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Research Article

A Comparison of Coverbal Gesture Use in Oral Discourse Among Speakers With Fluent and Nonfluent Aphasia

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Purpose: Coverbal gesture use, which is affected by the presence and degree of aphasia, can be culturally specific. The purpose of this study was to compare gesture use among Cantonese-speaking individuals: 23 neurologically healthy speakers, 23 speakers with fluent aphasia, and 21 speakers with nonfluent aphasia.
Method: Multimedia data of discourse samples from these speakers were extracted from the Cantonese AphasiaBank. Gestures were independently annotated on their forms and functions to determine how gesturing rate and distribution of gestures differed across speaker groups. A multiple regression was conducted to determine the most predictive variable(s) for gesture-to-word ratio.
Results: Although speakers with nonfluent aphasia gestured most frequently, the rate of gesture use in counterparts with fluent aphasia did not differ significantly from controls. Different patterns of gesture functions in the 3 speaker groups revealed that gesture plays a minor role in lexical retrieval whereas its role in enhancing communication dominates among the speakers with aphasia. The percentages of complete sentences and dysfluency strongly predicted the gesturing rate in aphasia.
Conclusions: The current results supported the sketch model of language–gesture association. The relationship between gesture production and linguistic abilities and clinical implications for gesture-based language intervention for speakers with aphasia are also discussed.

Gesture is the most common form of nonverbal behavior accompanying human communication. It is defined as spontaneous movements of hands and arms that flow simultaneously with speech (Kendon, 1980). A considerable number of studies have suggested that gestures are communicatively intended (e.g., de Ruiter, 2000; McNeill, 1992) and can enhance everyday social interaction. Moreover, coverbal gestures can supplement the semantic content of oral output (Kendon, 2000) through their representation of spatial/directional and dynamic aspects of language content. Beattie and Shovelton (1999) further supported the supplementary role gestures play in human conversation by arguing that listeners could obtain more semantic information when a conversational partner had used both language and gestures (as compared with the language-only condition) within a verbal exchange task.

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The view that gestures can assist lexical retrieval during oral production was illustrated in the lexical retrieval hypothesis (LRH) reported by Krauss and Hadar (1999). To be more specific, it was proposed that the spatial and dynamic features of a concept represented by gestures could activate word retrieval. Gillespie, James, Federmeier, and Watson (2014) further suggested that impaired language competency, such as speech dysfluency or word-finding difficulty, was a primary driving force for use of gestures. Additional evidence echoing the LRH was provided by Chawla and Krauss (1994), who demonstrated that unimpaired speakers used gestures more frequently during spontaneous speech as compared with rehearsed speech that was less demanding.

Gestures and language are closely related in their temporal and semantic aspects. There have been two contrasting views regarding their relationship. The first was proposed by McNeill (2005) in which gestures and language were argued to originate from a single thought process. Duffy and Duffy (1981) supported this view of verbal production paralleling gesture use and argued that gesture impairment was a concomitant of verbal impairment. Contrary to this view, de Ruiter (2000) reported the sketch model in which verbal production and gestures are claimed

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to be processed separately. In particular, the sketch model includes a "formulator" that mediates grammatical and phonological encoding of linguistic information and is responsible for verbal production. Another component of the model is the "gesture planner" that controls gesture production and operates with the formulator in a complementary manner. In this view, gesture production is not adversely affected by linguistic deficits, and gestures can be used as a complement in cases of verbal deficits, such as in naming impairment. Evidence supporting the sketch model has been provided by Sekine, Rose, Foster, Attard, and Lanyon (2013), who suggested that people with aphasia (PWA) tended to use gestures to compensate for difficulties in communication and/or lexical retrieval.

Due to the close relationship between the production of coverbal gestures and word-finding behaviors that occur during communication, Kendon (1988) proposed a method to systematize gestures along a continuum, which ranges from gesticulation, pantomime, and emblems to sign language, to allow a better understanding of gesture use with and without accompanying language. In particular, although *gesticulation* refers to idiosyncratic hand and arm movements that cannot exist without verbal output, *pantomime* depicts objects and actions in which the presence of language production is unnecessary. These two types of gestures have the least degree of formality, and more effort is required on the part of the listener to accurately recognize and analyze the gesture shape. On the other hand, emblems (such as forming a circle using the tips of the thumb and index finger to indicate *okay*) and sign language (such as American Sign Language) have the highest degree of formality. Both of them contain language properties and have culturally specific gestures that are understood by a community. The higher degree of formality also reduces listener ambiguity in their gesture shape.

Kendon's (1988) classification of gestures emphasized their forms and types but failed to address the functional roles they play in communication. To provide a more systematic method for gesture annotation, Kong, Law, Kwan, Lai, and Lam (2015) proposed a coding system to independently annotate gesture forms and functions. To be more specific, there are six forms of gestures modified on the basis of the classification by Ekman and Friesen (1969), Mather (2005), and McNeill (1992), including content-carrying gestures: (a) iconic gestures that specify the spatial and dynamic features of concrete objects or actions, (b) metaphoric gestures that specify abstract ideas, (c) deictic gestures that encompass pointing to a physically present referent or to an absent referent, and (d) emblems that are culturally conformed and universally understood by a community and non-content-carrying gestures: (e) beats that refer to hand-flicking movements following the speech rhythm and (f) nonidentifiable gestures that include ambiguous gestures or those that cannot be classified into the aforementioned categories. With reference to the content of the corresponding language output, each gesture is also classified into one of the following eight functions, namely (a) providing additional information to a message conveyed (Goldin-Meadow, 2003); (b) enhancing the speech content (Beattie & Shovelton, 2000); (c) providing alternative means of communication (Le May, David, & Thomas, 1988); (d) guiding and controlling the flow of speech (Jacobs & Garnham, 2007); (e) reinforcing the intonation or prosody of speech (Kong, Law, Kwan, et al., 2015); (f) assisting lexical retrieval (Krauss & Hadar, 1999); (g) assisting sentence reconstruction (Alibali, Kita, & Young, 2000); and (h) serving other nonspecific or noncommunicative functions, such as assisting the process of verbal dialogues without conveying topical information, regulating and organizing the process of coming together with language content, or the back-and-forth nature of speaking and listening. In cases in which a specific gesture was judged to serve more than one purpose, the final assignment was based on the primary function in relation to the language content (see details of coding criteria in Appendix A). Kong, Law, Kwan, et al.'s (2015) annotation scheme on gesture functions partly overlapped with the gesture-coding framework for children (Colletta, Kunene, Venouil, Kaufmann, & Simon, 2009) and challenged a previous assumption that one form of gesture could only serve one function (see Scharp, Tompkins, & Iverson, 2007).

Aphasia and Gesture Use

As there have been contrasting views on the associations between gesture and language production, researchers have attempted to clarify their relationship by comparing gesture use among PWA and unimpaired speakers. In line with McNeill (2005), the competence of using gestures among PWA has been reported to be inferior to that of controls in terms of gestural complexity (Glosser, Wiener, & Kaplan, 1986). This finding suggested concomitant impairment between gestural and linguistic skills in PWA. In contrast, it has also been reported that a significantly greater proportion of PWA used gestures, including iconic gestures (Cocks, Dipper, Pritchard, & Morgan, 2013), than their unimpaired counterparts, and many of the PWA produced iconic gestures that served communicative and/or facilitative functions (Sekine & Rose, 2013). This observation supported the sketch model (de Ruiter, 2000) and provided evidence for independent deficits of gesture and verbal production. Recent studies by Kong, Law, Wat, and Lai (2015) and Wat (2013) further corroborated the sketch model by concluding that the rate of gesture use among 48 PWA (with preserved nonverbal semantic abilities) was higher than that of their controls, and a higher proportion of PWA used coverbal gestures as compared with the control counterparts. Moreover, although the presence of hemiplegia in PWA did not affect their rate of using gestures, higher aphasia severity, weaker linguistic skills (as reflected by fewer complete and simple sentences), and lower degree of verbal semantic processing integrity were found to associate with an increased proportion of coverbal gesture use.

Although the majority of studies in the aphasiology literature have focused on discriminating gesture use between individuals with and without aphasia (e.g., Ahlsén & Schwarz, 2013; Kong, Law, Wat, et al., 2015; Wat, 2013), relatively few reports involved how gesture use varied across aphasia syndromes. Due to the fact that types of aphasia partly contribute to variability within the population of PWA, aphasia syndromes might hypothetically affect gesture use in PWA (Sekine et al., 2013). For example, with reference to conversational samples, speakers with Broca's, transcortical motor, and conduction aphasia were reported to use a higher rate of gestures than individuals with Wernicke's aphasia (Sekine et al., 2013). Moreover, nonfluent PWA also tended to use more meaning-laden (such as iconic or deictic) gestures (Sekine & Rose, 2013). Although this line of research regarding gesture use in PWA versus unimpaired speakers can lead to clinically important implications, a major limitation of existing reports has been the relatively small sample size, short and simple discourse samples used, and/or the limited range of gesture coding. To illustrate, Carlomagno and Cristilli (2006) compared the quantity of gestures used by fluent and nonfluent PWA versus unimpaired speakers. Although nonfluent PWA were found to have a greater gesturing rate than the other two groups, this conclusion was limited by its sample size of 10 controls and five participants in each aphasic group. The findings were also limited in their generalizability because the comparison was based on one discourse task—that is, news narration, using a simple gesture-coding system confined to beat, iconic, and deictic gestures only. In addition, the great majority of the abovementioned studies were conducted using native speakers in the West. Culturally specific gesture types exist across different languages (Graham & Argyle, 1975; Kendon, 1997; Yammiyavar, Clemmensen, & Kumar, 2008). Although Kong and Fung (2015) have investigated the factor of ethnicity on possible differences in gestural performance between 20 native English-speaking PWA in the United States and 20 native Cantonese-speaking PWA in Hong Kong, it remains unclear if and how previous findings on individuals of the Western culture would generalize and contribute to our understanding of gesture use among speakers of the East.

Aims

The current study aims to address the following three research questions:

1. How does the rate of gesture use vary across fluent PWA, nonfluent PWA, and unimpaired control speakers?
2. Using Kong, Law, Kwan, et al.'s (2015) coding system, how do the distributions of gesture forms and functions differ across fluent PWA, nonfluent PWA, and unimpaired control speakers?
3. Among speakers with aphasia, how well do the factors of hemiplegia, aphasia severity as reflected in aphasia quotient (AQ), semantic processing integrity, and complexity of linguistic output predict the rate of using coverbal gestures?

To be specific, fluent aphasia has been characterized by more preserved syntax (with a higher variety of grammatical constructions), articulation, and rhythm of speech but is deficient in meaning. Nonfluent aphasic speech, on the contrary, tends to be slow, labored with short utterance length, and impaired in the production of grammatical sequences (Goodglass & Kaplan, 1983). With reference to the sketch model (de Ruiter, 2000), we hypothesized that nonfluent PWA should produce more gestures (due to their more impaired grammatical encoding and impoverished oral discourse construction) than fluent PWA, who would in turn gesture more than controls (Question 1). The two PWA groups would also differ in their distributions of gesture forms and functions (Question 2). Out of the predictors, it was hypothesized that complexity of linguistic output and aphasia severity would have the greatest impact on gesture rate (Question 3) because a degraded formulator in the sketch model should be compensated by the gesture planner that controls gesture production.

Method

Database

The data of the current investigation were drawn from the Cantonese AphasiaBank (Kong & Law, 2016), which consists of multimedia data of discourse samples from 228 Cantonese-speaking participants, including 149 neurologically healthy speakers and 79 PWA, at the time of conducting this study. Among the PWA, there were 21 speakers with nonfluent aphasia and 58 speakers with fluent aphasia. All participants were right-handed. Each of the neurologically healthy, fluent aphasic, and nonfluent aphasic groups represented three age groups: young (18 years to 39 years, 11 months), middle (40 years to 59 years, 11 months), and elderly (60 years or older) and two education levels: low (secondary school or below, i.e., 0–13 years for the two younger groups, and primary school or below, i.e., 0–6 years for the elderly group) and high (postsecondary school, i.e., at least 14 years for the two younger groups, and secondary school or above, i.e., at least 7 years for the elderly group). Each participant was required to accomplish narrative tasks across four genres, including personal narrative, storytelling, procedural description, and picture description. In this study, tasks from the first three genres of narrative were extracted and analyzed and they encompassed (a) recounting an important event in life, (b) telling two familiar stories ("The Boy Who Cried Wolf" and "The Hare and the Tortoise"), and (c) describing the procedures of making a ham-and-egg sandwich. One additional task was extracted and analyzed for each individual with aphasia: (d) narrating the course of a stroke. All narrative tasks by each participant were videotaped in a quiet room and saved as separate video files (.mpg).

Each participant took language tests that have been culturally adapted for native Cantonese speakers in Hong Kong, including (a) Spoken Word–Picture Matching test (Law, 2004), (b) Written Word–Picture Matching test

(Law, 2004), (c) an adopted Cantonese version of the Pyramid and Palm Tree Test (adapted PPTT; Law, 2004), and (d) Synonym Judgment Test (SJT; Law, 2004) for assessing verbal semantic abilities; (e) selected items from the PPTT (Howard & Patterson, 1992) and Associative Match test in the Birmingham Object Recognition Battery (Riddoch & Humphreys, 1993) for assessing nonverbal semantic abilities; (f) selected items from oral pictured object naming (Snodgrass & Vanderwart, 1980); and (g) oral pictured action naming (Bates et al., 2003) for assessing oral naming abilities. In addition, each PWA was evaluated by the Cantonese version of the Western Aphasia Battery (CAB; Yiu, 1992) for classification of aphasia subtypes and assessment of aphasia severity in terms of AQ, and the Action Research Arm Test (Lyle, 1981) to evaluate the changes in limb functions resulting from hemiplegia.

Participants

Data from 67 participants in the Cantonese AphasiaBank were chosen for the present study. To ensure matching of demographic characteristics across the three speaker groups (i.e., nonfluent PWA, fluent PWA, and controls), subjects were carefully selected. To be specific, data of speakers with nonfluent aphasia in the database were first extracted. Speakers in the control and fluent aphasic groups were then selected by matching their age and education levels with the nonfluent aphasic group. The control group consisted of participants with no history of neurological damage that would adversely affect speech and language, and both fluent aphasic and nonfluent aphasic groups included participants who had suffered from a single stroke. All participants were age-matched (±3 years) and education-matched (±5 years) across the three speaker groups. On the basis of the results of the CAB (Yiu, 1992), the fluent aphasic group consisted of participants who were diagnosed with anomia (n = 22) or transcortical sensory aphasia (n = 1), and the nonfluent aphasic group was composed of participants who were diagnosed with Broca's aphasia (n = 10), isolation (n = 3), or transcortical motor aphasia (n = 8). Information on the three groups of speakers, including their mean age and years of education, is given in Table 1.

Data Analysis

All narrative samples were orthographically transcribed in the Child Language Analyses computer program (CLAN; MacWhinney, 2000) and saved as CLAN (.cha) files for analysis of linguistic performance. Each video file (.mpg) of the narrative samples was imported into the Eudico Linguistic Annotator (ELAN; Max Planck Institute for Psycholinguistics, 2002; Lausberg & Sloetjes, 2009) and saved as ELAN annotation format (.eaf) files for gestural analysis. Three tiers, namely participant (PAR), form, and function, were created in ELAN for independent annotation of orthographically transcribed narrative content and forms and functions of gestures, respectively. The transcription in a CLAN file of each narrative sample was linked to the corresponding video file via ELAN by manual input of the transcription onto the PAR tier.

Gestural Analysis

The criterion of annotating gestures in the present study follows that in Kong, Law, Kwan, et al. (2015). To be specific, a unit of gesture was defined as the period between hand(s) starting to move until returning to the original resting position (McNeill, 1992). If the hand(s) did not return to the original position at the end of the gesture, the next unit of gesture was counted if there was an obvious change in shape or trajectory of hand movement or a pause in hand movement (Jacobs & Garnham, 2007). Body-focused movements, such as moving hands from the lap to the table or scratching, were coded as being unrelated to verbal production in terms of timing, prosody, and meaning (Butterworth, Swallow, & Grimston, 1981). Given that body-focused movements were not linked to the communicative meanings of the verbal content, they were excluded from analysis in the present study. On the basis of the coding system proposed by Kong, Law, Kwan, et al., each gesture was annotated and categorized into one of the six forms and one of the eight functions independently on ELAN. The total number of gestures annotated in each narrative task was subsequently tallied. Details of the gestural annotation with examples for illustrations are given in Appendices B and C. To address Question 1, the ratio of gestures to words for each participant was calculated by dividing the number of gestures annotated by the total number of words produced across the narrative tasks. To address Question 2, different forms and functions of gestures were calculated as a percentage and compared across the three groups of speakers.

Linguistic Analysis

The transcripts in each narrative task were subject to the linguistic analysis detailed in Appendix D. First, the utterances were classified as either complete or incomplete sentences. Complete sentences were further divided as (a) simple sentences, (b) compound sentences, or (c) complex sentences. These types of sentences were subsequently tallied. Following Kong, Law, Kwan, et al.'s (2015) investigation, five linguistic measures were computed to reflect the linguistic performance of each speaker, including (a) percentage of complete sentences: number of complete sentences ÷ total number of sentences; (b) percentage of simple sentences: number of simple sentences ÷ total number of sentences; (c) percentage of regulators: number of utterances used for topic initiation, shift, and termination (Mather, 2005) ÷ total number of sentences; (d) percentage of dysfluency: number of pauses, interjections, repetitions, prolongations, or self-corrections (Mayberry & Jaques, 2000) ÷ total number of sentences; and (e) type–token ratio: number of different words ÷ total number of words, which could be generated in CLAN. Full details regarding examples and illustrations can be found in Appendix D.

Table 1. Information on participants in the control, fluent, and nonfluent aphasic groups.

Pair	Control	Nonfluent aphasia	Fluent aphasia
1	Cont101	ISM03	ANF17
2	Cont425	TMF02	ANM02
3	Cont420	TMF04	ANM10
4	Cont405	TMF01	ANM03
5	Cont302	BRM02	ANF01
6	Cont303	BRM03	ANM25
7	Cont401	BRM04	ANM05
8	Cont304	BRM06	ANM12
9	Cont416	TMM04	ANM08
10	Cont404	—	TSM02
11	Cont403	BRM08	ANM01
12	Cont408	BRM11	ANM33
13	Cont312	BRM12	ANM18
14	Cont326	TMF03	ANM15
15	Cont422	TMM06	ANM36
16	Cont618	TMM02	ANM07
17	Cont516	ISF01	ANM19
18	Cont521	BRM10	ANF15
19	Cont519	BRF04	ANF10
20	Cont626	TMM03	ANM37
21	Cont601	—	ANF06
22	Cont603	BRF03	ANF05
23	Cont608	ISF02	ANF13
Mean age (*SD*)	56.6 (8.1)	56.8 (9.2)	56.4 (8.8)
Mean years of education (*SD*)	10.1 (2.9)	9.4 (2.8)	8.9 (3.6)
Mean AQ (*SD*)	—	53.5 (17.8)	90.8 (7.7)

Note. Cont = control; ISM = male speaker with isolation aphasia; ANF = female speaker with anomia; TMF = female speaker with transcortical motor aphasia; ANM = male speaker with anomia; BRM = male speaker with Broca's aphasia; TMM = male speaker with transcortical motor aphasia; TSM = male speaker with transcortical sensory aphasia; ISF = female speaker with isolation aphasia; BRF = female speaker with Broca's aphasia; AQ = aphasia quotient. — = controls were not administered. The Cantonese WAB and nonfluent PWA were not matched for pairs 10 and 21.

Inter-rater and intrarater reliability

To establish the inter-rater and intrarater reliability of coding of gesture forms and functions, 10% of the data (i.e., data from two control speakers, two fluent PWA, and two nonfluent PWA) were randomly selected and reanalyzed by an independent rater (with a background in linguistics) who received training on using the coding system, and the third author, respectively. Kendall's tau coefficients were used to examine the consistency of gestural coding across and within raters. All coefficients were significant ($p < .05$ or better; see Table 2) with the level of significance for intrarater reliability of the total number of gestures better than that of inter-rater reliability. In summary, we demonstrated the acceptability of the inter- and intrarater reliability of this gesture annotation scheme.

Statistical Analysis

To test the assumption of normality of the data, a Kolmogorov–Smirnov test (Field, 2009) was used to examine if the dependent variable—that is, the gesture-to-word ratio of each speaker group—was normally distributed. Because the assumption of normal distribution was violated for the control and fluent PWA groups ($p < .01$), a nonparametric Kruskal–Wallis test was used to investigate any significant difference in rate of gesture use across the three speaker groups (Question 1). Three post hoc tests using nonparametric Mann–Whitney tests (Field, 2009) were used to examine the origin of the difference in gesturing rate. A Bonferroni correction was applied to obtain a more restrictive critical value (i.e., $0.05 \div 3 = 0.0167$) to avoid inflation of the Type I error rate (Field, 2009).

Prior to addressing Question 3, the predicted variable—that is, the gesture-to-word ratio—and the following predictor variables were input to generate a correlation matrix: (a) Action Research Arm Test scores of the right hand (ARAT-R) for indicating the degree of hemiplegia; (b) CAB AQ for demonstrating the aphasia severity; (c) percentage of complete sentences, (d) percentage of simple sentences, (e) percentage of regulators, (f) percentage of dysfluency, and (g) type–token ratio for quantifying linguistic performance; and (h) Spoken Word–Picture Matching test scores, (i) Written Word–Picture Matching test scores, (j) adapted PPTT scores, (k) SJT scores, (l) scores of selected items from the PPTT and Associative Match test in the Birmingham Object Recognition Battery, (m) scores of selected items from oral pictured object naming, and (n) scores of oral pictured action naming for showing the degree of semantic processing integrity. A correlation matrix was displayed to show the degree of correlation among the above predictor variables and to verify if assumptions of

Table 2. Inter-rater and intrarater reliability of gesture forms and functions.

Item	Kendall's tau coefficient	
	Inter-rater reliability	Intrarater reliability
Forms		
Iconic	0.89*	1.00*
Metaphoric	0.85*	0.94*
Deictic	0.92*	1.00*
Emblem	0.78*	0.82*
Beats	1.00*	1.00*
Nonidentifiable	0.79*	0.97**
Functions		
Providing additional information	0.78*	0.94*
Enhancing the speech content	0.69*	0.92*
Providing alternative means of communication	1.00*	1.00*
Guiding and controlling the flow of speech	0.63*	1.00*
Reinforcing the intonation or prosody of speech	1.00*	1.00*
Assisting lexical retrieval	1.00*	1.00*
Assisting sentence reconstruction	0.87*	0.80*
Serving other nonspecific or noncommunicative functions	0.69*	0.97**
Total number of gestures	1.00*	1.00**

*$p < .05$. **$p < .01$.

multicollinearity were fulfilled. All aforementioned variables with correlation coefficients lower than 0.60 were used as predictors for conducting a multiple regression with forward inclusion of predictor variables. This was done to investigate which variable(s) significantly predict(s) gesture-to-word ratio and the relative importance of each variable for the prediction of gesturing rate.

Results

A total of 951 gestures were produced by the nonfluent PWA group (n = 21), 799 by the fluent PWA group (n = 23), and 236 by the controls (n = 23). One transcortical motor speaker in the nonfluent aphasic group (4.8%) and four anomic speakers in the fluent aphasic group (17.4%) did not produce any gestures. On the other hand, a higher proportion of controls (six speakers or 26.1%) did not gesture across all genres.

Question 1 was how does the rate of gesture use vary across fluent PWA, nonfluent PWA, and unimpaired control speakers? To compare the gesture-to-word ratio across the three speaker groups, descriptive statistics for gesture-to-word ratio are given in Table 3. As predicted, nonfluent PWA had the highest rate of using coverbal gestures, followed by the fluent PWA group, and controls used the least proportion of gestures. The results of the Kruskal–Wallis test suggested significant differences across the three speaker groups, $H(2) = 20.13$, $p < .001$. Post hoc analyses using Mann–Whitney tests (see Table 4) revealed that the speakers with nonfluent aphasia ($M = 0.27$, $SD = 0.23$) had a significantly higher ratio than both speakers with fluent aphasia ($M = 0.10$, $SD = 0.13$) and control speakers ($M = 0.04$, $SD = 0.05$). However, the ratio produced by fluent PWA did not significantly differ from that produced by the controls.

Question 2 was how do the distributions of gesture forms and functions differ across fluent PWA, nonfluent PWA, and unimpaired control speakers? Concerning the distributions of gesture forms and functions, the results in Table 5 indicate that nonidentifiable and deictic gestures were the top two forms of gestures used across all three speaker groups. Concerning the functions of nonidentifiable gestures, it was found that 22.7% and 16.6% of them were associated with word retrieval in the nonfluent and fluent PWA, respectively (as compared with 0.8% in the control group). This was consistent to our prediction. The content-carrying gestures, which included iconic, metaphoric, and deictic gestures as well as emblems, mainly served the function of enhancing speech content for the three speaker groups. To be more specific, the controls and speakers with fluent aphasia also used 8.7% and 1.4% of iconic gestures, respectively, to retrieve words, but our nonfluent PWA did not use any iconic gestures to serve the same purpose. In contrast, 29.5% and 25.0% of iconic gestures were used by the nonfluent and fluent PWA, respectively, to provide additional information to the message being conveyed; none of the iconic gestures found in our control speakers were used for the same purpose. Although the speakers in both aphasic groups did not produce any metaphoric gestures to retrieve words, 10% of them were used by the controls to assist lexical retrieval.

Question 3 was how well do the factors of hemiplegia, aphasia severity as reflected in AQ, semantic processing integrity, and complexity of linguistic output predict the rate of using coverbal gestures? To assess the predictability of hemiplegia, aphasia severity, semantic processing integrity, and complexity of linguistic output for gesture use among speakers with aphasia, descriptive statistics of the predicted variable—that is, gesture-to-word ratio—and all predictor variables are provided in Table 6.

Table 3. Descriptive statistics of gesture-to-word ratio across the three speaker groups.

Speaker groups	*M*	*SD*	Range
Control	0.04	0.05	0.00–0.17
Fluent aphasia	0.10	0.13	0.00–0.48
Nonfluent aphasia	0.27	0.23	0.00–0.97

To show the degree of correlation among the predictor variables, a correlation matrix was obtained, and the results are shown in Table 7. The predictor variables that had significant correlations with gesture-to-word ratio included (a) ARAT-R, (b) CAB AQ, (c) percentage of complete sentences, (d) percentage of simple sentences, (e) percentage of dysfluency, (f) adapted PPTT, (g) SJT, (h) oral pictured object naming, and (i) oral pictured action naming. Among the above predictors, there were three groups of predictors that were conceptually and statistically highly correlated: (a) Oral pictured object and action naming scores were highly correlated because they both assess naming abilities, (b) there was a high correlation between adapted PPTT and SJT scores because they assess verbal semantic integrity, (c) percentage of complete sentences highly correlated with percentage of simple sentences because production of the former entails the ability to produce the latter.

Due to the high conceptual and statistical correlations in each of the abovementioned groups, only one predictor variable in each group was included in the forward multiple regression. The selections were based on their correlations with gesture-to-word ratio; the predictor variable with a higher correlation coefficient was entered in the forward multiple regression analysis. To be specific, because the correlation coefficients of percentage of complete sentences, SJT scores, and oral pictured object naming scores were higher than those of percentage of simple sentences, adapted PPTT scores, and oral pictured action naming scores, respectively, the predictor variables that were used in the forward multiple regression included (a) ARAT-R, (b) CAB AQ, (c) percentage of complete sentences, (d) percentage of dysfluency, (e) SJT score, (f) PPTT and Birmingham Object Recognition Battery, and (g) oral pictured object naming.

The results of the forward multiple regression are displayed in Table 8. Among the seven predictors, only percentage of complete sentences and percentage of dysfluency significantly predicted gesture-to-word ratio. To be specific, percentage of complete sentences accounted for 24.9% of the variation in gesture-to-word ratio, and percentage of dysfluency accounted for an additional 14.2%. Both predictor variables accounted for 39.2% of the variation in total. One should also note the relationships between our significant predictors and the predictor variable. In particular, when a speaker produced fewer complete sentences, he or she tended to be more dysfluent; this would lead to a relatively higher gesture-to-word ratio.

Table 4. Mann–Whitney test results of comparing gesture-to-word ratio of different groups of speakers.

Comparison between groups	*df*	*U*	*z* score	*p*	*r*
Control versus fluent aphasia	44	340.0	1.66	.097	.24
Fluent aphasia versus nonfluent aphasia	42	371.0	3.04	.002*	.46
Control versus nonfluent aphasia	42	423.5	4.28	.000*	.65

*$p < .0167$.

Discussion

The current study aimed to compare gesture use in terms of gesturing rate as well as their forms and functions among speakers with fluent and nonfluent aphasia and their controls. Previous studies on PWA's gesture use have suggested that PWA tend to produce a greater number of gestures per word than healthy speakers (e.g., Kong, Law, Wat, et al., 2015; Wat, 2013). Some investigators also argued that the semantic complexity of gestures was lower in PWA (e.g., Ahlsén & Schwarz, 2013). However, previous literature seldom considered the impact of variability in language abilities, with objective quantification of linguistic skills ranging from oral naming to production of complete sentences, among PWA on gesture production. This study is among the few examinations reported thus far in the literature that include data of a large number of controls carefully matched in age and education level with speakers with fluent as well as nonfluent aphasia to examine and compare coverbal gesture production during spontaneous oral discourse. On the basis of a gesture-coding system that allows independent annotation of gesture forms and functions (Kong, Law, Kwan, et al., 2015), the relationship between functions and specific gesture forms was summarized and compared across speaker groups.

Our results regarding nonfluent PWA gesturing significantly more frequently than both the controls and speakers with fluent aphasia are consistent with the findings obtained from Italian speakers (Carlomagno & Cristilli, 2006). They also further supported the conclusions by Sekine et al. (2013) and Sekine and Rose (2013), who found significantly more frequent coverbal gestures in PWA's conversation and story retelling than healthy controls. The hypothesis of separation of formulating verbal output from planning coverbal gestures as illustrated by the sketch model (de Ruiter, 2000) can also be further supported. de Ruiter and de Beer (2013) have recently argued that the formulator of verbal production in the sketch model is hindered in speakers with nonfluent aphasia. It is more important to note that the fact that our nonfluent PWA had a tendency to produce fewer words and complete sentences than their counterparts with fluent aphasia and that they were more impaired in oral naming abilities than fluent PWA echoed this claim by de Ruiter and de Beer. However, we acknowledge that this finding regarding a different gesture rate by fluency groups of PWA could have been confounded by aphasia severity because the fluent PWA in the present study were generally

Table 5. Distributions of forms and functions of gestures of different groups of speakers.

	Forms (%)																				
	Content-carrying gestures												Non-content-carrying gestures						Overall percentage of function		
	Iconic			Metaphoric			Deictic			Emblem			Beat			Non					
Distribution	C	F	NF	C	F	NF	C	F	NF	C	F	NF	C	F	NF	C	F	NF	C	F	NF
Percentage of forms	9.7	9.0	4.6	4.2	4.5	4.8	**27.5**	**15.9**	**29.4**	1.3	2.3	2.7	4.2	6.4	4.4	**53.0**	**62.0**	**53.7**			
Functions (%)																					
Provide[a]	**0.0**	**25.0**	**29.5**	10.0	11.1	6.5	3.1	17.3	14.3	0.0	5.6	7.7	0.0	0.0	0.0	0.0	0.2	0.0	1.7	5.8	6.1
Enhance[b]	**91.3**	**73.6**	**63.6**	**50.0**	**88.9**	**93.5**	**93.8**	**55.1**	**40.0**	**66.7**	**88.9**	**80.8**	0.0	0.0	0.0	0.0	0.0	0.0	37.3	21.4	21.6
Alternate[c]	0.0	0.0	6.8	10.0	0.0	0.0	0.0	0.0	1.1	33.3	5.6	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.7
Guide[d]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0	23.5	9.5	0.0	0.0	0.0	2.1	1.5	0.5
Reinforce[e]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	72.5	90.5	0.0	0.4	0.8	2.1	4.9	4.3
Lexical[f]	**8.7**	**1.4**	**0.0**	**10.0**	**0.0**	**0.0**	1.5	15.0	7.9	0.0	0.0	0.0	0.0	3.9	0.0	**0.8**	**16.6**	**22.7**	2.1	13.0	14.7
Sentence[g]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.2	0.0	0.8	0.8	0.1
Nonspecific[h]	0.0	0.0	0.0	20.0	0.0	0.0	1.5	12.6	36.4	0.0	0.0	7.7	0.0	0.0	0.0	**97.6**	**81.6**	**76.1**	53.0	52.6	51.9

Note. Total number of gestures of the nonfluent aphasic group (n = 21): 951. Total number of gestures of the fluent aphasic group (n = 23): 799. Total number of gestures of the control group (n = 23): 236. C = control speakers; F = speakers with fluent aphasia; NF = speakers with nonfluent aphasia.

[a]Providing additional information to message conveyed. [b]Enhancing the speech content. [c]Providing alternative means of communication. [d]Guiding and controlling the flow of speech. [e]Reinforcing the intonation or prosody of speech. [f]Assisting lexical retrieval. [g]Assisting sentence reconstruction. [h]Other nonspecific or noncommunicative functions.

less severe than their nonfluent counterparts. Mol, Krahmer, and van de Sandt-Koenderman (2013) have highlighted how severe PWA produced gestures that were less informative; our results can, therefore, be considered strong evidence to further support Mol et al.'s claim of the close link between degraded verbal language abilities (i.e., nonfluent PWA in our case) and cospeech gesture production. Relevant to this are the findings from Cocks et al. (2013), in which information in speakers' gestures produced during fluent speech as well as during word-finding difficulties were linked to a speaker's semantic knowledge.

The lack of significant differences in gesture-to-word ratio between the control and fluent PWA groups was surprising. Following the sketch model, it was possible that the degree of dysfunction in the formulator of verbal production among our fluent PWA speakers was not as severe as that in their nonfluent counterparts. This assumption could be supported by our findings of post hoc analyses that indicated speakers with fluent aphasia tended to have a higher number of words, more complete sentences, and better oral naming performance than nonfluent PWA. Note that the total number of words produced by the fluent PWA

Table 6. Descriptive statistics of the predicted and predictor variables.

Variable	Min.	Max.	*M*	*SD*
Gesture-to-word ratio	0.00	0.67	0.16	0.16
ARAT-R	0.00	57.00	23.15	25.51
CAB AQ	11.00	99.00	73.99	23.64
Percentage of complete sentences	0.06	0.96	0.61	0.27
Percentage of simple sentences	0.06	0.93	0.57	0.25
Percentage of regulators	0.00	0.14	0.02	0.03
Percentage of dysfluency	0.00	4.34	0.92	0.79
TTR	0.23	0.72	0.42	0.12
SWPM	36.00	126.00	109.63	18.97
WWPM	26.00	126.00	111.20	22.93
Adapted PPTT	7.00	27.00	21.66	5.09
SJT	0.00	58.00	41.80	13.85
PPTT and BORB	12.00	58.00	47.41	11.19
Object naming	0.00	98.30	65.57	29.07
Action naming	0.00	98.00	51.90	29.80

Note. ARAT-R = Action Research Arm Test for right hand; CAB AQ = aphasia quotient of Cantonese Aphasia Battery; TTR = type–token ratio; SWPM = Spoken Word–Picture Matching test; WWPM = Written Word–Picture Matching test; PPTT = Pyramid and Palm Trees Test; SJT = Synonym Judgment Test; BORB = Associative Match test in the Birmingham Object Recognition Battery.

Table 7. Correlation coefficients among predicted and predictor variables.

Correlation	ARAT-R	CAB AQ	Percentage of complete sentences	Percentage of simple sentences	Percentage of regulators	Percentage of dysfluency	TTR	SWPM	WWPM	Adapted PPTT	SJT	PPTT and BORB	Object naming	Action naming
Gesture-to-word ratio	–.327*	–.474**	–.484**	–.463**	.061	.439**	.123	–.270	–.268	–.428**	–.496**	–.053	–.494**	–.395**
ARAT-R		.369*	.382*	.391*	–.051	.043	–.061	.275	.278	.631**	.425**	.333*	.431**	.371*
CAB AQ			.824**	.745**	–.193	–.058	–.216	.698**	.703**	.620**	.704**	.392*	.824**	.836**
Percentage of complete sentences				.971**	–.119	–.005	–.261	.539**	.458**	.487**	.514**	.250	.616**	.618**
Percentage of simple sentences					–.068	.044	–.255	.514**	.411**	.461**	.453**	.218	.549**	.548**
Percentage of regulators						.166	.210	–.122	–.038	–.050	.013	.009	–.044	–.044
Percentage of dysfluency							–.340*	.254	.133	–.023	.012	.262	.009	.035
TTR								–.135	–.070	–.096	–.120	–.145	–.146	–.201
SWPM									.772**	.557**	.589**	.657**	.805**	.778**
WWPM										.600**	.559**	.532**	.767**	.733**
Adapted PPTT											.643**	.571**	.753**	.742**
SJT												.442**	.774**	.787**
PPTT and BORB													.629**	.640**
Object naming														.931**

Note. ARAT-R = Action Research Arm Test for right hand; CAB AQ = aphasia quotient of Cantonese Aphasia Battery; TTR = type–token ratio; SWPM = Spoken Word–Picture Matching test; WWPM = Written Word–Picture Matching test; PPTT = Pyramid and Palm Trees Test; SJT = Synonym Judgment Test; BORB = Associative Match test in the Birmingham Object Recognition Battery.

$^{*}p < .05$. $^{**}p < .01$.

Table 8. Results of multiple regression analyses.

Predictor	B	SE B	β	t	p
Step 1					
Constant	.34	.05			
Percentage of complete sentences	–.29	.08	–.50	–3.60	.001
Step 2					
Constant	.28	.05			
Percentage of complete sentences	–.31	.07	–.52	–4.12	.000
Percentage of dysfluency	.08	.03	.38	2.98	.005

Note. R^2 = .249 for Step 1 ($p < .01$). ΔR^2 = .142 for Step 2 ($p < .01$).

speakers was not significantly different from the nonfluent group; this could have been contributed by the high proportion of subjects with the anomic syndrome in the current fluent PWA group (95.7% or 22 out of 23 participants). One may argue that, instead of representing a full spectrum of fluent aphasia across different subtypes, the current results drawn from fluent PWA speakers might be limited to speakers with anomic aphasia. To allow more comprehensive reflection regarding the impact of linguistic impairment on gesture use in speakers with fluent aphasia, a wider range of fluent aphasic syndromes is needed in the future.

Concerning the relationship between functions and forms of gestures, although the majority of nonidentifiable gestures were not associated with specific functions across the three groups of speakers (76.1% to 97.6% of occurrence), a non-negligible proportion of these gestures were used for assisting lexical retrieval in the two aphasic groups (16.6% to 22.7% of occurrence). This observation is in contrast to the minimal proportion (0.8%) of nonidentifiable gestures that were used for word finding among controls. Instead, our control speakers seemed to perform differently during incidents of word-finding difficulties when other forms of gestures or fillers including *uh* or *um* (Barr & Seyfeddinipur, 2010) were present. Note that previous studies (e.g., Boyle, 2014, 2015; Doyle et al., 2000; McNeil et al., 2007) identified word-finding difficulties in connected speech with different indicators, including verbal, phonemic, or semantic paraphasia, neologism/jargon, false start, repetition, revision, filled or unfilled pause, comment, and indefinite word. Our criteria of word-finding difficulties in the present study were consistent with these indicators. Moreover, only gestures associated with successful word retrieval, with one or more unambiguous word-finding indicator(s) corresponding to the specific lexical target, were counted and coded as assisting in lexical retrieval. In cases in which a gesture was used to complement information in successfully resolved word retrieval events, it would have been coded as Function 1: Providing additional information to message conveyed: The gesture represents information that is additional to the speech content.

The observation that nonidentifiable gestures could be used to assist lexical retrieval by PWA should be interpreted with caution because, according to the LRH (Krauss & Hadar, 1999), only gestures that can specify the dynamic or spatial aspects of verbal content (such as iconic and metaphoric gestures) help lexical retrieval. Moreover, the distinction of gestures that serve the function of assisting word-finding difficulties from those that serve an interactive (or communicative) function (a) to seek help from a communication partner during difficulties in finding a target lexical item (Bavelas, Chovil, Coates, & Roe, 1995) or (b) to signal a time for a speaker to retrieve a word or to help the speaker concentrate, dispersing the cognitive burden resulting from searching for a word (Holler, Turner, & Varcianna, 2013) cannot be made easily. A follow-up study is being conducted to investigate the interactive function of coverbal gestures used by PWA during spontaneous language tasks and how this function varies with linguistic breakdown in aphasia.

An interesting observation in the present study involves the qualitatively different profiles of using iconic gestures among the three groups of speakers. The fact that only very few iconic gestures were used by the two PWA groups to retrieve words and no metaphoric gestures were associated with word finding among nonfluent PWA may further suggest the LRH (Krauss & Hadar, 1999) does not apply well to aphasia, particularly those with nonfluent aphasia. To be more specific, it was found that the controls used iconic gestures to retrieve words most frequently (8.7%), followed by the speakers with fluent aphasia (1.4%), and the speakers with nonfluent aphasia did not use any iconic gestures to search for words. Instead, both iconic and metaphoric gestures were highly associated with enhancing speech content across the three speaker groups (63.6% to 91.3% of occurrence for iconic gestures; 50.0% to 93.5% of occurrence for metaphoric gestures). It was further observed that iconic gestures played an important role in helping PWA to provide additional information to a message (29.5% in nonfluent PWA and 25.0% in fluent PWA), but no controls used them for the same purpose. A similar observation could be found in nonfluent PWA who produced 6.8% iconic gestures as speech replacing/alternate mode of communication in contrast to 0% in both fluent PWA and controls. These speech-replacing iconic gestures were likely to be communicative for nonfluent PWA as compared with emblems that are used by unimpaired speakers to replace verbal output. All in all, instead of assisting lexical retrieval as proposed in the LRH, the communicative function embedded in iconic and metaphoric gestures seemed to facilitate discourse output among PWA in a different way.

Our findings regarding some degree of relationship between semantic knowledge of words and their retrieval can provide evidence that gesture and language arise at a common point. Cocks et al. (2013) reported a significant correlation between semantic knowledge among PWA and their proportion of anomic behaviors that involved gestures. The potential impact of semantic impairment among PWA on gesture use is further illustrated in the present study. To be specific, a post hoc review of our raw data echoed Cocks et al.'s conclusion because our PWA who were higher in their degree of semantic processing impairment, as reflected by lower scores in the verbal and nonverbal semantic assessments, generally committed more semantic errors in their narrative production. Related to the above was the potential relationship between PWA's dysfluency and the frequency of word-finding difficulties. These two measures are intuitively interrelated, as increased dysfluency is commonly associated with problems in lexical access. As indicated by Arnold, Fagnano, and Tanenhaus (2003) and Fraundorf and Watson (2008, 2011), signs of dysfluencies have frequently been argued to reflect delays in planning and/or encoding of upcoming material in discourse. On the basis of the results shown in Table 5, our nonfluent PWA demonstrated a higher number of gestures for assisting lexical retrieval than their fluent PWA counterparts (6.67 vs. 5.30 gestures per speaker) as compared with the minimal use of 0.22 gesture per control speaker.

According to Rose, Raymer, Lanyon, and Attard (2013), significant gains in using gestures among PWA were reported only for trained (non-)symbolic gestures. The benefit of combining language and gesture intervention to facilitate PWA's positive changes of verbal production has also been emphasized (Carlomagno, Zulian, Razzano, De Mercurio, & Marini, 2013; Rose, 2013). Scharp et al. (2007) have concluded that what still remains unclear in applying existing research findings on gesture production to guide clinical rehabilitation of PWA's communication has been the insufficient considerations of individual differences in gesture production in typical and disordered populations and the lack of normative gestural profiles for different gesture types across various communicative contexts. It is believed that the findings in this study have provided some empirical evidence of group differences in the use of gestures. To be specific, the previously mentioned observations regarding how the two aphasic groups were different in using coverbal gestures to serve various communicative functions allowed us to propose two guidelines when planning and providing gesture-based language intervention to PWA: (a) Among the six gesture forms in the present study, iconic and metaphoric gestures are believed to have the greatest therapeutic impact, and (b) depending on the fluency type of aphasia, different gesture forms may be introduced to help PWA achieve specific communicative roles. In particular, iconic gestures (instead of emblems) can be considered more effective in acting as an alternative mode of communication for nonfluent PWA. Iconic, deictic, and emblem gestures work better for fluent PWA to enhance speech content. Non-content-carrying gestures of beats, on the other hand, tend to better aid the reinforcing of speech prosody among nonfluent PWA.

One should also note that pantomimes were coded as one of the iconic gestures in the current study. According to Bernardis and Caramelli (2007), iconic gestures can be produced both with and without speech and can vary in their degree of conventionality, but opposing claims have also been reported in which iconic gestures generally occur in the context of speech and frequently require the associated speech to be interpretable (McNeill, 2000). Unlike typical speakers whose pantomimes may occur without speech and can be highly communicative (Kendon, 1982), PWA's pantomime production has been found to be associated with replacing and/or assisting with the attempted production of errorful speech (see van Nispen, van de Sandt-Koenderman, Mol, & Krahmer, 2014). As such, these two classes of gestures may fulfill different communicative roles and are likely to draw on different underlying motoric and/or cognitive abilities (e.g., Gillespie et al., 2014), which warrants further study.

In relation to significant predictors of gesture-to-word ratio in PWA, it was found that only linguistic measures could reliably predict gesture use. Measures tapping aphasia severity, degree of hemiplegia, and semantic integrity failed to predict gesture performance in aphasia. The regression results showed that percentage of complete sentences (accounting for 24.9% of variance) was the strongest predictor, followed by percentage of dysfluency (accounting for 14.2% of variance). Although the former finding is novel, the latter is consistent with Sekine et al. (2013). There was a negative correlation between percentage of complete sentences and gesture-to-word ratio—that is, the fewer complete sentences PWA produced, the more frequently the speaker would gesture, such as in the case of nonfluent PWA who had a tendency to produce a smaller proportion of complete sentences but gesture significantly more frequently than their fluent counterparts. On the other hand, there was a positive correlation between percentage of dysfluency and gesture-to-word ratio—that is, the more frequently dysfluency occurred, the more frequently gestures were produced. According to Sekine et al., PWA may use more gestures when they perceive a need to use them to communicate and/or retrieve words whenever dysfluency occurs. It should also be highlighted that the overall aphasia severity (as reflected by the AQ of the CAB) failed to predict gesture-to-word ratio in PWA, albeit its significant correlation with gesture-to-word ratio (see Table 7); this finding extended Sekine et al.'s conclusion about the Western Aphasia Battery (Kertesz, 1982) that AQ was not the best predictor of gesture frequency in English-speaking PWA. Moreover, the results of the regression analyses provide additional empirical evidence to support the sketch model (de Ruiter, 2000), confirming the more degraded formulator among nonfluent PWA was compensated by a gesture planner that mediates gestures. In the clinic, the health care professional can justify the management of communication disorders focusing on gesture training as a therapeutic technique (or a component of the whole remediation) for PWA to compensate for, facilitate, or improve verbal impairment. Although exact criteria to determine treatment candidacy of gesture-based language intervention for PWA still remain inconclusive in the literature, clinicians are recommended to consider their PWA's percentage of complete sentences and percentage of dysfluency as they are planning related management.

One challenge in conducting research related to gestures is an inherent degree of subjectivity in annotating their forms and functions. However, the extent of subjectivity was lessened by providing clear definitions and examples of each gesture form and function in Kong, Law, Kwan, et al. (2015) coding system. Reliability measures in Kendall's tau coefficient regarding forms of gestures were good although those regarding functions of gestures were found to be fair. To be specific, coefficients of inter-rater reliability were equal to or lower than those of intrarater reliability except for the function assisting sentence reconstruction. To be specific, the coefficients of the functions enhancing the speech content, guiding and controlling the flow of speech, and serving other nonspecific or noncommunicative functions of inter-rater reliability were comparatively lower than those of intrarater reliability (see Table 2). Review of the annotation disagreements suggested that misinterpretation of how gesture functions were defined and unfamiliarity with the gesture-coding system led to mismatch of classifying functions of gestures across raters. This pinpoints the importance of providing users with definitions and examples of each gesture form and function as well as adequate training and time for familiarizing themselves with the coding system.

In conclusion, the present study has provided extended evidence for the sketch model of the language–gesture relationship, but there are two directions that deserve further research. First, future investigation regarding the use of interactive gestures by PWA will allow us to better understand the quantitative and qualitative differences in gesture use between speakers with fluent and nonfluent aphasia. The relationships between gesture use and language deficits can also be further examined. Second, the facilitative role that gestures play in retrieving words among PWA could be further explored by comparing the incidence of resolution of word-finding difficulties with versus without the involvement of gestures (e.g., Lanyon & Rose, 2009). This line of research will lead to a clearer understanding of the role gestures play in lexical retrieval and can potentially shed light on providing rationales to implement and incorporate gesture-based language intervention into conventional linguistic and behavioral management of aphasia.

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Appendix A

Gesture-Coding System

Gestures are defined as spontaneous hand and arm movements that flow simultaneously with verbal production (Kendon, 1980). Body-focused movements, such as moving the hand from the lap to the table or scratching behaviors, that do not flow simultaneously with the language output are not related to the content of verbal production (Butterworth et al., 1981). Therefore, they are not regarded as gestures in the present study.

A unit of gesture is defined as the period between moving the hand from one position and moving it back to the original position (McNeill, 1992). If the hand does not return to the original position, one unit of gesture is identified when there is a pause or obvious change in trajectory or shape of hand movement (Jacobs & Garnham, 2007).

On the basis of the gesture-coding system proposed by Kong, Law, Kwan, et al. (2015), the form and function of each gesture was annotated independently. There are six forms of gestures and eight functions. Detailed descriptions of each gesture form and function, with examples, are provided in Appendixes B and C, respectively.

Appendix B

Description of Forms of Gestures

Form	Example 1	Example 2
Iconic: specifies the spatial and dynamic features of concrete objects or actions	The speaker put his left palm face up, pretending that it was a map as he said, "我原先係問佢攞個地圖睇嘅" (Originally, I asked him to give me a map to look at).	When the speaker said, "先打爛隻蛋" (First, break the egg), he moved his hand down toward the table, miming the action of breaking eggs.
Metaphoric: refers to gestures that depict the pictorial content of abstract ideas	When the speaker said, "由嗰個位置行返我屋企起碼要成三個鐘" (It takes almost 3 hours to walk from there to my home), he showed his palm in two directions, indicating the two geographical locations.	The speaker put his hand on the table twice at two different places to represent the concept of "one team versus another" as he said, "你知團體賽啦, 一隊打一隊咖嘛" (You know, in a team competition, one team vs. another).
Deictic: refers to pointing to a physically present referent or to an absent referent	The speaker pointed to a picture of bread when he said, "夾麵包" (Place a piece of bread over the filling in a sandwich).	As the speaker said, "上去瑪嘉烈嗰陣時" (When he went to Princess Margaret Hospital), he pointed to the right.
Emblem: refers to gestures that are culturally conformed and universally understood by a community	The speaker said "龜贏" (The tortoise won), when he gave the thumbs up to indicate the meaning of success.	The speaker formed a Chinese number gesture by having the index finger and thumb close and the last three fingers extend when he said, "裡面有三樣嘢" (There are three things).
Beat: means hand-flicking movements that follow the speech rhythm	When the speaker said, "零八年, 零九年, 一零年, 同埋一二年" (In the years 2008, 2009, 2010, and 2012), he raised his finger one by one from the index finger to the little finger to synchronize with the speech rhythm.	When the speaker said, "佢仲犀利" (He is even better), his right hand flicked downward to emphasize the word *even*.
Nonidentifiable: refers to gestures that are ambiguous or cannot be classified into the aforementioned categories	The speaker tapped the table using the finger repeatedly throughout the whole description of experiencing a stroke.	The speaker made a quick flick with his hand, which was unrelated to the content or rhythm of verbal output.

Appendix C

Description of Functions of Gestures

Function	Example 1	Example 2
Providing additional information to message conveyed: The gesture represents information that is additional to the speech content.	The speaker touched his waist to and fro to indicate the location that was not specified in speech as he said, "嗰的錢同証件喺呢度咖嘛" (The money and passport were here).	The speaker touched his right arm using his left hand to indicate which arm he was mentioning when he said, "隻手有少少痺痺地" (The hand was a bit numb).
Enhancing the speech content: The gesture represents the same semantic meaning as the speech content.	The speaker put his left palm face up to represent the pan that appeared in his verbal output as he said "就燒熱個煎pan" (To heat the pan).	As the speaker said, "然後就擺的牛油入去啦" (Then, put the butter inside), he moved his hand down toward the table to represent the action *put* as mentioned in the speech.
Providing alternative means of communication: The gesture exists without speech accompanying and it can convey semantic meaning alone.	The speaker showed both of his palms face up to indicate "finished" at the end of the discourse without producing any speech.	The speaker held one hand in the air for a few seconds after finishing the discourse to indicate the sense of completion.
Guiding and controlling the flow of speech: The gesture follows the rhythm of speech.	When the speaker said, "有龜呀, 熊呀, 同埋兔仔" (There were tortoise, bear, and rabbit), his right hand flicked downward as each animal was mentioned.	The speaker showed his fingers one by one as each color was mentioned during the description of his trip: "有紅色, 藍色, 仲有白色" (There were red, blue, and white).
Reinforcing the intonation or prosody of speech: The gesture stresses the meaning of the target word.	When the speaker said, "又見到佢" (See him again), his hand moved sharply during the word *again* to emphasize that meaning.	When the speaker said, "唔小心仆左落去" (Fell down carelessly), he moved his hand downward to stress the word *fall*.
Assisting lexical retrieval: The gesture leads to successful word retrieval during word-finding difficulties with indicators of anomia (Boyle, 2014, 2015; Doyle et al., 2000; McNeil et al., 2007), including filled or unfilled pauses, comments, interjections, word and phrase repetition and substitution, paraphasia, neologism/jargon, false starts, revision, and circumlocutions.	When the speaker said, "上面呢就係…咩…水缸嗰度呀" (The above is…what…the water tank), he used a finger to outline the shape of the water tank to retrieve the words *water tank* during the word *what*.	When the speaker said, "要…要…要…雞蛋" (Need…need…need eggs), he pointed to the picture of an egg to retrieve the word *egg* during the word repetition of *need*.
Assisting sentence reconstruction: The speaker produces this gesture during modification of sentence structure or difficulties in sentence construction.	The speaker put his hand up to the level of his chest during sentence reconstruction when he said, "森林大會開…森林有個賽跑比賽" (The forest meeting had… there was a running race in the forest).	The speaker kept knocking the table with his hand during sentence reconstruction as he said, "我都係…我啲嘢就冇晒記性嘅" (I am also… my memory is not good in all stuff).
Other nonspecific or noncommunicative functions: The gesture was produced without any specific functions in relation to the speech content and rhythm.	The speaker moved his hand up from the table when he said, "行到S型咁" (walk in an S-shape). The gesture was unrelated to speech in terms of meaning and rhythm.	When the speaker said, "車我入醫院囉" (drove me to the hospital), he tapped the back of his left hand with his right hand, which did not have any specific functions.

Appendix D

Parameters for Measuring Linguistic Performance

There are five parameters for evaluating the participants' linguistic abilities.

1. Percentage of complete sentences: This is calculated by dividing the number of complete sentences by the total number of sentences.
   a. A complete sentence consists of one or more clauses or phrases with specific intonation. It includes the following types:
      i. A sentence with a subject plus predicate (主謂句), for example, 狼來了 (The wolf is coming).
      ii. A sentence of a predicate only that could exist alone (無主句), for example, 好肥 (Very fat).
      iii. A sentence of a predicate only but that is grammatically accurate only when it is accompanied by the previous sentence (不完全主謂句), for example, The previous sentence: 佢呢? (He?).
      A sentence of a predicate only: 係一個醫生 (Is a doctor).
      iv. A single-word sentence (獨詞句), for example, 咩話? (What?)
      v. A compound and/or complex sentence (複句)
         - A compound sentence consists of two or more simple sentences that are conjoined by coordinating conjunctions, such as *for*, *and*, *but*, *so*, for example, 我手腳麻痺, 所以行唔到 (My hands and legs were numb, so I could not walk).
         - A complex sentence consists of one or more dependent clauses at the beginning or end of the sentence or embedded within the sentence. A subordinate conjunction and relative pronoun usually appear, for example, 喺車站做野嗰個人俾張地圖我 (The person who worked at the station gave me a map).
   b. Incomplete sentences are defined as any sentences that are ill-formed and ungrammatical or have omission of sentence elements.
   c. Total number of sentences is the sum of number of complete sentences and incomplete sentences.
2. Percentage of simple sentences: This is calculated by dividing the number of simple sentences by the total number of sentences. A simple sentence is a complete sentence that contains only one clause or phrase. Simple sentences include (a) a sentence with a subject plus a predicate, (b) a sentence of a predicate only that could exist alone, (c) a sentence of a predicate only but that is grammatically accurate only when it is accompanied by the previous sentence, and (d) a single-word sentence.
3. Percentage of regulators: This is calculated by dividing the number of regulators by the total number of sentences. Regulators are sentences used for initiation, continuation, shifting, and termination in discourse (Mather, 2005). They are used to fill in the gaps and carry no meaning, for example, 就係咁 (That's it).
4. Percentage of dysfluency: This is calculated by dividing the number of occurrences of dysfluency by the total number of sentences. Occurrence of dysfluency is defined as a time when there is sound prolongation, word or phrase repetition, a pause, self-correction, or interjections, such as /ε_6/ or /ʌm/ (Mayberry & Jaques, 2000).
5. Type–token ratio: This is calculated by dividing the number of different words by the total number of words.
   a. Number of different words means the number of words that were counted once only regardless of their different bound morphemes. Mazes and bound morphemes were excluded.
   b. Total number of words means all words produced in the speech sample, excluding repetitions and self-corrections.