fewer intonation contours indicating speech continuation. Just as their speech rhythm is punctuated by pauses, their gesture flow is punctuated by beats that play an entrainment function. Furthermore, while PWA compensate for lexical deficiencies in part by using emblems, they make less use of other representational gestures (iconic and metaphoric gestures) than NAP in a discourse genre that is not based on image or procedure descriptions.

These results confirm the double function of gestures for PWA found by Kroenke et al. (2013): whereas some gestures like emblems may compensate for lexical deficiencies in PWA's discourse, other gestures like beats are used to facilitate the retrieval of the phonological form of words. Besides, as pointed out in the state of the art presented at the beginning of this paper, the use of iconic gestures to compensate for lacking words may be dependent on the degree of severity of aphasia and the more severely the patients are impaired, the more they may rely on representational gestures to fill gaps in speech and communicate with other people as found by Preisig at al. (2018). Although the patients selected in the present study are certainly impaired in their speech, their communication problems may not have reached a degree where people think of alternative strategies to improve their communication.

In order to be more effective, multimodal therapies should therefore take into account these specificities of PWA's language, so that they may better target the needs of these people and help them communicate better. Speech therapists should be aware themselves that PWA adopt different gesture patterns depending on the severity of their aphasia and that it is difficult for them to overcome the gestural habits they had before their stroke in terms of gesture-speech synchrony and alignment. Enlarging the set of conventional gestures PWA can rely on in interactions and encouraging their usual interlocutors to do so as well would probably be a good idea for the patients with a similar profile to those in the present study. Encouraging activities that involve rhythm in speech like poetry or singing (Schlaug et al. 2010; Sihvonen et al. 2020), if this is a possibility, would probably be quite efficient as well. Such therapies may offer PWA "a way of finding their own voice through reading, writing, and reciting poems to their caregivers and peers" (Shafi and Carozza 2011), although once again, such therapies probably do not suffice to recover from aphasia after a stroke and their effectiveness is also dependent on the type and severity of aphasia.

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Annex

Table 3: Number of gestures performed by the two groups of speakers.

	Aborted	Beats	Discourse	Emblems	Iconics	Metaphorics	Pointings	World search	TOTAL
BROCA 1	1	2	7	15	6	1	10	1	**43**
BROCA 2	5	60	22	19	15	8	24	15	**168**
TMC 1	15	61	22	12	19	3	23	5	**160**
TMC 2	2	23	22	3	0	0	4	5	**59**
Control 1	0	9	7	0	6	2	11	0	**35**
Control 2	2	15	28	0	39	21	7	2	**114**
Control 3	0	9	37	2	5	3	7	0	**63**
Control 4	0	25	25	2	5	10	11	1	**79**
TOTAL	**25**	**204**	**170**	**53**	**95**	**48**	**97**	**29**	**721**

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