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The use and function of gestures in word-finding difficulties in aphasia

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The use and function of gestures in word-finding difficulties in aphasia

Background: Gestures are spontaneous hand and arm movements that are part of everyday communication. The roles of gestures in communication are disputed. Most agree that they augment the information conveyed in speech. More contentiously, some argue that they facilitate speech, particularly when word finding difficulties occur. Exploring gestures in aphasia may further illuminate their role.

Aims: This study explored the spontaneous use of gestures in the conversation of participants with aphasia (PWA) and neurologically healthy participants (NHP). It aimed to examine the facilitative role of gesture by determining whether gestures particularly accompanied word finding difficulties and whether or not those difficulties were resolved.

Methods & Procedures: Spontaneous conversation data were collected from 20 PWA and 21 NHP. Video samples were analysed for gesture production, speech production, and word-finding difficulties. The first analysis examined whether the production of semantically rich gestures in these conversations was affected by whether the person had aphasia, and/or whether there were difficulties in the accompanying speech. The second analysis identified all word finding difficulties in the data and examined whether these were more likely to be resolved if accompanied by a gesture, again for both groups of participants.

Outcomes & Results: Semantically rich gestures were frequently employed by both groups of participants, but with no effect of group. There was an effect of the accompanying speech, with gestures occurring most commonly alongside resolved word finding difficulties. An interaction showed that this was particularly the case for PWA. NHP, on the other hand, employed semantically rich gestures most frequently alongside fluent speech. The second analysis showed that word finding difficulties were common in both groups of participants. Unsurprisingly, these were more likely to be resolved for NHP than PWA. For both groups, resolution was more likely if the word finding difficulty was accompanied by a gesture.

Conclusions: These findings shed light on the different functions of gesture within conversation. They highlight the importance of gesture during word finding difficulties, both in aphasic and neurologically healthy language, and suggest that gesture may facilitate word retrieval.

Keywords: aphasia, gesture, conversation, word-finding-difficulty, gesture function

Background

Gestures, in the form of spontaneous hand and arm movements are a ubiquitous feature of human communication (e.g., Beattie & Coughlan, 1999). Their roles are disputed. One is to convey information, most obviously when used in isolation. For example, a gesture might be employed in a noisy bar to request a drink. The *hand-in-hand hypothesis* (de Ruiter, Bangerter, & Dings, 2012) argues that the gestures used alongside speech are also meaningful. This is supported by studies showing that the gestures accompanying both neurologically healthy and aphasic speech convey meanings that mirror or augment what is said (e.g., Cocks, Dipper, Middleton, & Morgan, 2011; Hadar, Burstein, Krauss, & Soroker, 1998; Kong, Law, Wat, & Lai, 2015; Lott, 1999; Pritchard, Dipper, Morgan, & Cocks, 2015; van Nispen, van de Sandt-Koenderman, Sekine, Krahmer, & Rose, 2017; Wilkinson, Beeke, & Maxim, 2010). According to the *tradeoff hypothesis* (e.g., de Ruiter et al., 2012; So, Kita, & Goldin-Meadow, 2009) the communicative function of gesture increases if speech is difficult. Thus, neurologically healthy speakers gesture more when speech is obstructed experimentally (e.g., Bangerter, 2004; van der Sluis & Krahmer, 2007) or by environmental circumstances (e.g., Kendon, 1997; Meissner & Philpotts, 1975). In line with this view, many studies identify compensatory uses of gesture in aphasia, with gestures employed in place of compromised speech (e.g., Beeke, Wilkinson, & Maxim, 2001; Herrmann, Reichle, Lucius-Hoene, Wallesch, & Johannsen-Horbach, 1988; Lanyon & Rose, 2009; Lott, 1999; Sekine & Rose, 2013; Wilkinson, 2013).

Other researchers argue that gestures facilitate the process of speech production (Alibali, Kita, & Young, 2000; Butterworth & Hadar, 1989; de Ruiter, 1998; Krauss, Chen, & Chawla, 1996; Krauss, Chen, & Gottesman, 2000). The mechanism underlying this facilitatory process is contentious and has been argued to occur either at a conceptual (i.e., pre-linguistic) or lexical level. This facilitatory role for gesture is particularly prominent when speech is derailed, for example, because of word-finding difficulties (WFD).

WFD are a prominent symptom of aphasia indicating impaired lexical retrieval (e.g., Benson & Ardila, 1996; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Goodglass & Wingfield, 1997). They can cause lengthy disruptions to speech, which may be unresolved or only repaired with the assistance of the conversation partner (e.g., Goodglass & Wingfield, 1997; Herbert, Best, Hickin, Howard, & Osborne, 2003; Hickin, Herbert, Best, Howard, & Osborne, 2006; Lesser & Algar, 1995; Perkins, Crisp, & Walshaw, 1999). Neurologically healthy speakers may also experience problems with word retrieval. Such problems often manifest as tip-of-the-tongue (TOT) states, in which the word form is temporarily unavailable (e.g., Beattie & Coughlan, 1999; Burke, MacKay, Worthley, & Wade, 1991; Frick-Horbury & Guttentag, 1998; Goodglass, Kaplan, Weintraub, & Ackerman, 1976).

Facilitative gestures?

Studies investigating TOT states in neurologically healthy speech found that the production of gestures had an influence on speech fluency and TOT resolution (e.g., Frick-Horbury & Guttentag, 1998). This is difficult to investigate but one option is to compare speech production when participants are and are not allowed to gesture (e.g., Beattie & Coughlan, 1999; Frick-Horbury & Guttentag, 1998; Graham & Heywood, 1975; Morsella & Krauss, 2004; Rauscher, Krauss, & Chen, 1996; Rimé, 1982; Rimé, Schiaratura, Hupet, & Ghysselinckx, 1984). In most studies applying this restrictive technique, results suggested that speech production was more fluent when participants were allowed to gesture, hinting towards a facilitative function of gesture. In the studies of Beattie and Coughlan (1999) and Frick-Horbury and Guttentag (1998), for example, participants were given a definition and had to retrieve the described word. Only half of the participants were allowed to gesture. Despite their similar setup, the two studies produced different findings. In the study of Frick-Horbury and Guttentag (1998), participants who were allowed to gesture retrieved significantly more words than those that were prevented from gesturing. Beattie and Coughlan (1999) did not find such an effect. However, in contrast to the earlier study, they did find that the resolution of TOT states was more likely when gesturing was permitted. Despite the conflicting results and consequent disagreement of gesture function, the evidence points towards an important role for gesture production in word retrieval.

An alternative method to investigate the influence of gestures on speech production in neurologically healthy speech is to explore the temporal relationship between the two (e.g., Butterworth & Beattie, 1978; de Ruiter, 1998; Kendon, 1972, 1975; McNeill, 1987; Morrel-Samuels & Krauss, 1992; Schegloff, 1984). Morrel-Samuels and Krauss (1992), for example, investigated the relationship between gesture production and lexical familiarity in a photograph description task. They found that the distance between the gesture and the lexical affiliate (i.e., the word associated with the gesture) related to word familiarity: gestures for *less* familiar words were produced early and further from their lexical affiliate, whereas gestures for *more* familiar words were produced closer to their lexical affiliate. There are several possible explanations for this phenomenon. One is that participants attempted to prime the unfamiliar word by producing a gesture well in advance of its lexical affiliate. Another is that in order to initiate communication, in the delay of access to the phonological label, participants began expression through the gestural mode. It is therefore assumed that gesture production is tied to lexical access and may facilitate lexical retrieval.

Turning towards impaired lexical retrieval in aphasia, there is disagreement as to whether gestures facilitate lexical retrieval and help to solve WFD. Many studies that explored this question focused on the temporal relationship between gesture and speech (e.g., Ahlsén & Schwarz, 2013; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, Krauss, & Soroker, 1998; Hadar & Yadlin-Gedassy, 1994; Kong et al., 2015). Similar to the findings in neurologically healthy speech, all studies came to the conclusion that lexical retrieval was successful if the gesture immediately preceded its lexical affiliate. A different method of investigating gesture and speech production was chosen by Lanyon and Rose (2009). In their study the resolution rate of WFD and their co-occurrence with gesture was analysed. Overall, there was no significant difference between the number of gestures produced during resolved WFD compared to unresolved WFD. However, five PWA produced over 50% more gestures during resolved WFD than during unresolved WFD: These PWA were considered to have an impairment at the phonological level. According to the authors, the gestures of these PWA served as a cross-modal prime and facilitated lexical retrieval. These findings are in line with those of Kroenke, Mueller, Friederici, and Obrig (2013). Other studies have similarly found that PWA gesture during instances of WFD but have not found evidence of facilitation (e.g., Cocks et al., 2011; Cocks, Dipper, Pritchard, & Morgan, 2013; Kong, Law, & Cheung, 2018; Pritchard, Cocks, & Dipper, 2013).

Gesture classification

A widely used system for classifying gesture is Kendon's continuum, named by McNeill (1992, 2000) to acknowledge its originator. This separates gestures that occur alongside speech, termed gesticulations, from those that can stand alone. McNeill further subdivides gesticulations into iconics, metaphorics, deictics, and beats. Iconic gestures occur alongside concrete words and reflect an aspect of that word's meaning, such as a cup holding gesture to accompany the word 'drink'. Metaphoric gestures occur when someone creates a physical representation of an abstract idea or concept, for example, an extended flat upwards palm may represent 'a problem'. These gestures provide additional semantic meaning that complements the ongoing speech. Aalthough metaphoric gestures embody abstract semantic information, this information is semantically rich. Deictics and beats carry less semantic information. Deictics are pointing gestures, for example, to mark a location. Beats are rhythmic movements that mark the prosody of the accompanying speech. Standalone gestures include pantomimes and emblems. The former are complex, often sequential gestures, for example used to mimic an enacted event. Emblems form a sub-set of specific gestures, such as thumbs up, that have an agreed meaning within the user's culture. Kendon's continuum also includes sign language, but this will be disregarded here as it is an independent and complex linguistic system.

Kendon's continuum was used to classify gestures in the current study, with two modifications. The first introduced two additional types of standalone gestures. These were air writing, where the person traces letters in the air or against a flat surface, and numbers, which might comprise traced figures or holding up extended fingers to show values up to five. The appearance of these gestures in our data is consistent with prior evidence of their use by PWA (e.g., Cicone, Wapner, Foldi, Zurif, & Gardner, 1979; Sekine & Rose, 2013; Sekine, Rose, Foster, Attard, & Lanyon, 2013). The second modification introduced the overarching category of semantically rich gestures. As the name implies, these are gestures that reflect or augment the meanings being expressed, or which convey meaning independent of speech. Given their semantic content, they are hypothesised to play a key role in facilitation. This would be in line with findings of previous studies that semantically rich gestures often occur during word-difficulties (e.g., Lanyon & Rose, 2009; Morrel-Samuels & Krauss, 1992). They comprise: iconics, metaphorics, pantomimes, emblems, air writing, and numbers.

The current study

This study built on the work of Lanyon and Rose (2009) by examining the gestures that accompanied spontaneous conversation in 20 PWA and 20 NHP. It aimed to explore whether gesture facilitates speech production for both groups, and also to identify any roles for gesture additional to this faciliatory one.

Two analyses were conducted. The first identified all semantically rich gestures in the data and examined the co-occurring speech. The analysis investigated whether gestures were accompanied by fluent speech or by instances of WFD, and in the case of the latter whether those instances were resolved. It also recorded whether there was no accompanying speech, that is, because standalone gestures were employed. This analysis addressed the following questions:

- Are semantically rich gestures more likely to occur alongside WFD than fluent speech? And do they particularly accompany resolved WFD?
- Does the relationship between speech and gesture differ for PWA compared to NHP? For example, are PWA more likely to use gestures in the absence of speech?

In line with previous research, it was hypothesised that semantically rich gestures would particularly occur alongside WFD, at least for the PWA (e.g., Ahlsén & Schwarz, 2013; Carlomagno, Pandolfi, Marini, Di Iasi, & Cristilli, 2005; Cicone et al., 1979; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Lanyon & Rose, 2009; Sekine & Rose, 2013; van Nispen, van de Sandt-Koenderman, Mol, & Krahmer, 2014). However, PWA were also anticipated to use gesture in the absence of speech, and more so than the NHP group, pointing to its compensatory use. Evidence that semantically rich gestures were particularly accompanied by resolved word finding difficulties would suggest a facilitatory role.

The second analysis further explored the facilitatory potential of gesture. This extracted all instances of WFD in the data and determined whether the difficulty was resolved or unresolved. It then examined whether the difficulty was accompanied by a gesture (of any type). This second cut of the data enabled us to factor in WFD that occurred without gestures, and so compare resolution rates with and without gesture. Thus, the third research question addressed by this analysis was:

- Is the resolution of WFD associated with the production of a gesture? And is that the case for both PWA and NHP?

Given the ambiguous or negative findings of previous studies, the influence of gesture production could go into either direction: Either (1) participants may produce significantly more gesture during resolved WFD than during unresolved WFD (e.g., Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994; Lanyon & Rose, 2009) or (2) participants may not produce significantly more gestures during resolved WFD (e.g., Cocks et al., 2011; Cocks et al., 2013; Pritchard et al., 2013). A facilitatory role would be suggested if semantically rich gestures particularly accompanied resolved WFD, and, in the second analysis, if WFD were more likely to be resolved when they occurred with, rather than without a gesture.

Method

Ethical approval

The ethics committee of the School of Health Sciences (Division of Language and Communication Science) at City, University of London granted ethical approval on 22nd February 2013. This approval included the recruitment of PWA through London community stroke groups and through established aphasia community links available through previous aphasia projects within the division. Furthermore, it included contacting NHP through an existing database stored at the Department of Psychology at City, University of London and through personal contacts of the examiners.

Participants

Participants with aphasia (PWA). Twenty PWA (9 female, 11 male) were recruited via community groups to take part in this study. All PWA were more than 6 months post-stroke (range = 11 months to 9 years, M = 51.90, SD = 25.221) and between 23 and 83 years old (M = 60.60, SD = 15.537). Eleven PWA had completed tertiary education and nine PWA had reached and finished secondary education. All PWA were (originally) right-handed, 11 PWA had right hemiplegia. Inclusion criteria for the study were: (1) a left hemispheric stroke with aphasia, (2) at least six months post-onset to ensure medical stability, (3) fluent users of English prior to the stroke (via self-report), (4) normal or corrected-to-normal vision and hearing, and (5) meeting pre-determined screening cut-offs. Exclusion criteria included: (1) coexisting neurological diagnoses such as dementia and (2) being unable to consent to participation due to significant comprehension difficulties that were evident in conversation.

Neurologically healthy participants (NHP). Twenty-one NHP (12 female, 9 male) were recruited through an existing database stored in the Department of Psychology at City, University of London (all participants in this database had previously given consent to be contacted about other research projects taking place at City, University of London) and through personal links of the principal investigator. NHP were between 27 and 89 years old (*M* = 60.19, *SD* = 20.764). Seventeen NHP had completed tertiary education and 4 had reached and finished secondary education. Four NHP were left-handed. Participants had to be fluent users of English (established via self-report) and have normal or corrected-to-normal vision and no reported hearing loss. Exclusion criteria were history of neurological illness or insult and any other serious medical condition. PWA and NHP did not differ with respect to age (t (39) = 0.071, p = .944), gender (X^2 (1) = 0.605, p = .437), and education (t (39) = -1.643, p = .108).

Conversation partners (CP). PWA and NHP were each filmed in conversation with different conversation partners, including family members, friends, and students from the authors' University department. This mix of CP aimed to reflect everyday conversation situations and was balanced across both PWA and NHP, that is, each participant was filmed with a familiar and an unfamiliar conversation partner. The CP did not have a self-reported history of neurological illness, insult, or any other serious medical condition.

Assessment data

Assessment data are summarised below and in Table 2, also below.

Language skills. The Western Aphasia Battery – Revised (WAB-R; Kertesz, 2007) was conducted with all PWA in order to determine the syndrome and the severity of the aphasia as well as the fluency of spontaneous speech. Participants' aphasia quotient score (AQ) on the WAB-R ranged from 31.60 to 90.08 (*M* = 68.08, *SD* = 16.946).

Depending on their AQ score, PWA were categorised as having either mild, moderate, or severe aphasia. According to the WAB-R, seven participants were diagnosed as having Broca's aphasia, five had Conduction aphasia, five had Anomic aphasia, and three had transcortical motor aphasia (TMA). Fluency scores ranged between 2 and 9 (*M* = 4.08, *SD* = 2.093).

Cognitive skills. All participants were given the non-linguistic subtests of the Cognitive Linguistic Quick Test (CLQT; Helm-Estabrooks, 2001) to rule out any major cognitive impairment. The scores were corrected for age. While PWA ranged from 39.00% to 94.30% (*M* = 75.09%, *SD* = 17.608), indicating performances both within normal limits (WNL) and mild impairment, all NHP performed within normal limits (from 75.20% to 100.00%, *M* = 90.88%, *SD* = 7.963).

Motor skills. All participants completed the Action Research Arm Test (ARAT; McDonnell, 2008) to ensure complete full use of at least one upper limb. While NHP and CP scored 100% for both left and right upper limb, this was the case for only nine PWA. PWA experienced a range of motoric problems which affected the use of their right arm and hand. Eleven participants gestured unilaterally while the rest were able to gesture bilaterally. Additionally, PWA and NHP were given the Birmingham Praxis-Screen (BCoS-Praxis), a subsection of the Birmingham Cognitive Screen (BCoS; Bickerton et al., 2012). See Table 1 for the cut-off scores:

Table 1: Cut-offs of the four subtests for the BCoS-Praxis.

Subtests	< 65 years		65 – 74 years		> 74 years	
(max. score)	Score	%	Score	%	Score	%
Object use (12)	11	91.7%	10	83.3%	10	83.3%
Pantomime (12)	10	83.3%	9	75.0%	9	75.0%
Recognition (6)	5	83.3%	5	83.3%	4	66.7%
Imitation (12)	9	75.0%	9	75.0%	9	75.0%

Note. BCoS-Praxis = Birmingham Cognitive Screen – Praxis.

None of the NHP obtained scores that would suggest limb apraxia. The scores of 12 PWA, however, indicated that they had limb apraxia. This is marked in the last column in Table 2 below.

Table 2. Information and test scores of PWA.

ID	Gender	Age	Months post stroke	Type/location of stroke	WAB-R				BCos-Praxis				
					AQ	Severity	Syndrome	Fluency	O	P	R	I	Apraxia
1A	F	71	38	CVA, ischemia, left	68.2	moderate	Conduction	4	12	10	5	10	N
2A	F	79	50	CVA, ischemia, left posterior putamen, insular cortex, and corona radiata	86.6	mild	Anomic	9	12	11	5	10	N
3A	M	40	43	*no information available;* left	62.7	moderate	Broca's	4	12	8	5	9	Y
4A	M	75	83	CVA, ischemia, left MCA	75.6	moderate	Conduction	5	12	11	6	9	N
5A	M	73	19	CVA, ischemia, left MCA, frontal lobe	76.6	mild	TMA	4	12	12	5	9	N
6A	F	64	11	CVA, ischemia, left MCA	82.9	mild	Anomic	9	11	9	5	6	Y
7A	M	64	65	CVA, ischemia, left, basal ganglia	90.8	mild	Anomic	9	12	10	4	8	Y
8A	M	79	31	CVA, ischemia, left MCA	66.9	moderate	Conduction	6	12	8	5	6	Y
9A	M	58	40	CVA, ischemia, left MCA	68.6	moderate	Conduction	5	12	6	5	9	Y
10A	F	54	55	CVA, ischemia, left MCA	84.2	mild	Anomic	5	12	8	6	7	Y
11A	M	56	23	CVA, ischemia, left MCA	81.1	mild	Anomic	5	12	11	6	12	N
12A	F	54	65	CVA, ischemia, left MCA	76.6	mild	Conduction	5	12	12	6	9	N
13A	F	65	72	*no information available*; left	36.7	severe	Broca's	2	12	6	5	7	Y
14A	F	47	117	CVA, ischemia, left MCA	37.2	severe	Broca's	2	12	4	1	6	Y
15A	M	77	36	*no information available*; left	63	moderate	Broca's	4	12	8	4	6	Y
16A	M	56	56	CVA, ischemia, left MCA	31.6	severe	Broca's	2	12	6	3	9	Y
17A	M	83	44	CVA, ischemia, left MCA	77.2	mild	TMA	4	12	10	4	11	N
18A	F	23	58	CVA, ischemia, left MCA	64.1	moderate	Broca's	4	12	9	5	12	Y
19A	F	54	60	*no information available*; left	53	moderate	Broca's	4	12	11	5	8	Y
20A	M	40	42	CVA, ischemia, left MCA	77.8	mild	TMA	4	12	10	6	10	N

Note. PWA = participant/s with aphasia; F = female; M = male; WAB-R = Western Aphasia Battery – Revised; AQ = aphasia quotient; TMA = transcortical motor aphasia; BCoS-Praxis = Birmingham Cognitive Screen – Praxis; O = object use; P = pantomime; R = recognition; I = Imitation; Y = yes; N = no.

Procedure

Participants were not informed about the focus on gesture production until after their involvement in the project. Instead, they were invited to take part in a project about conversation in aphasia, comparing the effect of different conversation topics and conversation partners.

Setup/materials. Participants, their conversation partner and the camera were set up in a triangle. PWA/NHP and CP were seated in a 90° angle in order to face each other and to still capture the upper body part of the two speakers with the camera. To make sure that the gesturing of participants was visible, the dominant or functional arm respectively was facing the camera (12 left, 8 right for PWA and 4 left, 17 right for NHP). The camera captured the upper part of the body (from knees up to an arm length above the head). To ensure that gesturing was not impeded, PWA/NHP and their conversation partner were not allowed to have anything on their laps, in their hands and next to their chairs. There was approximately an arm-length of space to either side and above the head so that all gestures taking place in this sitting position could be captured on film.

Conversation topics. Participants were given four conversation topics to discuss with each partner, two narrative (i.e., a recollection of a happy event and a recollection of a busy weekend) and two procedural (i.e., how to make scrambled eggs and how to wrap a parcel). These topics aimed to elicit a range of everyday interactional discourse. All participants took part in eight conversations. For each conversation, at least 02:30 minutes were targeted, but the examiner did not stop the conversation. The camera was stopped as soon as the conversation came to a natural stop. Only the middle 02:00 minutes of the conversation sample were used for analysis. In total, 16:00 minutes of conversation per participant were analysed.

Coding procedure. The middle two minutes of all videos were coded using the gesture and sign language analysis program ELAN (Wittenburg, Brugman, Russel, Klassmann, & Sloetjes, 2006). Coding was conducted by using different tiers below the video. First of all, gesturing was identified and co-occurring speech was transcribed using ordinary orthographic conventions and, if necessary, broad phonemic transcription. Gestures were categorised according to our adapted version of Kendon's continuum (McNeill, 1992, 2000). There were eight categories of gesture: iconic, metaphoric, deictic, beat, pantomime, emblem, air writing & numbers, and other (i.e., gestures that did not fit in any of the categories). Iconic, metaphoric, pantomime, emblem, and air writing & number gestures were further collapsed into semantically rich gestures. Because of their semantic content, they are expected to play a key role in conversation. Since sign language is a complex language system, it was not included into this study. Following Lanyon and Rose (2009), instances of word-finding difficulties (WFD) were identified. The list of indicators of WFD by Murray and Clark (2006) has been used in earlier studies investigating gesture production in aphasia (e.g., Cocks et al., 2013; Pritchard et al., 2013). For the current study, the list was adapted by adding the last point about filling utterances and providing examples.

- A pause of at least 500ms
- A circumlocution around a target word, such as *the thing you use to stir things up* for *spoon*
- Onomatopoeia in the place of a target word, such as *brumm* for *driving*
- A semantic error, such as *fork* for *spoon* (either if the speaker is not satisfied with his/her choice of word and continues the word-searching behaviour or the conversation partner checks for understanding based on the context)

- A phonological error, such as *tork* for *fork*
- A neologism, a non-word in which less than 50% of target phonology was present (Marshall, 2006)
- A metalinguistic comment, such as *I don't know*
- A repetition, such as *you take that that that that thing*
- Filling utterances, such as *uh* and *um*

After identification, WFD were checked for co-occurrence with a semantically rich gesture, which are gestures that convey information about the co-occurring word and/or concept (i.e., with and without co-occurring speech). In other words, iconic, metaphoric, pantomime, emblem, and air writing & number gestures were regarded as semantically rich. WFD were also checked for resolution. A WFD was classified as resolved if the speaker followed it with a word appropriate for the context and not overtly rejected by the speaker. If there was no such target word, the WFD was classified as unresolved.

Inter-rater agreement

The videos of all conversations were coded and analysed by the principal investigator, an English-speaking speech and language therapist (SLT) with experience with aphasia. A second judge, a native English speaker, coded 10% of the videos for identifying gestures, different types of gestures, identifying WFD, and categorising the WFD for their co-occurrence with gesture and resolution in order to prove reliability. In instances of different coding, the version of the principal coder was used for further analysis. Table 3 reports the overall inter-rater agreement for the identification of gestures and WFD.

Table 3. Inter-rater reliability (% agreement) for the identification of gestures and WFD.

	Reliability level for PWA in %	Reliability level for NHP in %	Total reliability level in %
Identification of gestures	92.39	98.49	96.34
Identification of WFD	78.60	87.24	82.47

Note. PWA = participant/s with aphasia, NHP = neurologically healthy participant/s; WFD = word-finding difficulty/ies.

Overall, there was better percentage agreement for NHP than for PWA and the reliability for the identification of gestures was better (PWA: 92.39%; NHP: 98.49%) than the reliability for the identification of WFD (PWA: 78.60%; NHP: 87.24%). Reliability for the different type of gesture and the different type of WFD was tested using Cohen's κ. Judges reached substantial agreement for the gesture type in PWA, $\kappa = .637$, $p < .001$, and moderate agreement for gesture type in NHP, $\kappa = .585$, $p < .001$. Substantial agreement was reached for both PWA, $\kappa = .730$, $p < .001$, and NHP, $\kappa = .706$, $p < .001$ for the type of WFD.

Analysis 1: Semantically rich gestures

The analysis first identified all the semantically rich gestures (i.e., iconic, metaphoric, pantomime, emblem, and air writing & number gestures) in the data. The speech co-occurring with these semantically rich gestures was then identified and coded under four categories: resolved WFD, unresolved WFD, fluent speech, and no speech. A 2x4 repeated measures 2-way ANOVA was used to explore whether the number of semantically rich gestures was influence by group (PWA vs. NHP) and/or co-occurring speech. Evidence of gesture facilitation would be provided if gestures particularly occur alongside resolved WFD.

Analysis 2: Word-finding difficulties

In the previous analysis, only semantically rich gestures were taken into consideration. This left out WFD that either occurred together with semantically empty gestures or without a gesture at all. Therefore, the second analysis identified all WFD in the data. The WFD were coded as resolved and unresolved, using the criteria outlined above. The analysis then determined if the WFD was accompanied by a gesture. Here, gestures from any of the categories along Kendon's continuum (McNeill, 1992, 2000) were included. A 2x2 Pearson's Chi Square analysis was used to determine if WFD were more likely to be resolved if they were accompanied by a gesture.

Results

On average, all participants employed a high number of gestures during the conversations, NHP produced even more gestures than PWA. The mean number of iconic and emblem gestures was similar in PWA and NHP. However, while PWA on average produced more pantomime, air writing & number, and deictic gestures, the proportion of metaphoric and beat gestures was higher in NHP. Furthermore, PWA produced more than twice as many gestures that could not be categorised in comparison to NHP. Table 4 gives more details about the distribution of gesture types:

Table 4. Mean number of gestures produced across all conversations per participant.

	PWA		NHP	
	M (*SD*)	%	*M* (*SD*)	%
Overall	355.32 (92.519)	n/a	384.10 (76.674)	n/a
Semantically rich gestures				
iconic	114.53 (53.174)	32.23	132.40 (38.602)	34.47
metaphoric	72.32 (45.382)	20.35	105.00 (57.857)	27.34
pantomime	0.74 (0.991)	0.21	0.35 (0.988)	0.09
emblem	0.84 (1.259)	0.24	0.45 (1.572)	0.12
air writing & numbers	16.95 (28.448)	4.77	0.80 (1.765)	0.21
Semantically empty gestures				
deictic	49.74 (22.905)	14.00	24.70 (13.413)	6.43
beat	44.21 (34.271)	12.44	94.80 (55.287)	24.68
other	56.00 (26.160)	15.76	25.60 (13.430)	6.66

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; *M* = mean; *SD* = standard deviation.

Analysis 1: Semantically rich gestures

The first analysis extracted all semantically rich gestures in the data. For each gesture, the co-occurring speech was identified as one of four categories: (1) resolved WFD, (2) unresolved WFD, (3) fluent speech, and (4) no speech. Table 5 gives an overview of the distribution across all conversations per participant:

Table 5. Distribution of the co-occurring-speech categories of semantically rich gestures (in %) across all conversations per participant.

	PWA		NHP	
	M	*SD*	*M*	*SD*
Resolved WFD	50.23	12.488	47.40	11.963
Unresolved WFD	27.25	13.072	1.28	1.574
Fluent speech	19.14	10.173	50.59	12.511
No speech	3.38	7.797	0.73	0.536

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; *M* = mean; *SD* = standard deviation.

Of the eight variables (four co-speech categories x two participant groups), five were normally distributed, while three were not, W (20) = .852, p = .006 for PWA (resolved WFD), W (21) = .725, p < .001 for NHP (unresolved WFD), and W (20) = .365, p < .001 for PWA (no speech). As the majority of all variables were normally distributed, the planned parametric analyses were employed.

A 2x4 repeated measures 2-way ANOVA was conducted to explore the production of semantically rich gestures. The between-factor was group (PWA vs. NHP) and the within-factor was co-occurring speech (resolved WFD, unresolved WFD, fluent speech, no speech). There was a main effect of speech category, indicating that the production of semantically rich gestures was influenced by co-occurring speech, and the effect size was large, F (3, 117) = 135.731, p < .001 (η_p^2 = .777). Overall, resolved WFD occurred most often (48.82%), followed by fluent speech (34.84%), while unresolved WFD (14.26.%) and no speech (2.06%) occurred less often. All pairwise comparisons were significant at p < .001. There was also an interaction of category and group, showing that the distribution of the co-occurring-speech categories was linked to the group participants belonged to (either aphasia or not), and the effect size was large F (3, 117) = 43,617, p < .001 (η_p^2 = .528). There was no main effect of group though, and the effect size was small. This indicated that the groups did not differ with respect to the overall numbers of semantically rich gestures produced. To explore the differences between the different categories of semantically rich gestures, pairwise comparisons (with Bonferroni correction) were conducted.

An overview of the distribution of the different categories of co-occurring speech in PWA and NHP are given in Figure 1 where the significant pairwise comparisons are represented by the horizontal lines:

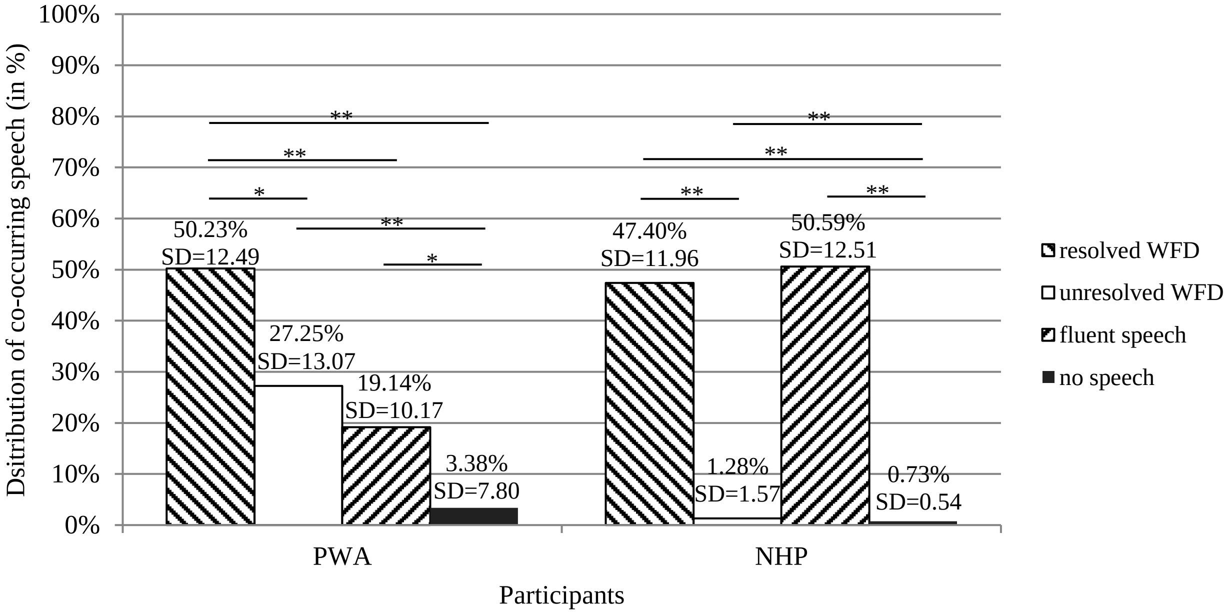

Figure 1. Distribution of the co-occurring-speech categories of semantically rich gestures (in %) for PWA and NHP (** = significant at p < .001; * = significant at p < .05), including standard deviation (SD).

Figure 1 shows that both groups of participants produced a large number of semantically rich gestures alongside resolved WFD. For PWA, this category was significantly greater than any other. The figure also illustrates the source of the interaction. The two participant groups most clearly differ with respect to two categories. PWA produced over 27% of semantically rich gestures alongside unresolved

WFD, a category that was rare for the NHP. Conversely gesture production alongside fluent speech was the most frequent category for NHP (over 50%) while only the third most common for PWA (19.14%). Both groups produced only a small number of semantically rich gestures occurring without speech.

This analysis showed that semantically rich gestures were particularly likely to occur alongside resolved WFD. However, this finding was mediated by a group interaction showing that the distribution of semantically rich gestures did vary across the two groups. PWA particularly tended to employ semantically rich gestures alongside WFD, and most so when those difficulties were resolved. This pattern was less evident in the data from NHP. Here, gestures were as likely to accompany fluent speech.

Analysis 2: Word-finding difficulties

Descriptive statistics revealed that both PWA and NHP on average experienced a similar number of WFD. In fact, NHP experienced more WFD (M = 117.80, SD = 23.171) than PWA (M = 107.84, SD = 30.183). Each WFD was coded as resolved or unresolved. The analysis also determined whether or not the WFD was accompanied by a gesture (of any type). In contrast to analysis 1, gestures that cannot be counted as semantically rich were also included into analysis 2. The data are reported in Tables 6 and 7.

A 2x2 Pearson's Chi Square analysis was conducted for PWA and NHP (Pring, 2005), to examine the relationship between the production of gestures in WFD and their resolution. For both participant groups, results revealed a significant relationship between these two factors, X^2 (1) = 12.356, $p < .01$ (PWA) and X^2 (1) = 40.657, $p < .01$ (NHP). This indicates that WFD that occurred with gestures were more likely to be resolved than WFD that occurred without gesture production.

Table 6. Chi Square analysis of the different types of WFD for PWA.

PWA	WFD +resolved	WFD -resolved	TOTAL
WFD +gesture	1054	330	1384
WFD -gesture	495	222	717
TOTAL	1549	552	-

Note. PWA = participant/s with aphasia; WFD = word-finding difficulty/ies.

Table 7. Chi Square analysis of the different types of WFD for NHP.

NHP	WFD +resolved	WFD -resolved	TOTAL
WFD +gesture	1313	35	1348
WFD -gesture	910	84	994
TOTAL	2223	119	-

Note. NHP = neurologically healthy participant/s; WFD = word-finding difficulty/ies.

Post-hoc analyses

Relationship between aphasia severity and number of gestures produced without speech. Unexpectedly, PWA only produced a small percentage of gestures without speech. One explanation for this may be that their level of language impairment did not require them to use gestures in a compensatory manner. Post-hoc correlation analyses investigated the relationship between aphasia severity (WAB-R AQ) and the proportion of gestures without speech. Results revealed no significant link. This indicates that aphasia severity did not have an influence on the production of compensatory gestures.

Relationship between age and overall number of WFD. Descriptive analysis revealed that NHP produced a very high number of WFD, in fact, they produced marginally more WFD than PWA. This suggests that WFD are quite common in speech production. A potential explanation for the high number of WFD in the group of neurologically healthy participants may be because of their age. Post-hoc analyses, however, did not reveal a relationship between age and the number of WFD for either participant group.

Discussion

This study examined the gestures that accompanied spontaneous conversation in PWA and NHP. Sixteen minutes of conversation were analysed per participant, across a range of topics and with different conversation partners, so ensuring that a substantial body of data was available. Participants were not informed that gesture was the focus of interest. Thus, gestures were naturally occurring rather than elicited.

The study aimed to illuminate the relationship between speech and gesture, and specifically whether gesture facilitates speech production. In the first analysis, all semantically rich gestures were extracted from the data, together with the co-occurring speech. We investigated whether these gestures were more likely to occur alongside WFD than fluent speech, and whether they particularly accompanied resolved WFD. We also examined whether patterns varied for PWA compared to NHP.

Taking the second question first, PWA did not differ from NHP in the overall number of gestures produced. Kong et al. (2018) found a similar effect. However, there were clear differences in how those gestures related to speech. In the NHP group about half of all gestures occurred alongside WFD, and half accompanied fluent speech. In contrast, over 77% of semantically rich gestures produced by PWA occurred alongside WFD, compared to just 19% that occurred with fluent speech. The use of gesture in the absence of speech was rare for either group, although marginally more evident for PWA.

The question of whether gestures particularly accompanied resolved WFD could be answered ‘yes’ across all the data. However, this finding was mediated by group.

This is because the category of speech most often accompanied by gestures in the NHP group was fluent speech. However, when comparing types of WFD, gesture overwhelmingly occurred with resolved WFD and only 1% of gestures occurred alongside those that were unresolved. This pattern of association between gestures and word-finding resolution was also true in the data of PWA. Over half of their semantically rich gestures accompanied resolved WFD, compared to 27% that accompanied unresolved WFD.

These data are suggestive about the roles of gesture in speech production. The fact that many gestures accompanied WFD may point to a facilitative role; that is, these gestures may have helped to resolve those difficulties. In line with this view, there was a greater tendency for gestures to accompany resolved rather than unresolved WFD, particularly for NHP. However, data from the first analysis were far from conclusive. Given their healthy status, we would expect NHP to resolve the majority of WFD. Their use of gestures may have been incidental to that resolution. In the case of the PWA, there was a substantial proportion of gestures alongside unresolved WFD. Here, the barrier to lexical activation may have been so great that facilitation could not occur. Alternatively, these gestures may have played a communicative role; that is, to convey information to the conversation partner that was blocked in speech. We did not collect data that explored the timing of gesture in relation to the WFD. If we had, it would have been possible to see whether the gesture occurred before or after the resolution of the WFD. This would help to answer the question about a potential facilitative role of gesture.

Both groups of participants produced gestures alongside fluent speech, particularly the NHP. This finding suggests that, even if gestures do facilitate speech, this was not their only role. Previous studies (e.g., Alibali, Flevares, & Goldin-Meadow, 1997; Kendon, 2000; Melinger & Levelt, 2004) have argued that gestures can additionally augment what is said. For example, Kendon (2000) describes instances in which the gesture specifies directional information that is not conveyed by the accompanying verb. He also highlights pragmatic augmentations, for example, where the gesture conveys information about the speaker's attitude towards what is being said. Although the specific content of gestures was not examined here, it seems likely that many of the gestures accompanying fluent speech in this study were playing a similarly augmentative role (e.g., describing a person's dislike for scrambled eggs).

The use of gesture in the absence of speech was rare. This finding was unexceptional in the case of NHP, who would be expected to rely on speech production. It was perhaps more surprising for the PWA, given that previous studies have found a greater use of such gestures in this population (e.g., Beeke et al., 2001; Herrmann et al., 1988; Lanyon & Rose, 2009; Lott, 1999; Sekine et al., 2013; Wilkinson, 2013). The use of stand-alone gestures might be most evident if aphasia is severe, where very limited access to speech might encourage the use of gestures as a compensatory means of communication. In a post-hoc analysis, we explored whether there was a correlation between aphasia severity scores (WAB-R AQ) and the number of gestures used without speech. The result was not significant. However, the small sample size and the fact that only three participants in the sample had severe aphasia limited the opportunity for achieving significance.

The second analysis conducted in this study further explored the facilitative role of gesture. This identified all the WFD that occurred in the data, and coded whether or not those difficulties were resolved. It then determined whether or not each WFD was accompanied by a gesture. The data were scrutinised to determine if the resolution of

WFD was particularly associated with the production of a gesture, and if that was the case for PWA and NHP.

Before considering the role of gesture one unexpected finding from this analysis should be discussed. This was the high number of WFD experienced by the NHP. Indeed, they experienced marginally more such difficulties than the PWA. This finding contrasts with previous research, reporting rare instances of WFD in healthy speakers (e.g., Brown, 1991; Burke et al., 1991). Care was taken to exclude NHP with any neurological difficulty, including screening with the CLQT (Helm-Estabrooks, 2001). The presence of an undiagnosed impairment, therefore, seems an unlikely explanation for our finding. NHP were age matched with the stroke group (mean age = 60.19), so normal ageing effects may have affected their word retrieval (e.g., Bortfeld, Leon, Bloom, Schober, & Brennan, 2001; Burke et al., 1991; Rastle & Burke, 1996). However, this was challenged by another post-hoc analysis, which showed that there was no relationship between the number of WFD experienced by each participant and their age. The final, and most likely explanation, relates to the criteria used to identify WFD. These included pauses of under a second (500ms), and fillers such as ‘um’ and ‘er’. Such criteria admitted very fleeting derailments, that might not be included in other studies. Our observations suggest that the WFD of the PWA were much less subtle, e.g. in terms of duration, although we did not measure latencies. Our data also show that they were much less likely to be resolved (see Tables 6 and 7).

Turning to the role of gesture, the second analysis offered further and perhaps more convincing evidence that gestures help to resolve WFD. In both groups, more WFD were resolved than not resolved (this was overwhelmingly the case for the NHP). Moreover, there was a greater likelihood of resolution if the WFD was accompanied by a gesture, and this was, again, the case in both participant groups. For PWA, 68% of resolved WFD were accompanied by gestures, compared to 59% of unresolved difficulties. For the NHP, 59% of resolved WFD were accompanied by gestures, compared to 29% of the unresolved difficulties.

Taken together, both analyses conducted point to an association between gesture production and the resolution of WFD. This association has been reported in many previous studies of PWA (e.g., Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994; Lanyon & Rose, 2009) (although see Cocks et al., 2011; Cocks et al., 2013; Pritchard et al., 2013 for exceptions). In the case of NHP, evidence has been derived from studies in which gesture has been inhibited, with subsequent negative effects on speech fluency (e.g., Frick-Horbury & Guttentag, 1998; Morsella & Krauss, 2004; Rauscher et al., 1996; Rimé, 1982; Rimé et al., 1984). In the current study, a facilitative role of gesture in healthy speech was indicated, without the potential confounds that arise from gesture inhibition.

Findings from this study are consistent with the idea that the facilitation of speech is a primary role for gesture production. Both studies reporting findings from NHP (e.g., Morrel-Samuels & Krauss, 1992) and studies reporting on PWA (e.g., Lanyon & Rose, 2009) have suggested this. Different teams of researchers have argued for different processes by which this faciliatory effect can occur, relating to distinct theoretical models (e.g., the Lexical Facilitation Model by Krauss et al. (2000) and the Sketch Model by de Ruiter (2000)). Although we are not seeking to adjudicate between these models, some points can be made. The gestural facilitation of speech is clearly consistent with the Lexical Facilitation Model. However, this was not the only gestural role that was uncovered in our data. In particular, the occurrence of gesture alongside fluent speech pointed to an augmentative role. This function is readily accounted for by the Sketch Model. Here, semantic information generated by the conceptualiser can be distributed to both the gesture planner and linguistic formulator, thus allowing for different elements of the message to be conveyed by the different modalities.

Before concluding, a number of limitations need to be acknowledged in this study. Our data are not informative about the timing of gestures in relation to the accompanying speech. Such timing information might further argue for the facilitative role of gesture, for example if gestures were seen to precede word finding resolution.

Our data measured gesture production over time, and not the number of gestures produced per word. The latter might have illuminated more differences between the two participant groups. However, previous studies have found that patterns in the data tend to be similar over both metrices (e.g., Cocks et al., 2013; Herrmann et al., 1988; Kong et al., 2015; Lott, 1999; Macauley & Handley, 2005; Pritchard et al., 2013; Sekine & Rose, 2013; Sekine et al., 2013).

Additional qualitative information about the content of gestures and the accompanying speech would also illuminate how gestures augment what is conveyed. The role of gestures in the interaction, e.g. whether conversation partners responded to gesture content, was also not explored.

This study adds to the evidence that gestures may facilitate speech, both in aphasic and healthy language. The findings of a potential facilitative role of gesture can be accommodated by the Lexical Facilitation Model, while additional roles (e.g., compensatory or augmentative) are explained by the Sketch Model. Our findings also carry interesting clinical implications. Gesture has been successfully deployed in a number of word finding treatments for PWA (e.g., Caute et al., 2013; Kroenke, Kraft, Regenbrecht, & Obrig, 2013; Marshall et al., 2012; Rose, Raymer, Lanyon, & Attard, 2013). This study may highlight its facilitative role in naturally occurring conversation. Promoting and enhancing that role may be a productive route for aphasia intervention.

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