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# A comparison of co-verbal gestures employment in oral discourse among normal speakers and speakers with aphasia

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**Abstract**

The study has systematically investigated how gestures are used in discourse differently between speakers with and without aphasia. Among speakers with aphasia, how gestures differed in several factors, including (1) hemiplegia, (2) aphasia severity, (3) linguistic performances and (4) semantic processing impairment on gesture use were also examined. Gesture analysis using the recently proposed coding system of gestures was conducted in 48 speakers with aphasia and 12 normal speakers to update the normative data of 119 normal speakers in the previous study. The results show that speakers with aphasia produced significantly more gestures than normal speakers. Among speakers with aphasia, the presence of hemiplegia didn't affect the frequency of gesture use. However, those with more severe aphasia, more complete sentences and simple sentences in discourse, verbal semantics processing impairment were found to use gestures more frequently in all discourse tasks. The relationship between gesture and speech in speakers with aphasia, whether gestures were used as compensation in communication and/or assisting lexical retrieval with the presence of language deficits due to aphasia, is discussed.

Gesture is a kind of non-verbal means of communication. It refers to body movements for communication of ideas, intentions or feeling (Knapp, & Hall, 1997). McNeill (1992) had given a more precise definition to gesture – arm and hand movements that synchronize with speech. The above two definitions showed that gesture is a kind of movements mainly by arm and hand related to speech for communication. Gesture can be used together with verbal means such as speaking during communication in order to supplement speech, regulate speech flow, maintain attention during speech and focus on speech content (Kendon, 2004).

In normal speakers, the role of gesture in relation to speech was described in two main viewpoints in the literature. Some authors (de Ruiter, 2000; Kendon, 1994; McNeill, 1992) suggested that gesture has a communicative role, while the others (Hadar, & Butterworth, 1997; Krauss, & Hadar, 1999) argued that gesture is employed during lexical retrieval process during speech. The communicative role of gesture can be supported by a study in Rausher et al. (1996) who found that speech involving spatial content was less fluent when gesture use was prohibited by limiting arm and hand movements. On the other hand, Morrel-Samuels and Krauss (1992) found that speakers used gestures when speaking words with lower familiarity which suggested that gesture may have a role in lexical retrieval.

There are also two conflicting views – compensatory or impaired use of gesture as a result of language deficits – about gesture in speech in speakers with aphasia who exhibited language impairment. The compensatory role of gesture in speech was supported by de Ruiter (2006) and Feyereisen (1987) who found that speakers with aphasia produced more co-speech gestures for their less informative speech as compensation. On the contrary, Cicone et al. (1979) proposed that gesture and speech are highly related that they may be originated from a single process. Gesture use would be impaired if speech was impaired as a result.

There were studies investigating the role of gesture in communication in speakers with aphasia. Comparisons were made between normal speakers with normal language abilities and speakers with aphasia who had language deficits. Using a natural conversational setting, Le May et al. (1988) reported significantly more use of gestures to describe physical movements in speakers with aphasia than normal speakers, while the results from studies by Glosser et al. (1986) and Feyereisen (1983) were totally different in which they found no significantly difference in frequency of gesture use in terms of gesture/word ratio between normal speakers and speakers with aphasia. However, the conflicting results may due to the methodological variability aroused from the free conversational context. In addition, the sample size of these studies was limited to at most 12 subjects with aphasia and 6 normal subjects so that discrepancy of findings would be resulted. Also, the discrepancy may due to the differences between the gesture coding systems employed in different studies. For example, ‘baton’ (a kind of gestures which modified the speech prosody) was counted as gesture in study by Le May et al. (1988), while it was classified as ‘others’ which means cannot be classified in Glosser et al. (1986)’s study.

As the variations between different gesture coding systems may complicate the annotation and interpretation in studies about gesture use (Scharp et al., 2007), Kwan (2012) had proposed a gesture classification framework to code gestures in terms of forms and functions independently. The gesture forms were divided into content-carrying including iconic, metaphoric, deictic and emblem, and non-content carrying including beats and non-identifiable; while the eight gesture functions included providing substantive information, enhancing speech content, providing alternative means of communication, guiding speech flow, reinforcing speech prosody, assisting lexical retrieval, assisting sentence re-construction and no specific functions. The coding system was then used to annotate gestures produced by 119 normal Cantonese speakers stratified into 2 genders, 3 ages and 3 educational levels in oral discourse tasks including sequential event, story-telling and monologue. The results indicated that content-carrying gestures were mainly used for helping listeners to decode speech content, while non-content-carrying gestures (namely beat and non-identifiable) were mainly used for emphasizing speech content. Moreover, the study found that speakers with higher language proficiency, as reflected by type-token ratio and percentage of regulators, produced fewer gestures while old ages used gestures more frequently. It is possible to draw a conclusive result about the gesture use in language deficits by comparing the gesture use among normal speakers and speakers with aphasia using this gesture coding system. However, while these studies only involved normal speakers, whether the proposed gesture coding systems can be applied to speakers with impaired language ability is still questioned.

Besides the comparison of gesture use between normal speakers and speakers with aphasia, employment of gestures as a function of hemiplegia, aphasia severity, linguistic performance and verbal semantic processing impairment among speakers with aphasia is in great interest.

Hemiplegia, especially on the right-side, is usually coincident with left hemispheric aphasia. McNeill (1992) suggested that the dominant hand was mainly responsible for gesture use. For right-handers, right-hand activity is related to left-hemisphere control of speech functions (Kimura, 1973) so that they may rely on the dominant right hand for gesture productions. As left-side hemisphere stroke can cause right-side hemiplegia, it is possible that gesture produced by the dominant hand in right-handed speakers with a left hemispheric stroke will be limited in terms of frequency. However, not many studies have investigated the effect of hemiplegia on gesture use. One of the few examples from Pedelty (1987) who found that paralysis of dominant hand would limit gesture use in terms of the number of gesture components and the gesture complexity.

For the relationship between the degree of aphasia severity and gesture use, besides the aforementioned studies which investigated the language deficits (which can be related to aphasia severity), Pedelty (1987) compared the gesture use between speakers with Broca's aphasia (more severe) and Wernicke's aphasia (less severe) in terms of gesture rate (calculated by dividing the number of gestures by the total number of words over the task). The results indicated that speakers with Broca's aphasia produced a significantly higher gesture/word ratio than speakers with Wernicke's aphasia. It suggested the compensatory use of gestures for limited language abilities. This finding was further supported by Fucetola et al. (2006) who found that aphasia severity predicts ability in functional communication which includes gesture use.

To investigate how gesture use is related to language ability, the current study compared linguistic performance represented by type-token ratio, percentage of simple sentences, complete sentences, regulators and dysfluency, in speakers with different frequency of gesture use. There were studies explored the relationship of gesture use and language in normal speakers. For instance, speakers with lower lexical diversity produced more gestures (Crowder, 1996); speakers with more dysfluency of speech occurrences used less gestures; speakers employed gestures for regulating speech including topic shifting or speech continuation (Mather, 2005). However, these findings could only be applied to normal speakers. How language ability of speakers with aphasia relates to gesture use was seldom investigated. It is possible that by identifying the effect of different parameters of language productions and gesture use, the relationship between speech and gesture can be further determined.

Based on the cognitive neuropsychological model of language, semantic process acts as a central role in all language modalities including reading, writing, speaking and gesture use (Hillis, 2001). It is possible that gesture use will be hindered with impairment found in semantic processing in speakers with aphasia. Most of the studies investigated the relationship between non-verbal semantic processing impairment and gesture use. For example, Fucetola et al. (2006) found that non-verbal semantic processing predicted the ability in functional communication in speakers with aphasia. Hogrefe et al. (2012) also found that impairment in non-verbal semantic processing abilities limited the formal diversity of gestures which indicates their potential information content. There have been few studies investigating verbal semantic processing impairment on gesture use. It is still questioned on how semantic processing impairment, either verbal or non-verbal, affects gesture use.

Most studies about gesture use are conducted in Western countries using speakers of foreign languages. Kwan (2012) was the first to examine the employment of gestures during oral narratives among normal Cantonese Chinese speakers. As gestures can be culturally specific (Kendon, 1997; McNeill, 1992), for example, the meanings of emblem for 'hand purse' (all fingers are press together at the tips and held upright) were different in Spain which means 'lots of people' and in Italy which means 'a query' (McNeill, 1992), Kwan's study has provided a basis of understanding gesture use of Cantonese Chinese speakers with language deficits in the current study. By investigating the gesture use in speakers with aphasia in the Cantonese population, culturally specific data can be yielded and applied to clinical implications such as gestural communication implementation in treatment of aphasia.

To conclude, the current study aimed to investigate the gesture use between normal speakers and speakers with aphasia using gesture coding framework proposed by Kwan (2012). Also, how gestures differed as a function of hemiplegia, aphasia severity, linguistic performance and semantic processing impairment among speakers with aphasia were examined. Four research questions relating the aims of the study are shown as follow:

1. Can the Kwan's system (2012) of independent coding of gestures in terms of forms and functions on normal speakers be applied to speakers with aphasia?
2. With reference to Kwan's system (2012), what are the differences of gesture use in terms

of frequency, distribution of form and function between normal speakers and speakers with aphasia?

3. How do factors of hemiplegia, aphasia severity, linguistic performance and semantic processing impairment affect gesture use in terms of frequency of gesture use among speakers with aphasia?

## Method

The source of data used for the current study came from the language database by Kong et al. (2009), in which aphasic Cantonese speakers' demographic data, screening of dysarthria and apraxia, results in Cantonese Aphasia Battery (CAB; Yiu, 1992), hearing test and Action Research Arm Test (ARAT; Lyle, 1981) were stored. Each participant was asked to narrate an important event in their life, to tell two highly familiar stories (Turtle and Hare and Crywolf) after presentation of picture cards, and to describe the procedure of making a ham and egg sandwich in front of photos of the ingredients. All the productions by the subjects were videotaped in a sound-proof room.

In addition to narrative tasks, each aphasic subject was administered the following language tests: (1) Spoken Word – Picture Matching Test adapted for Chinese speakers (SWPM; Law, 2007), (2) selected items from the Pyramid and Palm Trees Test (Howard, & Patterson, 1992) and the Associative Match Test in the Birmingham Object Recognition Battery (Riddoch, & Humphreys, 1993) that are culturally appropriate for Chinese subjects (Law, 2007), (3) object naming of selected items from Boston Naming Test, Short Form (Kaplan et al., 2001; Law, 2007), and (4) action naming of selected items from Verb Naming Test (Thompson, 2011; Law, 2007).

### Participants

Using the database (Kong et al., 2009), 131 normal Cantonese speakers (12 normal subjects were newly included and 119 subjects had been done in Kwan (2012)'s study) and

48 Cantonese speakers with different types of aphasia due to a single left hemispheric damage after stroke were selected and included in the study.

**Data Analysis**

All productions were transcribed orthographically as files in the Child Language ANalyses computer program (CLAN; MacWhinney, 2003). The language samples collected were used for linguistic performance analysis. Gesture analysis was firstly done by linking each language sample and its corresponding digitized video using the EUDICO Linguistic ANnotator (ELAN; Max Planck Institute for Psycholinguistics, 2002; Lausberg & Sloetjes, 2009). Then, three independent tiers were generated in each ELAN document to annotate the (1) linguistic information of the transcript, (2) forms of gestures appeared, and (3) function for each gesture used.

**Linguistic performance**

The linguistic performance of speakers with aphasia was done following the linguistic analysis of normal speakers in Kwan (2012). For each participant's language samples, the total numbers of simple and complete sentences (in which the sum of them will be the total number of sentences) were tallied. Five linguistic parameters were quantified in the language samples of speakers with aphasia: (1) type-token ratio (TTR) – total number of different words/total number of words; (2) percentage of simple sentences – number of simple sentences/total number of sentences; (3) percentage of complete sentences – number of complete sentences/total number of sentences, (4) percentage of regulators (productions used for speech initiation, continuation, shift, and termination; Mather, 2005) – number of regulators/total number of sentences; and (5) percentage of dysfluency (pauses, interjections, repetitions, prolongations, or self-corrections; Mayberry & Jaques, 2000) – number of dysfluency/total number of sentences. Details of the five linguistic parameters with examples were summarized in Appendix A.

**Coding of form and function of gesture**

The current study employed Kwan (2012)'s system of gesture coding with some modification of the labels of forms and functions. Details about the gesture coding system with examples in different forms and function of gestures in speakers with aphasia were shown in Appendix B.

A unit of gesture was defined as the period between the start of a hand movement and the end in which the hand(s) returned to a resting position (McNeill, 1992). The gesture could also be defined by a pause in hand movement or a change in shape or trajectory if the hands did not return to their resting position (Jacobs & Garnham, 2007). Self-adapting motions like touching the head or changing hand position from the lap to the desk were not counted as gesture in the analysis due to the lack of semantic attachment (Jacobs & Garnham, 2007).

Six forms of gestures, modified based on the classification by Ekman and Friesen (1969) and McNeill's (1992), were proposed:

1. Iconic: gestures that outline the shape of an object or the motion of an action. For example, a speaker put his/her palms together beside right ear to pretend sleeping when saying 'When I was sleeping…'
2. Metaphoric: gestures that outline pictorial content to communicate an abstract idea. For example, a speaker moved his/her hands in semi-circular motion from the centre to indicate the concept of 'around' when saying 'There were a lot of people around me.'
3. Deictic: familiar pointing, indicating objects in conversational space. For example, a speaker point to the picture of 'egg' with his/her index finger when saying 'We can cook it first.'
4. Emblem: gestures with standard properties and language-like features. For example, a closed fist held with the thumb upward represented universally as 'Good'.

5. Beat: rhythmic beating of a finger, hand or arm. It can be simply a hand or arm flicking up and down or back and forth rhythmically.
6. Non-identifiable: uncodable gestures due to ambiguity or visual obstruction.

In terms of gesture functions, 8 functions of gestures which were adopted from previous studies and classified according to their role in communication were shown as follow:

1. Providing substantive information to the listener: gestures give additional information related to the speech content (Goldin-Meadow, 2003). For example, a speaker twisting his/her palm which pretending holding the knob when saying 'Open the door' in order to give information of how he/she open the door (whether by pushing or using a key).
2. Enhancing the speech content: gestures, which help decode the speech to the listener, gives the same meaning to the speech content (Beattie & Shovelton, 2000). For example, a speaker put his/her right palm onto the left one when saying 'The sandwich was made after putting a piece of bread onto the ham.'
3. Providing alternative means of communication: gestures with meaning in the absence of speech (Le May et al., 1988). For example, a speaker produced the OK sign without speaking anything to answer the question of 'Are you ready?'
4. Guiding and controlling the flow of speech: gestures that reinforce the rhythm of the speech (Jacobs & Garnham, 2007), i.e. the gesture movement is synchronized with the pace of speech.
5. Reinforcing the intonation or prosody of speech: gestures used to emphasize speaker's meaning. For example, a speaker gave a strong flick at the word 'angry' in the sentence 'I am very angry!".
6. Assisting lexical retrieval: gestures that are intended to facilitate word retrieval (Krauss & Hadar, 1999), especially at times of long pause, word-finding difficulty, interjections

and circumlocution during speech (Mayberry & Jaques, 2000). For example, a speaker exhibited a long pause during the speech would produce gestures before uttering the target word.

7. Assisting sentence re-construction: gestures used to modify syntactic structures, re-construct sentences or refine sentence structures (Alibali, Kita, & Young, 2000).
8. No specific function deduced: gestures that do not exhibit the seven functions mentioned above with unclassifiable function.

Frequency of each gesture form and function was obtained for each participant in ELAN. The distribution of gestures used in different forms and functions between normal speakers and speakers with aphasia was then formulated and compared. A ratio of total number of gestures per word in all discourse tasks was calculated as a measure of frequency of gesture use in all discourse tasks.

**Statistical Analysis**

Normality of all the data were tested using Kolmogorov-Smirnov test (Field, 2009). If the scores were normally distributed, parametric test was used; on the contrary, non-parametric test was used if the data violated the normality.

To compare the gesture use in normal speakers and speakers with aphasia, normal speakers (N = 48) and speakers with aphasia (N = 48) with matched age were selected for analysis. Frequency of gesture use was indicated using number of gestures per word (gesture/word ratio) in all discourse tasks.

The effect of hemiplegia on gesture use in speakers with aphasia was investigated in subjects with hemiplegia (N = 16) and subjects without hemiplegia (N = 18). The presence of hemiplegia was determined using the scores of right hand performance in ARAT (R-ARAT). Subjects with hemiplegia scored 0 and subjects without hemiplegia scored more than 53.

To investigate the effect of aphasia severity on gesture use, correlation test was implemented between AQ, which roughly indicated the severity of aphasia, and gesture/word ratio. Gesture use between speakers with fluent type and non-fluent type of aphasia were also investigated. 12 pairs of speakers with fluent and non-fluent type of aphasia with matched age and education were selected for the analysis.

The relationship between linguistic performance and gesture use among speakers with aphasia was investigated. The 48 subjects were ranked according to their gesture/word ratio. The top third of the subjects (16 subjects) were regarded as speakers with high frequency of gesture use (High-Gesture group); while the bottom third of subjects (16 subjects) were regarded as speakers with low frequency of gesture use (Low-Gesture group). Comparisons were made among the five language parameters in the two groups of high and low gesture frequency. The independent variable was frequency of gesture use; while the dependent variables included (1) percentage of complete sentence in overall utterances, (2) percentage of simple sentence in overall utterances, (3) type-token ratio of words, (4) percentage of regulators in overall utterances and (5) percentage of dysfluency in overall utterances.

To investigate the effect of semantic processing impairment on gesture use and distribution of forms of gestures, correlation test was implemented between scores in naming tests (in both object and action naming) which indicated the presence of semantic processing impairment and gesture/word ratio in all discourse tasks.

Finally, inter-rater and intra-rater reliabilities of the gesture coding on speakers with aphasia were calculated for the existing data. Ten percent of data, i.e. 5 out of 48 subjects, were selected randomly and re-analyzed the forms and functions of gestures independently by the author and another speech therapist student. Correlation test was implemented to calculate if there were significant differences between the ratings of every form and function. Point-to-point agreement was employed to reflect the reliability.

# Results

Comparisons were made about (1) the gesture use among normal speakers and speakers with aphasia and (2) the gesture use among speakers with aphasia in different factors including hemiplegia, aphasia severity, linguistic performance and semantic processing impairment. Intra- and Inter-reliability of the gesture coding in speakers with aphasia were also established.

## Gesture use among normal speakers and speakers with aphasia

Based on the modified gesture classification framework, the distribution of forms and functions of gestures employed among 119 normal speakers in Kwan (2012) was updated with the gesture analysis of 12 normal speakers (N = 131). Also, the distribution of forms and functions of gestures employed among 48 speakers with aphasia was developed in this study (as shown in Table 1). The distribution of forms and functions of gesture employed by normal speakers remained the almost the same as Kwan (2012). There were about 35% of the normal speakers (N = 46) who produced no gestures throughout the discourse tasks, while there were only about 10% of speakers with aphasia (one transcortical motor and four anomic aphasia) produced no gestures throughout all the discourse tasks. Out of the total 3249 gestures annotated in speakers with aphasia, only about 60% were coded as non-identifiable gestures which were much less than those in normal speakers (about 83%).

It was found that they shared the same pattern of distribution of gesture functions in all kinds of gesture forms. Content-carrying gestures including iconic, metaphoric, deictic and emblem were mainly for enhancing the speech content. For the non-content-carrying gestures, beats were mainly used for reinforcing speech prosody and guiding speech flow, most non-identifiable ones had no specific functions. Unlike the normal speakers, 24.7% of the non-identifiable gestures by speakers with aphasia were used for assisting lexical retrieval.

Table 1. *Distribution of forms and functions of gestures employed in normal speakers (N = 131) and speakers with aphasia (N = 48)*

| | *Forms* | | | | | | | | | | | | % of functions (Frequency) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Content-carrying gestures | | | | | | | | Non-content-carrying | | | | | |
| | Iconic | | Metaphoric | | Deictic | | Emblem | | Beat | | Non | | | |
| | Normal | Aphasic | Normal | Aphasic | Normal | Aphasic | Normal | Aphasic | Normal | Aphasic | Normal | Aphasic | Normal | Aphasic |
| % of form[a] | 3.5% | 6.4% | 2.4% | 7.0% | 6.1% | 12.7% | 1.1% | 4.3% | 3.4% | 10.6% | 83.5% | 59.0% | | |
| (Frequency) | (115) | (208) | (78) | (229) | (197) | (411) | (36) | (140) | (109) | (343) | (2707) | (1918) | | |
| *Functions* | | | | | | | | | | | | | | |
| Sub[b] | 10.4% | 22.1% | 5.1% | 7.4% | 7.1% | 21.4% | 5.6% | 10.7% | 0.0% | 0.0% | 0.0% | 0.0% | 1.0% (32) | 5.1 % (166) |
| Enh[c] | **84.3%** | **74.5%** | **80.8%** | **92.6%** | **90.4%** | **60.1%** | **88.9%** | **81.4%** | 0.0% | 0.0% | 0.0% | 0.0% | 11.4% (370) | 22.4% (728) |
| Alt[d] | 0.9% | 3.4% | 1.3% | 0.0% | 0.0% | 1.5% | 2.8% | 5.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% (3) | 0.6% (20) |
| Gui[e] | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 25.7% | 20.7% | 0.0% | 0.1% | 0.9% (28) | 2.2% (72) |
| Rein[f] | 0.0% | 0.0% | 5.1% | 0.0% | 0.0% | 0.2% | 0.0% | 0.0% | **74.3%** | **77.3%** | 0.0% | 0.1% | 2.6% (85) | 8.2% (268) |
| Lex[g] | 4.3% | 0.0% | 3.8% | 0.0% | 2.0% | 7.5% | 2.8% | 0.7% | 0.0% | 1.5% | 0.5% | 24.7% | 0.8% (26) | 15.7% (511) |
| Sent[h] | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.1% (4) | 0.1% (4) |
| No[i] | 0.0% | 0.0% | 3.8% | 0.0% | 0.5% | 9.2% | 0.0% | 2.1% | 0.0% | 0.6% | **99.4%** | **74.9%** | 83.1% (2694) | 45.6% (1480) |

*Note 1*. Total number of gestures in normal speakers: 3242; Total number of gestures in speakers with aphasia: 3249

*Note 3.* Part of the data in normal speakers (N = 119) was adopted from Kwan (2012).

*Note 2.* [a]% of forms: Percentage of forms in total number of gesture; [b]Pro: Providing substantive information; [c]Enh: Enhancing speech content; [d]Alt: Providing alternative means of communication; [e]Gui: Guiding and controlling speech flow; [f]Rein: Reinforcing speech prosody and intonation; [g]Lex: Assisting lexical retrieval; [h]Sent: Assisting sentence construction; [i]No: No specific function

Gesture use in normal speakers and speakers with aphasia was compared in terms of the gesture/word ratio using Mann-Whitney test. Speakers with aphasia (*M* = 0.18, *SD* = 0.20) were found to produce significantly higher gesture/word ratio than normal speakers (*M* = 0.02, *SD* = 0.03) in all discourse tasks ($U = 403.5$, $p < .0001$).

**Effect of hemiplegia on gesture use in speakers with aphasia**

Mann-Whitney test was used. No significant difference was found between speakers with (*M* = 0.24, *SD* = 0.24) and without hemiplegia (*M* = 0.14, *SD* = 0.17) in the gesture/word ratio ($U = 96.0$, $p = .102$).

**Effect of aphasia severity on gesture use in speakers with aphasia**

Spearman's rank-order correlation was used to determine the relationship between AQ scores and gesture/word ratio in speakers with aphasia. There was a significant negative correlation ($r_s(46) = –.510$, $p < .0001$) between AQ scores (*M* = 81.39, *SD* = 15.21) and gesture/word ratio (*M* = 0.18, *SD* = 0.20). This indicated that speakers with more severe aphasia (with lower AQ scores) tended to use more gestures during discourse tasks.

Gesture use was also investigated in fluent and non-fluent type of aphasia using independent t-test. Speakers with non-fluent type of aphasia (*M* = 0.34, *SD* = 0.28) were found to produce significantly higher gesture/word ratio than speakers with fluent type of aphasia (*M* = 0.09, *SD* = 0.10) in all discourse tasks ($t(22) = –2.883$, $p = .009$) .

**Effect of linguistic performance on gesture production in speakers with aphasia**

The effect of linguistic performance in terms of the five parameters on gesture production in speakers with aphasia was shown in Table 2. Log transformation was done on the data of percentage of dysfluency as it was not normally distributed. Five independent t-tests were then performed separately to compare the five linguistic parameters among the two groups. Speakers who produced more gestures had significantly lower percentage of complete sentences and simple sentences than speakers with few or no gestures.

Table 2. *Linguistic performance of the high and low frequency gesture group*

| Linguistic parameters | Gesture group | Descriptive statistics | | Independent sample t-test | | |
|---|---|---|---|---|---|---|
| | | Mean | SD | t | df | *p*-value |
| Type-token ratio (TTR) | Low | 0.36 | 0.09 | –0.304 | 30 | .763 |
| | High | 0.37 | 0.12 | | | |
| Percentage of complete sentence | Low | 0.83 | 0.10 | 4.135 | 30 | .000* |
| | High | 0.54 | 0.26 | | | |
| Percentage of simple sentence | Low | 0.75 | 0.11 | 3.466 | 30 | .002* |
| | High | 0.52 | 0.24 | | | |
| Percentage of regulators | Low | 0.03 | 0.03 | –0.281 | 30 | .780 |
| | High | 0.04 | 0.04 | | | |
| Percentage of dysfluency | Low | 0.85 | 0.40 | –2.350 | 30 | .026 |
| | High | 1.39 | 0.96 | | | |

*Note*. *Level of significance: .01

**Effect of semantic processing impairment on gesture use in speakers with aphasia**

The scores in object and action naming tasks were used as an indicator of verbal semantic processing. Correlation between the naming scores and gesture use per word was evaluated using Spearman's rho coefficient. It was found that there was a significant negative correlation between the scores in naming tasks (M = 149.12, SD = 31.40) and the gesture/word ratio (M = 0.15, SD = 0.16) in all discourse tasks ($r_s(28) = –.507$, $p < .004$). Subjects with lower scores in naming tasks (indicating impairment in semantic processing) produced gestures more frequently.

**Inter- and Intra-rater reliability**

Inter-rater and intra-rater reliability on gesture analysis were investigated by Kendall's tau coefficients as shown in Table 3. All coefficients were significant at $p < 0.05$ or better, with all the coefficients for intra-rater higher than inter-rater. The reliability of inter-rater was particularly lower than that of intra-rater in the form 'beats' and the functions 'providing substantive information', 'guiding speech flow' and 'assisting lexical retrieval'.

Table 3. *Reliability measures of forms and functions of gesture by Kendall tau coefficient*

| | | Kendall tau coefficient | |
|---|---|---|---|
| | | Inter-rater reliability | Intra-rater-reliability |
| **Forms** | Iconic | 0.84** | 0.95** |
| | Metaphoric | 0.70** | 0.85** |
| | Deictic | 0.83** | 0.95** |
| | Emblem | 0.89** | 0.91** |
| | **Beats** | **0.57**** | **0.71**** |
| | Non-identifiable | 0.91** | 0.96** |
| **Functions** | **Providing substantive information** | **0.45**** | **0.88**** |
| | Enhancing speech content | 0.93** | 0.94** |
| | Alternate means of communication | 1.00*** | 1.00*** |
| | **Guiding speech flow** | **0.39*** | **0.81**** |
| | Reinforcing prosody of speech | 0.76** | 0.90** |
| | **Assisting lexical retrieval** | **0.63**** | **0.92**** |
| | Assisting sentence reconstruction | 1.00*** | 1.00*** |
| | No specific function | 0.87** | 0.97** |
| Total number of gestures | | 1.00*** | 1.00*** |

*Note.* * = p ≤ .05, ** = p ≤ .01, *** = p ≤ .001

Intra- and inter-rater reliability was also investigated by point-to-point agreement, as shown in Table 4. Intra-rater reliability was found to be good while inter-rater reliability was found to be fair. In inter-rater reliability, disagreement was noted mainly between beats and non-identifiable (with 34% of the gestures were mismatched) in the forms of gestures and between ‘no specific functions’ and ‘reinforcing speech content’ (with 24% of the gestures were mismatched) in the functions of gestures.

Table 4. *Reliability measures of forms and functions of gesture by point-to-point agreement*

| | Point-to-point agreement | |
|---|---|---|
| Gestures | Inter-rater reliability | Intra-rater reliability |
| Forms | 75.46% | 92.75% |
| Functions | 71.69% | 89.86% |

## Discussion

This study aimed to compare the co-verbal gesture productions between normal speakers and speakers with aphasia and investigate several factors including hemiplegia, aphasia severity, linguistics performance and semantic processing impairment among speakers with aphasia on gesture use. Gesture productions of 48 speakers with aphasia were investigated using the independent gesture coding system in terms of form and functions (Kwan, 2012). The production of gestures between normal speakers and speakers with aphasia was compared. It was found that only 10% of the speakers with aphasia produced no gestures. Moreover, the frequency of gesture use (gesture/word ratio) in aphasia was found to be significantly higher than that in normal speakers. In terms of non-identifiable form of gestures, there were a higher percentage of non-identifiable gestures coded in normal speakers than that in speakers with aphasia. There was a considerable amount of non-identifiable gestures used for lexical retrieval in speakers with aphasia, while there were nearly none of the non-identifiable gestures used for lexical retrieval in normal speakers. Nevertheless, the functions of specific forms of gesture in speakers with aphasia were found to be similar to those in normal speakers. Besides, this study examined how gesture production was different as a function of several factors related to aphasia, including hemiplegia, aphasia severity and verbal semantic processing impairment. No significant difference was found in gesture production between individuals with and without hemiplegia. However, in terms of severity, individuals with higher AQ score (indicating less severe aphasia) or who were fluent speakers produced significantly fewer gestures per words. In addition, speakers with verbal semantic processing impairment were found to produce significantly more gestures per word than those who are relatively intact. Speakers with a high frequency of gesture use, i.e. a higher gesture-to-word ratio, also produced significantly fewer complete sentences and simple sentences than those with low frequency gesture use, suggesting that the syntactic ability predicts the gesture use among speakers with aphasia.

The finding that speakers with aphasia showed higher frequency of using gestures than their normal counterparts could be explained using the speech-gesture production model, namely The Sketch Model, proposed by de Ruiter (2000). In this model, it is proposed that both routes of gesture production and speech production are originated from the conceptualizing stage (the initial stage proposed in speech production model by Levelt, 1989) and would be employed at the same time during communication. Based on the assumption that gesture is communicative to the speaker, the gesture modality could help compensate if speech failure occurred during communication (de Ruiter, 2000). For speakers with aphasia, it was possible that the speech modality in terms of the Sketch model failed due to the language deficits found. In order to repair the breakdown in the speech modality, the gesture modality then took over the role in communication. As a result, speakers with aphasia would employ gesture more frequently than normal speakers without language deficits in order to assist communication.

On the other hand, considering the different proportion and distribution of functions in non-identifiable form of gesture between speakers with aphasia and normal speakers, this finding could possibly be explained by Goldin-Meadow (1999) that speakers would employ gestures to compensate the speech-content for listeners and also assist word retrieval. In order to maintain the effectiveness of communication with others, speakers with aphasia, who typically exhibited some language deficits, would produce gestures relatively more frequently than the normal speakers in content-carrying form. To encounter the word retrieval difficulties during communication, speakers with aphasia would produce gestures in order to assist lexical retrieval.

It is worth mentioning that the distribution of functions of gesture use in terms of form of gestures between speakers with aphasia and normal speakers were found to be similar.

This finding suggested that the gesture production systems in both normal speakers and speakers with aphasia were likely the same, i.e. the language deficits found in speakers with aphasia did not impair the gesture production during communication.

For the insignificant result found in gesture use and hemiplegia, it could be explained that the hand preference in speakers with aphasia had been changed due to the compensation of the right hemisphere to the damaged left hemipshere (Foundas et al., 1995). Despite the presence of right-side hemiplegia, speakers with aphasia would switch their hand preference from right (which was dominant pre-morbidly but impaired post-morbidly) to left due to the compensatory effect of right hemisphere on damaged left hemisphere. Thus gesture use by speakers with hemiplegia was not affected by the use of the non-dominant hand to gesture.

The finding in which speakers with more severe aphasia (in terms of AQ score and fluent/non-fluent type comparison) employed specific forms of gestures more frequently than speakers with mild severity supported the view that gestures were used more frequently for compensation despite the language deficits found in speakers with higher degree of aphasia severity (Pedelty, 1987; Herrmann at el., 1988 and Hogrefe, 2012). The alternative view that gesture production parallels language deficits (Cicone et al., 1979 and Glosser et al., 1986) seemed not tenable. This finding could also be explained using the Sketch model by de Ruiter (2000) as discussed above. For speakers with more severe aphasia where verbal deficits were more prominent, the capacity of using the modality for speech production diminished, leaving them to rely on the modality for gesture production to assist communication.

For the linguistic performance on gesture use in speakers with aphasia, those produced relatively more complete sentences and simple sentences during the discourse tasks were found to have a low frequency gesture use. The use of complete and simple sentences was related to the fluency of the speakers with aphasia, i.e. speakers with non-fluent type of aphasia probably produced a lower proportion of complete sentences and hence more simple sentences. As a result, speakers with limited syntactic ability would use gesture more frequently as a compensatory means to achieve better communication with others. There have been few studies investigating the relationship between speaker's syntax and frequency of gesture use. This investigation has filled the gap and provided some insights into examining the syntactic ability of speakers with aphasia about the relationship between language and gesture production.

Unlike previous studies, it was found in the current study that verbal semantic processing impairment predicted the frequency of gesture use in speakers with aphasia. Specifically, most studies in the literature (e.g. Fucetola et al., 2006 and Hogrefe et al., 2012) suggested that non-verbal semantic processing impairment predicted gesture use. This finding could be explained by the facilitative use of gesture on word retrieval (de Ruiter, 2000). As picture naming tasks indicated particularly the verbal semantic processing impairment, those speakers with the impairment were more likely to have difficulty in word-finding. Gesture would then be produced in any form to assist word retrieval during communication.

The present findings in general showed support for the Sketch model by de Ruiter (2000). Besides, the findings showed that gesture was used in both for word retrieval and compensatory use with language deficits. It was suggested that gesture use may have more than one role in communication rather than suit either communicative intent hypothesis or lexical retrieval hypothesis only (Rose, 2006).

The reliability of gesture analysis in speakers with aphasia in inter-rater reliability was found to be fair using point-to-point agreement. Reliability of gesture analysis was investigated by intra- and inter-rater reliabilities. Fair reliability was found when point-to-point agreement was used to in inter-rater reliability testing. Regarding the forms of gesture, disagreement was found in annotating between non-identifiable and beats in which 34% of the gestures was mismatched. It was possibly due to the confusion between the aforementioned 'atypical' beats and typical beats during the gesture analysis. For example, the inter-rate coded some hand flicking movements which were produced by the speakers rhythmically during discourse tasks but the hand movements were not synchronized or accompanied with speech. These hand flicking gestures were then mismatched by the inter-rater as typical beats. Regarding the function coding, disagreement was found between no specific functions and reinforcing speech content (24% was mismatched). For instance, the inter-rate coded some hand flicking movements which were not synchronized with speech as reinforcing the speech content. As beats were mainly produced for reinforcing the speech content, it was possible that when beats were mis-annotated by the inter-rater, the functions of the mis-annotated beats would also be rated as reinforcing the speech content.

This study can provide insights, mainly in two directions, on the clinical management of speakers with aphasia incooperating the use of gestures. On one way, as the findings in this study further confirmed the compensatory role of gesture in communication, gestures could be employed by speakers with severe aphasia as an alternative means of communication. More content-carrying gestures could be introduced to speakers with severe aphasia so that they could be able to repair communication breakdowns due to severe language deficits. A recent study by Daumüller and Goldenberg (2010) found that speakers with severe aphasia showed improvement in the use of practiced communicative gestures. On the other hand, the findings also support the view that gesture use could assist lexical retrieval. It is possible that speakers with aphasia, particularly with word-finding difficulties, can employ gestures in order retrieve corresponding words. For example, Pashek (1997) found that gesture training using iconic gestures could help improve word retrieval difficulties. Feyerisen (1983) also suggested that gesture use could be employed to resolve verbal encoding difficulties exhibited by speakers with aphasia.

The coding system by Kwan was designed to code gestures in terms of form and function in normal speakers. The applicability of the system to gesture analysis of speakers with aphasia was then investigated. It was observed that speakers with aphasia often produced 'atypical' beats (McNeill, 1992) during the tasks. The 'atypical' beats were counted as non-identifiable form as they were not synchronized with speech. Some of them were counted as with no specific function, while some of them were counted as assisting lexical retrieval in terms of gesture function. Overall, the applicability of the coding system by Kwan was satisfactory as the coding system of gestures by Kwan (2012) can generally be applied on speakers with aphasia without any new forms or functions found.

There are two aspects in which further study could be conducted. First, although it was suggested that gesture use can be employed in treatment of aphasia as an alternative means of communication or a way to assist lexical retrieval as mentioned above, study of the efficacy of treatment using specific forms of gestures can be investigated. Secondly, the current study mainly investigated the frequency of gesture use among speakers with aphasia. The study could be further extended to investigate how gesture use was different in terms of each form and function in different factors such as severity of aphasia and presence of hemiplegia. A more detailed analysis of gesture use in speakers with aphasia will shed new light on the relationship between language and gesture production could be further investigated.

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## Appendix A

### Parameters for measuring linguistic performance (Kwan, 2012)

I. ***Type-token ratio (TTR):*** total number of different words/total number of words.

  a. Total number of different words refers to each different word counted once regardless of the differences in bound morphemes, excluding unintelligible utterances and bound morphemes.

  b. Total number of words refers to all words in the speech sample except those for repetition and self-correction.

II. ***Percentage of complete sentence:*** total number of complete sentence/total number of sentences.

  a. Total number of complete sentences refers to the number of complete sentences which consist of more than one clause or a phrase in Cantonese (Ma, 2001). Examples were shown as the followings:

    (i) Sentence with a subject and predicate 主謂句

      e.g. 烏龜跑贏咗 (The turtle won the race)

    (ii) Sentence without subject but a predicate only 無主句

      e.g. 開咗個爐 (Start the cooker)

    (iii) Sentence with a predicate only which is grammatically correct with the previous sentence 不完全主謂句

      e.g.「隻免仔點呀？」「*好唔開心*」 ('How was the rabbit?' '*Very unhappy*')

    (iv) Single-word sentence 獨詞句

      e.g. 邊度? (Where?)

    (v) Compound and complex sentence 複句

      - Compound sentence refers to sentence joining two or more simple sentences with different subjects and predicates by coordinating conjunctions (such as for, and, but, so), e.g. '因為牧童講大話，所以啲村民唔信佢' (The villagers won't believe the boy again as he told lies)

- Complex sentence refers to sentence containing one or more dependent clause either at the beginning, middle or end of the sentence using subordinating conjunction or relative pronoun, e.g. '呢個故事教訓我哋唔好講大話' (This story told us that we should not tell lies)

b. Total number of sentences refers to the sum of complete and incomplete sentence (ungrammatical, ill-formed or omission of sentence element).

III. ***Percentage of simple sentences:*** total number of simple sentences/total number of sentences.

a. Total number of simple sentences refers to (1) sentences with a subject and predicate, (2) sentences without subject but a predicate, (3) sentences with a predicate only which is grammatically correct with the previous sentence, and (4) single-word sentences.

IV. ***Percentage of regulators:*** total number of regulator/total number of sentences.

a. Regulators are sentences for initiation, shifting, continuation and termination of conversations (Mather, 2005), such as '就係咁囉' (This is it), without any meaning.

V. ***Percentage of dysfluency:*** incidents of dysfluency/total number of sentences.

*a.* Dysfluency can be repetition of words or syllables, sound prolongation, pause and interjection such as /e6/ and /um/ (Mayberry & Jaques, 2000).

# Appendix B

## Gesture coding system for speakers with aphasia

### Forms and functions of gesture

Every unit of gesture would be coded in two dimensions – form and function. The six forms of gesture were developed based on McNeill's classification of gesture (1992). The eight major functions were summarized based on the functions of gesture found in different literature. The definition of every form and functions with two examples of each form was illustrated in the tables below.

**Example of different forms of gestures**

| **Form** | **Example 1** | **Example 2** |
|---|---|---|
| **Iconic:** outlines the shape of an object or the motion of an action. | The speaker twisted his hand in rotary action, pretending he was opening the cooker when he said the word, '撻火' (open the cooker). | When the speaker said '瞓覺' (sleep), he put his palm beside the ear to pretend to action of 'sleep'. |
| **Metaphoric:** shows pictorial content of an abstract idea. | When the speaker said '周圍都冇人喺度' (There's no people around me), his index finger drew a circle from the centre to represent the concept of 'around'. | When the speaker said '火腿呢，就要煎佢兩面' (fry both sides of the ham), his palm facing up and down to represent 'both sides'. |
| **Deictic:** familiar pointing, indicating objects in conversational space | When the speaker said '佢即刻跑過嚟' (He rushed here immediately), he pointed to left hand side to represent 'him'. | The speaker pointed to the picture of egg on the paper, while he said '雞蛋' (Egg). |
| **Emblem:** gestures with standard well-formed properties and language-like features. | When the speaker said '咩都冇喇' (There's nothing), he open his arms and palms facing upward to indicate 'nothing'. | The speaker patted his chest, which indicated the meaning of 'I', when he said '我中風嗰時呢' (When I had stroke). The gesture was universally accepted as the meaning of 'I'. |
| **Beat:** rhythmic beating such as a simple hand or arm flick up and down or back and forth. | When the speaker said '美國、台灣、新加坡都有人去' (The participants come from America, Taiwan and Singapore), he flicked his arm down rhythmically to indicate the countries. | When the speaker said '去到醫院' (Arrived to the hospital), his right hand flicked downwards in synchrony with the stressed word 'hospital'. |

| Form (Con't) | Example 1 | Example 2 |
|---|---|---|
| **Non-identifiable:** uncodable gestures due to ambiguity or visual obstruction. | The speaker's flicked his hand up and down but didn't synchronize with speech his whole description of the story 'The Crying Wolf'. | The speaker rose up and moved his hand to another position during his monologue. |

**Examples of different functions of gestures**

| Function | Example 1 | Example 2 |
|---|---|---|
| **Providing substantive information to the listener:** gives information in addition to the speech content (Goldin-Meadow, 2003). | When the speaker said '開門' (open the door), his hand pretended to open the door by an twisting action to give additional information on the way he open the door. | When the speaker said '咁樣俾人綁住' (I was tied in this way), he pretended to be tied by outlining a circular motion with his hand to providing additional information about how he was tied. |
| **Enhancing the speech content:** gives the same meaning to the speech content (Beattie & Shovelton, 2000). | When the speaker said '沺埋塊麵包上去就食得' (You can eat after putting the bread), the speaker pretended to put a piece of bread on a sandwich. | When the speaker said '我呢隻手郁唔到' (I can't move my hand), he put one hand onto another hand to assist listeners' understanding of the which hand he can't move. |
| **Providing alternative means of communication:** carries meaning in the absence of speech (Le May et al., 1988). | The speaker put his thumb up to indicate 'good' without saying anything. | The speaker produced the OK sign solely to answer the question of 'Are you ready to start?' without any speech. |

| **Function (Con't)** | **Example 1** | **Example 2** |
|---|---|---|
| **Guiding and controlling the flow of speech:** reinforces the rhythm of the speech (Jacobs & Garnham, 2007). | When the speaker said '上晝做物理治療，下晝做職業治療' (I received physiotherapy in the morning, and occupational therapy in the afternoon), the speaker flicked his hand twice when he mentioned the words 'physiotherapy' and 'occupational therapy'. | When the speaker said '九月十四日就出院喇' (I was out of hospital on 14th September), he flicked his hand rhythmically to synchronize the speech. |
| **Reinforcing the intonation or prosody of speech:** emphasize his/her meaning of speech. | When the speaker said '真係好唔開心' (I am really unhappy), his hand flicked at every syllable to emphasize his unhappiness. | The speaker put his hand sharply on the table to emphasize the word 'wolf' when saying '隻狼真係嚟喇' (The wolf really comes). |
| **Assisting lexical retrieval:** intended to facilitate word retrieval at times of long pause, word-finding difficulty, interjections and circumlocution during speech (Mayberry & Jaques, 2000). | When the speaker said '首先打隻…e6…雞蛋先' (First open… e6… an egg), he pointed to the egg on the picture during the production of /e6/. | When the speaker said 'e6…呢個係咩呢？e6…' (e6… what is this? e6…), he put up his palm and held it. |
| **Assisting sentence re-construction:** modify syntactic structures, re-construct sentences or refine sentence structures (Alibali, Kita, & Young, 2000). | When the speaker said '啲村民就嗌+… 個牧童就大聲嗌狼來了' (The villagers shouted… the shepherd shouted the wolf is coming loudly), he put up his hand and then down on the table during the reformation of the sentence. | When the speaker said '我中風嘅時候+… 我係做清潔嘅' (When I had stroke… I am a scavenger), he moved his palm from left to right during the reformation of the sentence. |

| **Function (Con't)** | **Example 1** | **Example 2** |
|---|---|---|
| **No specific function deduced:** does not show any of the above seven functions. | When the speaker describing how he learnt calligraphy, he kept moving his index finger in a circular motion without any synchronization of the sentences. | The speaker occasionally put his palm up and down during the moments of silence when he was describing how he acquired stroke. |