The use of gestures in the conversations of people with aphasia

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Declaration

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Abstract of the study

Background: Gestures are spontaneous hand and arm movements that frequently accompany speech and play an important role in everyday communication. When communication is impaired by aphasia, gestures are affected as well. It is important to find out how people with aphasia (PWA) use gesture as an accompaniment to speech, as a compensatory modality, and during lexical retrieval. This novel study examined the use and functions of gesture in conversation and investigated parameters (i.e., conversation partner, topic, and participant factors) that could have an influence on gesture production.

Methodology: Language and conversation data of 20 PWA and 21 neurologically healthy participants (NHP) were collected. Participants took part in conversations with two conversation partners (familiar and unfamiliar) and two conversation topics (narrative and procedural). Video samples were analysed for gesture production, speech production, and word-finding difficulties (WFD).

Results: The two groups of participants produced a similar number of gestures (t (37) = -1.060, p = .296). Gesture type was not examined statistically but showed some marginal differences between groups. Unfamiliar conversation partners elicited significantly more gestures than familiar conversation partners (F (1, 37) = 24.358, p < .001). Additionally, participants produced significantly more gestures in procedural than in narrative topics (F (1, 37) =44.807, p < .001). While all participants experienced a similar number of WFD, there was a difference between PWA and NHP regarding gesture production and resolution of WFD: NHP resolved the majority of all WFD, independent of a co-occurring gesture. Nevertheless, for PWA and NHP, there was a significant relationship between gesture production and the resolution of the WFD (X^2 (1) = 12.356, p < .01 for PWA and X^2 (1) = 40.657, p < .01 for NHP), indicating that WFD that occurred with gestures were more likely to be resolved than WFD that occurred without gesture production. Participants used gestures with different functions, such as facilitative gestures to resolve WFD or augmentative gestures to supplement speech. For PWA, different participant factures, such as fluency of speech (r_s (17) = .487, p = .035), lexical production skills (r_s (17) = .584, p = .009), and cognition (r_s (17) = .582, p = .009) were linked to gesture production.

Conclusions: These findings shed light on gesture processing and the different functions gestures can serve within conversation. Furthermore, they highlight the importance of pragmatic influence, such as conversation topic and conversation partner on the production of gestures. The significant relationships between participant factors and gesture production in aphasia extend the understanding of relevant skills needed to successfully employ gestures in conversation. Next to language skills, such as speech fluency and lexical retrieval, cognitive skills affected gesture production as well.

List of acronyms

η_p^2	partial eta squared
A	(participant/s with) aphasia
A	augmentative gestures (in systematic literature review)
ANOVA	analysis of variance
AQ	aphasia quotient
ARAT	Action Research Arm Test
BCoS	Birmingham Cognitive Screen
C	control (participant/s)
C	compensatory gestures (in systematic literature review)
CA	conversation analysis
CAB	Cantonese version of the Western Aphasia Battery (WAB)
CLQT	Cognitive Linguistic Quick Test
CP	conversation partner/s
CVA	cerebrovascular accident
ELAN	linguistic annotation software
F	ANOVA
F	familiar (conversation partner/s)
F	facilitative gestures (in systematic literature review)
FCP	familiar conversation partner/s
GP	general practitioner
HF	high-frequent
HI	high-imageable
κ	Cohen's kappa
KDT	Kissing and Dancing Test
LF	low-frequent
LG	large group design study
LI	low-imageable
M	mean
MCA	middle cerebral artery
MF	medium-frequent
MG	medium group design study
min	minute(s)
ms	millisecond(s)
N	narrative topic (in systematic literature review)
N1	1st narrative conversation topic (i.e., happy memory)
N2	2nd narrative conversation topic (i.e., busy weekend)

N/A	not applicable
NHP	neurologically healthy participant/s
OANB	Object and Action Naming Battery
p	p-value of statistical significance
P	procedural topic (in systematic literature review)
P1	1^{st} procedural conversation topic (i.e., wrapping parcel)
P2	2^{nd} procedural conversation topic (i.e., making scrambled eggs)
PA	pilot (participant/s with) aphasia
PF	pilot familiar (conversation partner/s)
PG	post graduate
PUF	pilot unfamiliar (conversation partner/s)
PALPA	Psycholinguistic Assessments of Language Processing in Aphasia
PhD	philosophical doctorate
PPTT	Pyramids and Palm Trees Test
PWA	participant/s with aphasia
PWA_f	participant/s with fluent aphasia
PWA_{nf}	participant/s with non-fluent aphasia
PWAD	participant/s with Alzheimer's type dementia
qual.	qualitative analysis
quant.	quantitative analysis
r	Pearson's r (parametric correlation)
r_s	Spearman's rho (non-parametric correlation)
RQ	research question
SC	single case design study
SD	standard deviation
SE	standard error
SE	semantically empty gestures
sem.	semantic(s)
SG	small group design study
SLT	speech and language therapist
SR	semantically rich gestures
t	t-test (comparison)
TOT	tip-of-the-tongue
UF	unfamiliar (conversation partner/s)
UFCP	unfamiliar conversation partner/s
UG	undergraduate
unrel.	unrelated
VAST	Verb and Sentence Test

W	Shapiro-Wilk test (normality test) & Wilcoxon signed-rank test
WAB-R	Western Aphasia Battery – Revised
WCST	Wisconsin Card Sorting Test
WFD	word-finding difficulty/ies
WNL	within normal limits
z	z-score (reported in Wilcoxon signed-rank tests)

Chapter 1 Introduction

When people talk, they almost always gesture with their hands. Sometimes people gesture more, sometimes less. Gesturing is a central part of human communication and plays an important role in everyday conversation (e.g., Beattie & Coughlan, 1999), although often, people are not aware of their use of their hands when they are speaking. Gesturing happens both consciously and unconsciously.

Different gesture types can be distinguished. A widely used classification system is Kendon's continuum, named by McNeill (1992, 2000) to reflect the researcher who first described gestures in this way. The continuum distinguishes between gestures that usually occur with speech (gesticulations) and gestures that usually occur without speech (pantomimes and emblems). Furthermore, he includes sign languages at the far end of the classification system, even though they are independent, complex language systems. Within McNeill's classification system, one can also distinguish between gestures based on their semantic richness, that is, whether they reflect or augment the meaning conveyed in speech.

Those semantically rich gestures that do relate directly to speech are termed *gesticulations* and they often carry the same "idea unit" as speech, which suggests a close link between gesture and language (Kendon, 1980). Imaging study evidence showing activation in both the language area and the non-speech motor area brain during speech production appears to confirm the close link (e.g., Corballis, 2003; Erhard et al., 1996; Fried et al., 1991; Grabowski, Damasio, & Damasio, 1998; Iverson & Thelen, 1999; Krams, Rushworth, Deiber, Frackowiak, & Passingham, 1998; Ojemann, 1984; Özyüerek, Willems, Kita, & Hagoort, 2007; Pulvermüller, 2005; Pulvermüller, Preissl, Lutzenberger, & Birbaumer, 1996). According to Rizzolatti and Craighero (2004), such evidence suggests that there are neurological links between gesture and language production.

Further evidence has been supplied by studies of the temporal link between gesture and speech, as gesture onset usually occurs at the same time as the lexical affiliate or immediately before it (e.g., Butterworth & Beattie, 1978; Morrel-Samuels & Krauss, 1992). An extension of this temporal link was investigated by Mayberry and Jaques (2000) who analysed gesture and speech in participants with severe stuttering disorders. They found that when speech stopped, hand and arm gestures would stop as well, and as soon as the speech flow continued, gesturing continued.

Many researchers have sought to answer the question of why people gesture, and in doing so they have illuminated the function of gestures in communication. There is evidence for gestures augmenting speech, adding information to what is conveyed verbally (e.g., Alibali, Flevares, & Goldin-Meadow, 1997; Bavelas, Gerwing, Sutton, & Prevost, 2008; Beattie, 2004; Beattie & Shovelton, 2002; Broaders & Goldin-Meadow, 2010; Cassell, McNeill, & McCullough, 1998; de Ruiter, 2007; Goldin-Meadow, 2003; Goldin-Meadow, Alibali, & Church, 1993; Kendon, 1997, 2000; McNeill, 1992, 2000; Melinger & Levelt, 2004; So, Kita, & Goldin-Meadow, 2009). Gestures replacing speech (i.e., compensatory gestures) were found in healthy language as well, even though neurologically healthy participants (NHP) convey more information through speech (e.g., Bangerter, 2004; de Ruiter, 2006; Melinger & Levelt, 2004; van der Sluis & Krahmer, 2004, 2007). The temporal link and the occurrence of the gesture immediately prior to its lexical affiliate led researchers to assume a facilitative function of gesture as well, that is, it was argued that gestures might assist in the process of speech production (e.g., Butterworth & Beattie, 1978; de Ruiter, 1998; Kendon, 1972, 1975; McNeill, 1987; Morrel-Samuels & Krauss, 1992; Schegloff, 1984).

Gesture processing models like the Sketch Model by de Ruiter (2000) or the Lexical Facilitation Model by Krauss, Chen, and Gottesman (2000) attempt to explain the relationship between gesture and speech further. Questions relating to gesture can be illuminated by data from NHP and from participants with language impairment. One such impairment is aphasia. Aphasia is an acquired neurological language disorder due to brain damage, for example, caused by stroke. According to the statistics of the Stroke Association (2015), each year about 152,000 people in the UK have a stroke and it is estimated that about a third of all stroke survivors have aphasia (Engelter et al., 2006). Aphasia varies across individuals but in all cases there are impairments to the processes that produce speech and language. The use of gesture by participants with aphasia (PWA), therefore, can illuminate the links between gesture and language and its possible compensatory and facilitative functions.

The aim of this study was to investigate gesture production in different types of conversation and with different conversation partners in neurologically healthy participants and participants with aphasia, in order to find out more about the relationship between gesture and speech. Gesture production was analysed and gestures were categorised according to their semantic content. Furthermore, word-finding difficulties (WFD), their co-occurrence with gesture, and their resolution were investigated in order to shed light on the facilitative function of gesture production. Different functions of gestures were then defined depending on their co-occurrence with a WFD, with fluent speech or without speech. Gestures occurring with resolved WFD were contrasted with unresolved WFD. Finally, the influence of the aphasia severity, the fluency of speech and the impairment of linguistic and non-linguistic skills on the production of gestures were investigated.

Investigations of gestures have shifted from formal gesture production tasks towards gesture production in a more natural communication setting, that is, in spontaneous speech (cf., Glosser, Wiener, & Kaplan, 1986). Conversation was chosen as the focus of the present study because of its important role in everyday life. According to Davidson, Worrall, and Hickson (2003), conversation is the most commonly used communicative action. Based on the features and context of conversation in everyday life, Ventola (1979) ascribes conversation a fundamental role in establishing and maintaining interpersonal relationships.

Although conversation is spontaneously constructed by two or more conversation partners, there are parameters that can be manipulated in research, like conversation topic and conversation partner. Language analysis has shown that both parameters have an influence on speech production (e.g., Clark & Marshall, 1981; Clark & Schaefer, 1987; Fleming & Darley, 1991; Ulatowska, Allard, & Chapman, 1990; Ulatowska, Macaluso-Haynes, & North, 1981; Ulatowska, North, & Macaluso-Haynes, 1981). With the close link between gesture and speech it is expected that gestures would be influenced by these parameters as well. However, this has not been investigated yet.

Studies investigating gesture production in spontaneous speech in aphasia found evidence that PWA use more (but less complex) gestures than NHP (e.g., Hogrefe, Ziegler, Weidinger, & Goldenberg, 2012; Hogrefe, Ziegler, Wiesmayer, Weidinger, & Goldenberg, 2013). Furthermore, different types of aphasia were shown to elicit different gesture behaviour that mirrored participants' speech output. For example, participants with fluent speech production used also more fluent gestures while participants with non-fluent aphasia were non-fluent in their gesture production as well (e.g., Sekine & Rose, 2013; Sekine, Rose, Foster, Attard, & Lanyon, 2013). There is also evidence to suggest that PWA use gestures in different contexts and with a different function than NHP. Some research suggests that PWA are particularly likely to gesture when they experience WFD (e.g., Feyereisen, 1983; Hadar, Wenkert-Olenik, Krauss, & Soroker, 1998; Hadar & Yadlin-Gedassy, 1994; Le May, David, & Thomas, 1988; Pedelty, 1987). The function of gesture in this context, however, is disputed (e.g.,Cocks, Dipper, Middleton, & Morgan, 2011; Cocks, Dipper, Pritchard, & Morgan, 2013; Dipper, Pritchard, Morgan, & Cocks, 2015; Pritchard, Cocks, & Dipper, 2013). Gestures may be facilitative, help to stimulate the production of the blocked word or they may be compensatory, so enabling the concept to be conveyed by an alternative means.

A number of factors seem to affect gesture production in aphasia. Some relate to fluency of speech and the type of the aphasia (see above), other participant factors, such as semantic processing skills and executive functions were found to affect gesture production as well (e.g., Cocks, Dipper, et al., 2013; Dipper et al., 2015; Hogrefe et al., 2012; Hogrefe et al., 2013; Purdy, 1992, 2002; Purdy, Duffy, & Coelho, 1994; Purdy & Koch, 2006; Yoshihata, Watamori, Chujo, & Masuyama, 1998). While studies investigating gestures by formal tasks found an influence of motor skills, such as limb apraxia (e.g., J. R. Duffy & Watkins, 1984; Goodglass & Kaplan, 1963; Kadish, 1978; Pickett, 1974; Wang & Goodglass, 1992), this link was not found in studies investigating the spontaneous production of gestures (e.g., R. J. Duffy, Duffy, & Mercaitis, 1984; Macauley & Handley, 2005; Pritchard et al., 2013; Rose & Douglas, 2003).

Following this introduction, **Chapter 2** will provide an overview of the theoretical background on which this study is based. The first part of this literature review (2.1) is about the use of gestures in spontaneous speech in general, including different gesture processing models. 2.2 summarises the different parameters that influence spontaneous speech, such as type of conversation/discourse and the familiarity of the conversation partner. The following subsection (2.3) gives an overview of aphasia and the different layers of language that can be impaired in this condition. In 2.4 gesture production in aphasia is described, starting with a brief overview of gesture research using formal gesture production tasks before focusing on gesture in spontaneous speech.

Chapter 3 turns towards the studies that analysed gesture production in spontaneous speech settings with PWA. This systematic literature review was also conducted to finalise the research questions. These are stated in **Chapter 4** together with their hypotheses.

Details of conducting the study, including the participants (pilot participants and study participants, both PWA and NHP), the materials and the procedure are given in **Chapter 5**, the methodology. Furthermore, details about the different layers of analysis, that is, language analysis, including WFD, gesture analysis, and data analysis are provided at the end of this section.

Chapter 6 presents the results of the different analyses and is organised according to the research questions stated in **Chapter 4**.

Finally, **Chapter 7** is devoted to a general discussion about the findings of this study where implications and limitations of this study are discussed as well.

Chapter 2 Background

2.1 Gesture

Gestures are spontaneous hand and arm movements that occur alongside or without speech and play an important role in everyday communication (Beattie & Coughlan, 1999; Kendon, 1997). Gestures that occur with speech, so-called gesticulations, are closely linked to the flow of speech and often carry the same meanings or idea units as speech (Kendon, 1980). According to McNeill, Levy, and Pedelty (1990), these meanings or ideas, however, are expressed in different ways: While speech can be segmented into phonemes, words, and phrases, gestures are global as they have no inherent language. Unlike speaking, the decision to gesture is not always conscious and speakers can gesture to complement and to supplement information that is given in speech (Broaders & Goldin-Meadow, 2010; Goldin-Meadow et al., 1993; Iverson & Goldin-Meadow, 1998; McNeill, 1992; Stokoe, 2000; L. A. Thompson & Massaro, 1994). In this way, gestures can provide additional information to conversation partners about the meaning of verbal utterances and help to clarify even abstract concepts (Krauss & Hadar, 1999).

2.1.1 Use of gesture.

There is good evidence that conversation partners pay attention to gestures as, for example, communication suffers when there is a mismatch between speech and gesture (e.g., Alibali et al., 1997; Beattie, 2004; Broaders & Goldin-Meadow, 2010; Cassell et al., 1998; de Ruiter, 2007; Goldin-Meadow et al., 1993; Hadar, Wenkert-Olenik, et al., 1998; McNeill, Cassell, & McCullough, 1994). Speakers vary when and how they use gestures, with gestures being most frequent when conversation partners have eye contact (Kendon, 1997). However, speakers use gestures even when they cannot be seen, such as when talking on the phone (Bavelas et al., 2008) or on the intercom (Hadar & Butterworth, 1997; E. Williams, 1977). Furthermore, Iverson and Goldin-Meadow (1998) found that congenitally blind speakers also gesture even though they have never seen anybody gesturing. The study also showed that the same visually impaired speakers continued gesturing after they were told that their conversation partner was visually impaired as well. Such evidence has led to the suggestion that gestures are not produced simply for the benefit of the listener. They may also support the speaker, for example, by facilitating lexical access (Krauss, Chen, & Chawla, 1996), facilitating thinking process (Iverson & Goldin-Meadow, 1998; McNeill, 1992; Rauscher, Krauss, & Chen, 1996), or improving memory (Cook, Yip, & Goldin-Meadow, 2010). The function of gesture is one topic explored in this thesis. This review addresses it again in section 2.1.3.

The relationship between speech and gesture is of great theoretical interest. Indeed the strong ties between speech and gesture have stimulated discussions about the neurological links between the modalities (Rizzolatti & Craighero, 2004) and the possible gestural origins of language (Corballis, 2010). For example, the synchronous interruption of both speech and co-speech gestures in severe stuttering investigated by Mayberry and Jaques (2000), led to hypotheses about the general coordination of motor systems (Kelso, Tuller, & Harris, 1983). Another example can be found in language acquisition. Prior to spoken two-word-phrases, children start to combine single words and gestures to convey phrasal concepts (Goldin-Meadow, 2007; Goldin-Meadow & Wagner, 2005). Gesture therefore assists the language system and substitutes for the words the child has not acquired yet (Goldin-Meadow, 2007).

Not all gestures are the same. Speakers use different types of gestures when producing speech. Gestures can be distinguished according to different factors, such as their relationship with speech and language. For example, the gestures of children who combine single words and gestures into phrasal concepts are produced without speech (Goldin-Meadow, 2007; Goldin-Meadow & Wagner, 2005). The following section will focus on these different gesture types alongside with general characteristics of gesture.

2.1.2 Characteristics of gesture.

Several researchers have proposed gesture classification systems (e.g., Butterworth, Swallow, & Grimston, 1981; de Ruiter, 2000; Efron, 1972; Ekman & Friesen, 1969; Kendon, 1982; Lausberg, 2007; McNeill, 1985). Depending on their research interest, the foci of these classification systems differ, for example, classifying according to gestural form, meaning, or function. Nevertheless, all classification systems agree on one characteristic: They distinguish hand and arm gestures from body-focused movements (e.g., scratching, twitching, grooming, and self- touching) as the latter are neither temporally synchronised with speech nor carry any content information apparent in speech. Throughout this study, the gesture classification system of McNeill (1992, 2000) will be used and is described in more detail in the following.

Kendon (1982) was one of the first to define different types of gestures. He outlined four main categories: (1) gesticulation, (2) pantomime, (3) emblem, and (4) sign language. McNeill (1992, 2000) adopted the same categories and argued that they formed a continuum which he named *Kendon's continuum* (McNeill, 1992, 2000). This is displayed in Figure 2.1:

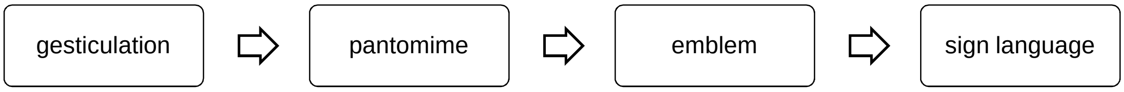

Figure 2.1. ***Kendon's continuum according to McNeill (1992, 2000).***

Moving from left to right, the continuum describes how the different types of gestures behave in relation to (1) linguistic properties present in the gesture, (2) conventions (i.e. idiosyncratic or socially regulated), (3) semiotic characteristics, and (4) speech (i.e. how obligatory speech is for the gesture to be meaningful).

Gesticulations occur alongside speech. Many studies refer to gesticulation as *co-speech* gestures indicating the temporal relationship with speech. Pantomime and sign languages usually replace speech[1]. While gesticulations are idiosyncratic and spontaneous movements, pantomime gestures often involve more complex and sequential movements when depicting objects and actions. Gesticulations also differ from pantomimes in terms of the combination of movements: Pantomimes can be combined to create sentence-like expressions whereas gesticulations rely on the co-occurring speech and cannot be combined. Emblems are lexicalised gestures that differ between cultures. While the sign which consists of thumb and index finger forming a ring while the other three fingers are extended is perceived as a sign of encouragement often referred to as *OK sign* in Western Europe, the sign is offensive in other cultures. These lexicalised signs are, like pantomime, usually used without speech. Sign languages, for example, British Sign Language (BSL), American Sign Language (ASL), or German Sign Language (*Deutsche Gebärdensprache*, DGS) occupy the far right continuum. They are elaborated language systems having their own grammar and vocabulary, just like any spoken language.

McNeill (1992, 2000) distinguishes further between different sub-categories of gesticulations[2]:

[1] It has to be noted here that one could argue that sign language can be produced concurrently with speech, or at least with elements of speech (e.g., mouthing). The point of this is, however, the degree to which co-occurring speech is needed for the gestures to convey meaning (see above). While sign language is entirely independent from speech, gesticulation is opaque if speech is absent.

[2] Later, McNeill defined an additional fifth category of co-speech gestures, 'cohesives', which connect semantically related gestures that are spread over the conversation. He further describes them to be either of iconic, metaphoric, or deictic nature. To avoid gesture category overlap, these connective gestures are only considered as being iconic, metaphoric, or deictic. The category is not being used in this study.

(1) Iconics reflect the meaning of the speech pictographically, for example, hands shaped like holding a cup when talking about a cup or drinking. They refer to concrete entities.
(2) Metaphorics are similar to iconics but depict an abstract concept, for example, a *light bulb* for *thinking*.[3]
(3) Deictics are indicative or pointing movements usually with the index finger. They often accompany pronouns like *this* and *that*.
(4) Beats are simple, rhythmic, and repetitive movements that do not carry any semantic information. They are used to mark stress and prosody.

Throughout the study, McNeill's classification system will be used. Gestures will be categorised as gesticulations, pantomimes, and emblems. Both pantomime and emblem gestures do not rely on language structure as they are independent. Nevertheless, they can be incorporated in speech. As sign language is fully conventionalised and carries all linguistic properties (i.e., it is a different language), it will not be part of the study. Gesticulations will be further subcategorised by McNeill's system. Thus, the gestures of both NHP and PWA will be delineated to identify differences between these groups as each type of gesture has a fundamentally different relationship to speech and may be affected by brain damage in different ways (McNeill et al., 1990).

2.1.3 Functions of gestures.

Researchers agree on gestures serving specific functions in communication. However, the literature reflects considerable disagreement on the link between gesture and speech production. Understanding this link is vital for understanding why gestures are produced. Some researchers argue that gesture and speech go *hand in hand* (de Ruiter, Bangerter, & Dings, 2012), that is, speakers use gestures to augment speech and convey a communicative intention (Kendon, 2000; McNeill, 2000; So et al., 2009). A slightly different view is captured in the *tradeoff* hypothesis (de Ruiter et al., 2012) according to which gesturing increases if speaking gets more difficult and vice versa. Thus, speakers use gestures to compensate or to replace speech (Bangerter, 2004; de Ruiter, 2006; Melinger & Levelt, 2004; van der Sluis & Krahmer, 2004, 2007). Another view is that gestures facilitate speech production, according to which gestures primarily support the speaker. This is particularly the case in WFD where gestures are produced to facilitate lexical retrieval (Krauss et al., 2000)[4]. These three functions of gestures (i.e.,

[3] For example, the hand is placed near the head and the fingers open in a sudden movement from the first to an open hand indicating that something is 'switched on'.
[4] There may be other facilitative gesture functions. Reviewing the literature gave the impression that previous studies have mainly focused on the facilitative role of gestures in lexical retrieval.

augmentative, compensatory, and facilitative) in neurologically healthy speech are reviewed in turn in the following sections.

2.1.3.1 Augmentative – gestures accompany speech.

One explanation for gesture production is that gestures are produced to accompany speech. They add information to what is said and act communicatively (i.e., they enhance the conversation). de Ruiter et al. (2012) called this account the *hand-in-hand hypothesis* and contrasted it with the *tradeoff hypothesis* (see 2.1.3.2) according to which the speaker chooses either gesture or speech in terms of their communicative load depending on the context. According to the *hand-in-hand hypothesis*, gestures are produced parallel to speech (both in terms of timing and content) when talking or describing scenes to a conversation partner. This account assumes that gestures are produced not only for the speaker, but also for the listener and is consistent with the observation that speakers produce more gestures in face-to-face conversations (Bavelas et al., 2008; Goldin-Meadow, 2003; Kendon, 1997). This view was supported by several research studies (e.g., Alibali et al., 1997; Bavelas et al., 2008; Beattie, 2004; Beattie & Shovelton, 2002; Broaders & Goldin-Meadow, 2010; Cassell et al., 1998; de Ruiter, 2007; Goldin-Meadow, 2003; Goldin-Meadow et al., 1993; Kendon, 1997, 2000; McNeill, 1992, 2000; Melinger & Levelt, 2004; So et al., 2009). These and a selection of other studies and their outcomes will be presented in the following paragraphs.

A number of studies have found evidence that listeners pay attention to the content of gesture produced alongside speech, particularly when the gesture and speech carry mismatching information (Beattie, 2004; Beattie & Shovelton, 2002; Broaders & Goldin-Meadow, 2010; Cassell et al., 1998; McNeill, 1992; McNeill et al., 1994; Melinger & Levelt, 2004). Adding to this evidence base, gesture-speech mismatches have been investigated in development (Alibali et al., 1997; Goldin-Meadow et al., 1993), and findings suggest that latent knowledge that is not fully developed is revealed in gestures, adding to the idea that gesture and speech work together in communicating a message and that not everything is expressed through speech.

Gestures can also add different semantic information to a word depending on its exact meaning. Kendon (2000) analysed the narration of the fairy tale “Little Red Riding Hood” by a student pretending to be telling it to an audience of children. In two instances, the narrator was talking about slicing something, but whereas the verb *slice* was used in both examples, the co-speech gestures produced alongside the verb phrase depicted two different actions congruent with the different connotations intended. This adaptation of gesture form not only shows that speech and gesture collaborate to form a unity (cf., Alibali et al., 1997), it also reveals that gesticulations are not lexicalised but spontaneous movements that are created on the spot.

All these papers provide support for the proposal that gestures can, at least to some extent, augment speech and add information that is not conveyed verbally (e.g., spatial information and movement were mainly communicated via gestures not via speech). Other studies, however, found evidence for gesture serving different roles in conversation as well. For example, in certain situations, gestures were found to replace speech even in neurologically healthy speech (e.g., Goldin-Meadow, 2007; Kendon, 1997; Meissner & Philpotts, 1975). In the following subsections, this gesture function will be reviewed in more detail.

2.1.3.2 Compensatory – gestures replace speech.

According to de Ruiter et al. (2012), an alternative view of the *hand-in-hand hypothesis* (see 2.1.3.1) is the so-called *tradeoff* hypothesis (e.g., Bangerter, 2004; de Ruiter, 2006; Melinger & Levelt, 2004; van der Sluis & Krahmer, 2004, 2007). Inherent in the hypothesis is that gesture is compensatory when speech becomes more difficult and vice versa.

Gesture has been shown to compensate for speech in various contexts including: (1) situations in which the experimenter manipulates the communicative environment to make it relatively harder/easier to convey a message in speech (e.g., Bangerter, 2004; van der Sluis & Krahmer, 2007), (2) naturally occurring situations where speech is difficult, such as noisy environments (e.g., Kendon, 1997; Meissner & Philpotts, 1975), and (3) in language development (e.g., Goldin-Meadow, 2007; Tomasello, Carpenter, & Liszkowski, 2007). Another context in which gesture is compensatory is when language is compromised by aphasia (see 2.3). Studies of gestural compensation in aphasia will be reviewed in section 2.4.4.2.

These studies combine to provide evidence about the communicative uses of gesture in situations in which both speakers had eye-contact. The gesture used in such situations has been interpreted as supporting the conversation partner. But people continue gesturing when they cannot be seen, for example, when talking on the phone (cf., Bavelas et al., 2008; Hadar & Butterworth, 1997; E. Williams, 1977) suggesting that gestures are not produced simply for the benefit of the listener but may also support the speaker. The following subsections will explore the different ways gesture might support the speaker.

2.1.3.3 Facilitative – gestures resolve word-finding difficulties.

In the beginning of this chapter, several studies were mentioned that explored gesture production when speakers could not see each other (Bavelas et al., 2008; Hadar & Butterworth, 1997; E. Williams, 1977). Iverson and Goldin-Meadow (1998) reported that congenitally visually impaired people gestured even if they knew that their conversation partner was blind as well. These findings suggest that gestures may not only play an important role for the conversation partner but also for the speaker, for example, during WFD (Krauss et al., 1996). It is difficult to directly investigate the influence of gesture production on WFD. One option is to compare speech production when participants are allowed to gesture to speech production without gesturing (e.g., Beattie & Coughlan, 1999; Frick-Horbury & Guttentag, 1998; Graham & Heywood, 1975; Morsella & Krauss, 2004; Rauscher et al., 1996; Rimé, 1982; Rimé, Schiaratura, Hupet, & Ghysselinckx, 1984). Most researchers applying this technique came to the conclusion that participants' speech was more fluent when they were allowed to gesture (especially when it included spatial information). Two of these studies will be picked out here as they investigated gesture production in the context of word-finding difficulty, a common symptom in aphasia.

A TOT state is a type of WFD and is defined as a temporary moment during which the speaker is not able to retrieve a word. While WFD can occur at different stages of language processing, a TOT is assumed to occur between lexical and phonological encoding (cf., Levelt, 1989). There is evidence to suggest that gestures may help to resolve these difficulties by priming lexical retrieval (e.g., Beattie & Coughlan, 1999; Frick-Horbury & Guttentag, 1998). In both studies, participants were given a definition and were asked to come up with the word that was described. Half of the participants were allowed to gesture, the others were not. The two studies came to rather different results: While Frick-Horbury and Guttentag (1998) observed that participants who were allowed to gesture were able to retrieve significantly more words overall than those that were prevented from gesturing, Beattie and Coughlan (1999) did not find such an effect. When analysing successfully resolved TOT states, on the other hand, Frick-Horbury and Guttentag (1998) did not find a significant difference between participants who were allowed to gesture and those who were not, whereas Beattie and Coughlan (1999) did. In their study, participants who were allowed to gesture resolved significantly more TOT states than those who were prevented from gesturing. Although the disagreement on the specific findings makes it difficult to come to a conclusion about the function of gesture in lexical retrieval, the evidence points towards an important role for gesture in word-finding, which has important implications for investigating gesture production in impaired language such as aphasia (see 2.3). Aphasic speech is often characterised by WFD. If gestures help to resolve these difficulties, it would support the view that gestures can play a facilitative role in speech production. This issue will be further discussed 2.4.4.3.

Rather than inhibiting gesture production, an alternative method of investigation explores the temporal relationship between gesture and speech (e.g., Butterworth & Beattie, 1978; de Ruiter, 1998; Kendon, 1972, 1975; McNeill, 1987; Morrel-Samuels & Krauss, 1992; Schegloff, 1984). Researchers analysed spontaneous gesture and speech production. The study of Morrel-Samuels and Krauss (1992) found evidence of an influence of lexical familiarity on the speed of gesture production. In a task in which participants were asked to describe photographs to someone not able to see them, the higher the familiarity of the lexical affiliate, the closer the distance between the onset of the gesture and the onset of the word; the lower the familiarity, the earlier the gesture was produced before the word. These findings suggest that participants attempted to prime the unfamiliar word by producing a gesture more in advance of its lexical affiliate than would be the case for familiar words. Thus, it is assumed that gesture production is tied to lexical access (cf., Butterworth & Beattie, 1978). Nevertheless, it is questionable whether one can directly infer from a temporal link between gesture and speech to a link between the two in terms of content. The synchronicity of gesture and speech production may also be explained by a general coordination of motor systems introduced by Kelso et al. (1983).

Investigating a facilitative role of gesture production, especially in lexical retrieval, has been found challenging in neurologically healthy speech. Inhibiting gesture production was one way to investigate the importance of gesture production for lexical retrieval. Alternatively, researchers analysed the temporal relationship between gesture and lexical affiliate. The function of facilitative gestures in the context of comprised language in aphasia will be reviewed in 2.4.4.3 and may shed light on the complex relationship of language and gesture.

2.1.3.4 Summary.

The three different functions of gesture production (augmentative, compensatory, and facilitative) have been explored in many research studies. While studies agree on gestures serving both to supplement and replace speech, investigating the facilitative function of gestures has led to conflicting results. Manipulating the production of gestures to shed light on whether they are needed to make speech more fluent is a conscious interference with an unconscious process. Alternatively, to make assumptions from investigating the temporal relationship between gesture and speech may not capture the facilitative function entirely. The next section looks at the theoretical processing of gesture and its relationship to speech production.

2.1.4 Gesture processing.

The previous sections have outlined the characteristics (i.e., different types; see 2.1.2) and functions of gestures (e.g., augmentative, compensatory, and facilitative; see 2.1.3). To understand the link between language and gesture production, researchers have come up with different gesture processing models. These are often based on models of language production (e.g., architecture for language production by Levelt (1989)) and have been extended to account for gesture production as well. According to de Ruiter and de Beer (2013), one can roughly distinguish between two types of hypotheses/models: (1) the **Interface Hypothesis**, which is based on the *Growth Point Theory* (McNeill, 1992; McNeill & Duncan, 2000), the *Sketch Model* (de Ruiter, 2000), and the *Interface Model* (Kita & Özyürek, 2003) and (2) the **Lexical Facilitation Model** (Krauss et al., 2000).

These two processing approaches differ in terms of the primary function of gesture production. Although this thesis does not aim to adjudicate between these hypotheses/models, because both might operate at different times in discourse production, they are outlined briefly in the following sections.

2.1.4.1 Interface Hypothesis.

The Interface Hypothesis was established by de Ruiter and de Beer (2013). It is based on the *Growth Point Theory* (McNeill, 1992; McNeill & Duncan, 2000), which was then implemented into the *Sketch Model* (de Ruiter, 2000) and further expanded into the *Interface Model* (Kita & Özyürek, 2003). According to this hypothesis, gestures are pre-linguistic and arise during conceptual preparations for speaking. Via feedback from linguistic processing, they are influenced by language parameters (e.g., clause structure and lexical semantics). The link between gesture and speech therefore occurs already at the interface between thinking and speaking.

The Sketch Model by de Ruiter (2000) will be used to exemplify the models combined in the interface hypothesis and will be reviewed in this section in more detail. The basis of this model is the architecture for language production proposed by Levelt (1989). According to de Ruiter (2000), the Sketch Model (see Figure 2.2) focuses on different types of gestures, that are, iconic, metaphoric, deictic, emblem, and pantomime gestures while other models (e.g., Krauss et al., 2000 below) only attempt to account for co-speech iconic or metaphoric gestures.

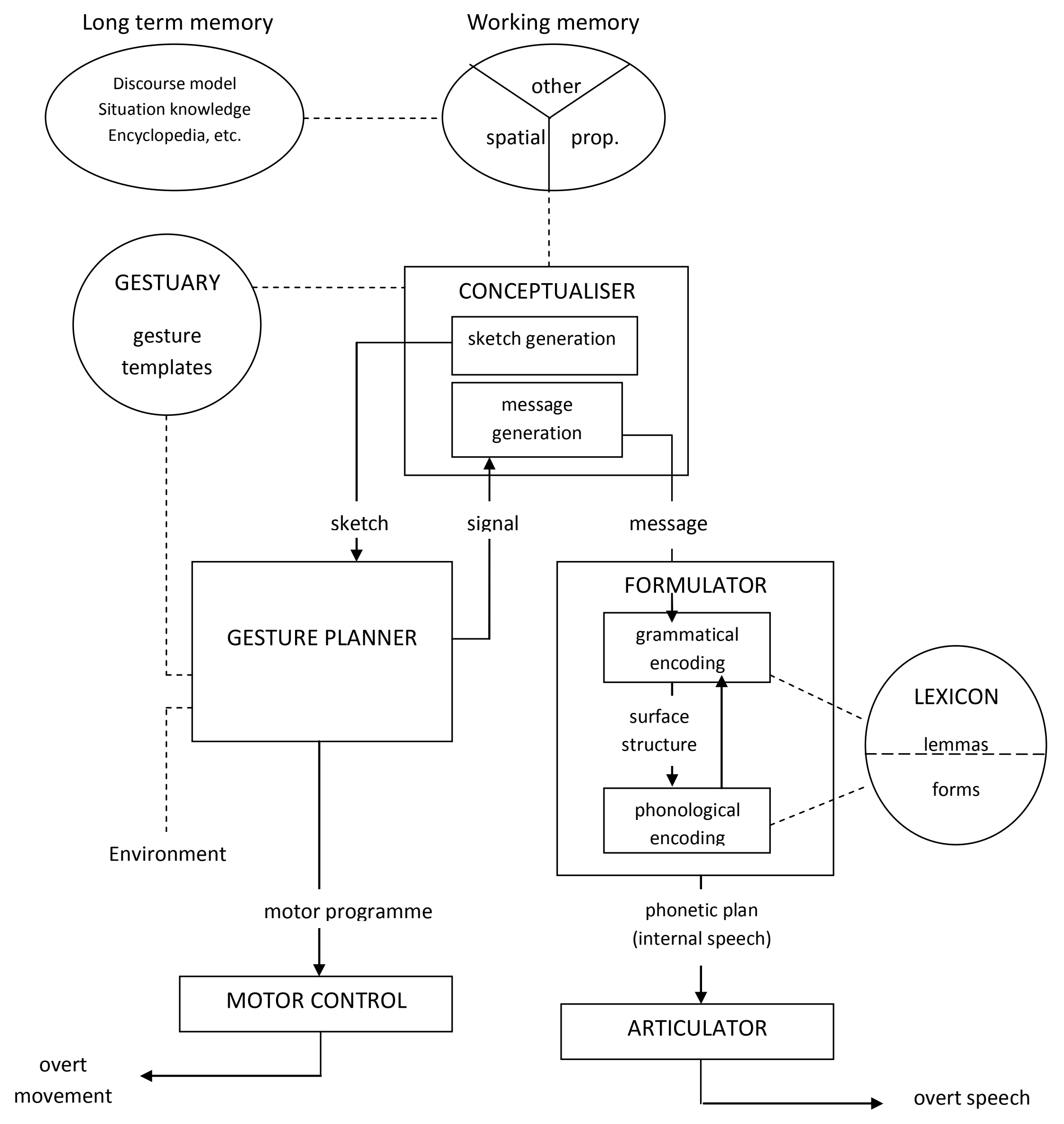

Figure 2.2. ***The Sketch Model by de Ruiter (2000).***

With this model, de Ruiter (2000) proposed that the production of both gesture and speech originate pre-linguistically in the conceptualiser. Propositional and imagistic knowledge stored in working memory are retrieved and the speaker decides which part of the message is conveyed verbally and which gesturally. For example, ideas that are difficult to express verbally will be gestured. This assumption could lead to either augmentative or compensatory gestures. The studies by Beattie and Shovelton (2002) and Melinger and Levelt (2004), for example, came to the conclusion that gestures augmented speech, especially by providing spatial information and information about movement. The compensatory function of gesture production was illustrated by Meissner and Philpotts (1975) who investigated a gesture system developed by saw mill workers in British Columbia in an environment where it was more difficult to convey information verbally than gesturally.

The further processing of gesture and speech diverges from this point on. From the conceptualiser, a so-called *sketch* of the gesture concept is sent to the gesture planner to develop a motor programme taking into account all the information from the environment, such as the available space to gesture and the motor procedures. Conventionalised gestures such as emblems (see 2.1.2), are stored in the gestuary to which the gesture planner has access. From the gesture planner, a motor programme is sent to the motor control in order to produce an overt movement, that is, a gesture.

At the same time as the sketch is developed further into a movement, the pre-linguistic verbal message is sent from the conceptualiser to the formulator. In the formulator, both the grammatical and the phonological encoding take place, before the phonetic plan is sent to the articulator in order to produce overt speech.

An extended version of the Sketch Model is the Interface Model by Kita and Özyürek (2003) which is based on data of different languages. This suggests that semantic and syntactic packaging of information of the spoken language (English, Turkish, and Japanese in their original dataset) has an influence on how a certain concept is expressed in gesture. Similar to the Sketch Model, the Interface Model assumes that gestures can be augmentative or compensatory but not facilitative (except via feedback[5]).

2.1.4.2 Lexical Facilitation Model.

In contrast to the Interface Hypothesis in general and de Ruiter's Sketch Model in particular (see 2.1.4.1), Krauss et al. (2000) argued in their Lexical Facilitation Model that the production of co-speech gestures was primarily to facilitate lexical retrieval. The Lexical Model is influenced by the thinking of Hadar and Butterworth (1997) and the observations that participants continue to gesture when they do not have eye contact with their conversation partner/s, such as when talking on the phone (Bavelas et al., 2008) or on the intercom (Hadar & Butterworth, 1997; E. Williams, 1977). Unlike the Sketch Model which accommodates iconic, metaphoric, deictic, emblem, and pantomime gestures, Krauss et al. (2000) focused solely on what they termed 'lexical gestures' which de Ruiter and de Beer (2013) assumed to be comparable to iconic gestures (see 2.1.2).

[5] There are three feedback mechanisms within the Sketch Model because of which the speaker may know early about an upcoming error and triggers semantic information to be boosted. More detail on these feedback mechanisms are given in 7.1.3.

According to this model, a concept consists of propositional and non-propositional information. While the propositional information is encoded in speech, gestures are derived from the non-propositional component and express primarily spatio-dynamic features. The processing of these two types of representation diverges at the level of the working memory. In the next step, the spatio-dynamic features of the non-propositional representation are selected and specified before they are sent to the motor planner in order to be programmed and executed.

At the same time, the propositional representation of the concept is sent to the conceptualiser before the pre-linguistic message arrives at the formulator. Here, both grammatical and phonological encoding take place and a phonetic plan is sent to the articulator.

An important feature of the Lexical Facilitation Model and the main difference to the Interface Hypothesis is the feedback that goes directly from the gesture production (i.e., kinesic motor in the model) to the speech production process at the level of the phonological encoder. According to Krauss et al. (2000), this is where the gesture facilitates the access to the lexical form of the word before the phonetic plan is sent to the articulator. It also explains the temporal relationship between gesture and speech that has been the focus of many research studies (e.g., Butterworth & Beattie, 1978; de Ruiter, 1998; Kendon, 1972, 1975; McNeill, 1987; Morrel-Samuels & Krauss, 1992; Schegloff, 1984).

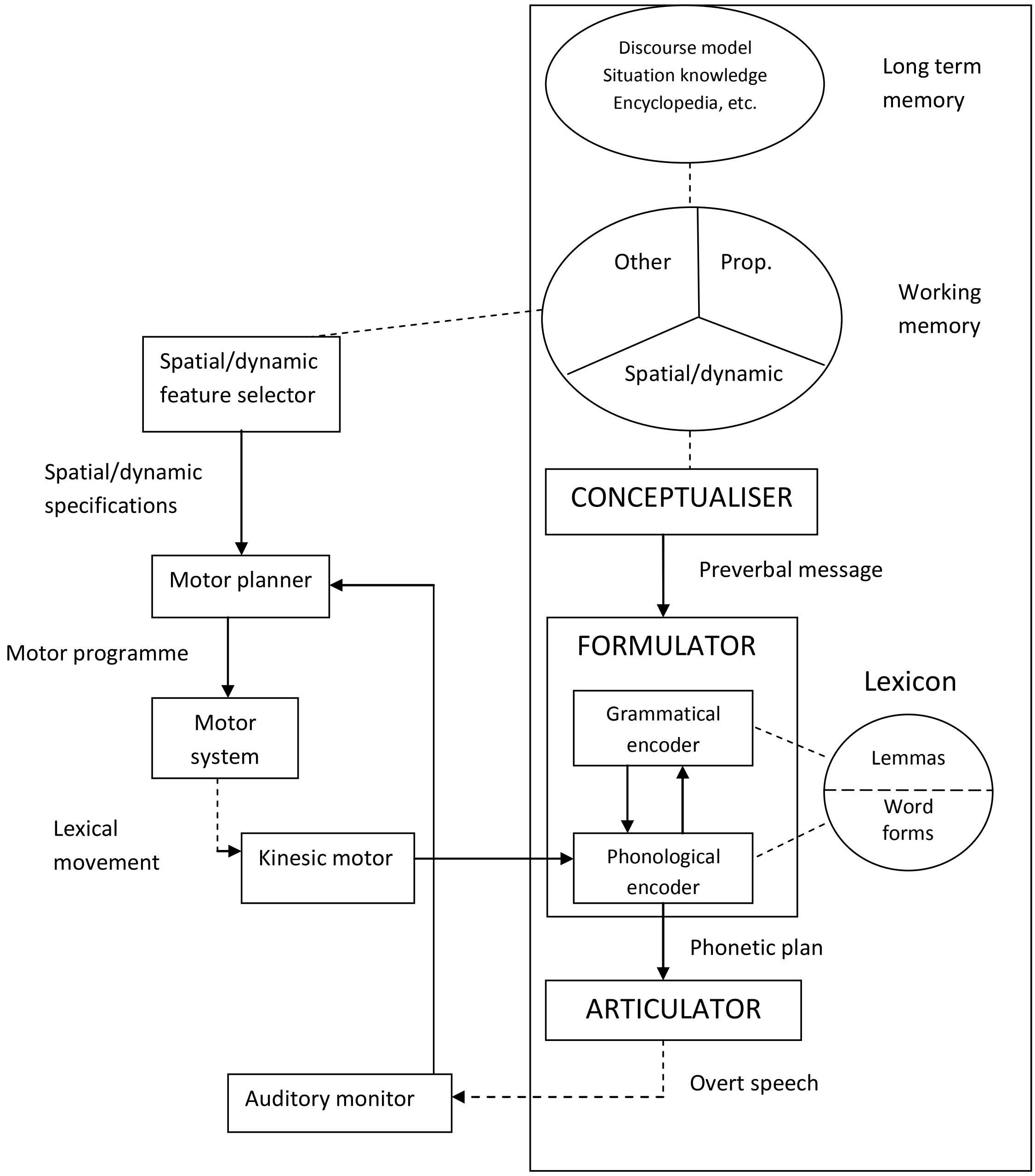

Figure 2.3. ***The Lexical Facilitation Model by Krauss et al. (2000).***

2.1.4.3 Summary.

Both the Interface Hypothesis and the Lexical Facilitation Model assume that gesture and speech processing diverge at a pre-linguistic level. While there is a link between the conceptualiser and the gestuary in the Sketch Model, this is not the case in the Lexical Facilitation Model. Both models agree on gesture and speech being processed individually from then on. While the Lexical Facilitation Model proposes a feedback loop from gesture production to the level of the phonological encoder in speech production to facilitated lexical retrieval, the Interface Hypothesis does not have this feature. Instead, it assumes that gesture either augments or replaces speech if something cannot be conveyed verbally. This feedback loop in the Lexical Facilitation Model represents also a direct connection between speech (i.e., phonology) and gesture rather than between language (i.e., semantics) and gesture, as it is the case in the Interface Hypothesis. This suggests that the Lexical Facilitation Model allows for gesture to compensate only after overt lexical access failure whereas the Interface Hypothesis allows for gesture and language to share the communicative burden from the outset.

In this section, gesture processing was based on studies investigating neurologically healthy participants (NHP). The processing of gestures in aphasia will be briefly discussed in 7.2.1.1 in light of the findings of this study.

The majority of the reviewed studies in this section investigated gesture production in conversational speech. Different parameters of conversation that may influence the level of language and gesture production are explained in the following sections.

2.2 Conversation

The production of gesture and verbal language are vital parts of human communication, including in the most frequent communicative activity in everyday life which is conversation (Davidson et al., 2003). Conversation is a spontaneous way of sharing opinions, ideas, and thoughts across two or more speakers (Clark, 2001). It is therefore of great importance for human interaction (Cassell, 2000) and plays a fundamental role in establishing and maintaining interpersonal relationships (Ventola, 1979).

Every conversation is different; at least to a certain extent. Nevertheless, two conversation parameters have been identified in the literature that can be manipulated in order to compare participants' performance: (1) the conversation topic (2.2.1) and (2) the conversation partner (2.2.2). These parameters will be reviewed in turn before making assumptions about their influence on gesture production (2.2.3) and aphasia (2.2.4).

2.2.1 Conversation topic.

Conversation topic has been found to affect speech and language in various ways, for example, there is evidence that topic influences speech fluency. Bortfeld, Leon, Bloom, Schober, and Brennan (2001) asked NHP to describe pictures either of abstract geometric figures or of children. They hypothesised that because of planning difficulty, participants would produce less fluent speech when describing the figures. Results revealed the opposite though: NHP were less fluent when describing children. A re-analysis showed that particularly men experienced higher disfluency rates when describing pictures of children and often relied on the women to take the lead. The authors acknowledged that this could have skewed the results but did not go into detail in terms of planning load. Nevertheless, the different performance of participants in both tasks suggests an influence of the topic on speech fluency, albeit in a different direction than predicted.

The familiarity of the topic of conversation has been shown to affect the formality of the language used to discuss it (T. Herrmann, 1983). When NHP were asked to talk about both familiar and unfamiliar topics in conversation[6], results showed that less familiar conversation topics required more formal language than familiar topics.

Ulatowska and colleagues (Ulatowska et al., 1990; Ulatowska & Bond, 1983; Ulatowska, Macaluso-Haynes, et al., 1981; Ulatowska, North, et al., 1981) distinguished between narrative and procedural topics. They argued that narrative topics, such as sharing an experience or retelling a video, mainly serve to entertain other people and therefore consist of components that carry critical information load and develop the story line. In contrast, procedural topics, which instruct a person on how to do something, such as make a cup of tea, are goal-oriented and include more object-related language than narrative topics. This is necessary in order to describe the necessary steps to complete the task.

Despite the differences in their methodologies, all mentioned studies came to the conclusion that the topic of a conversation had an influence on the performance of participants and their speech production. The distinction between narrative and procedural topics is a common one in conversation research and no studies investigating the influence of other conversation topics could be identified. Interestingly, the mentioned studies are mainly from the 1980s and 1990s, which may indicate that this is not an active area of research; at least not in neurologically healthy speech. The influence of conversation topic in aphasia will be discussed in section 2.2.4.1.

2.2.2 Conversation partner.

Not only does the topic of a conversation have an influence on the speaker but also the conversation partner. T. Herrmann (1983) argued that the formality of speech changed

[6] Unfortunately, T. Herrmann (1983) did not provide any detail on what he considered as a familiar or an unfamiliar topic.

according to the familiarity of the conversation partner/s as well. If, for example, the speaker is talking to someone familiar, s/he uses a relatively low and informal level of speech and more colloquial terms. This manifests with more implicit language, abbreviated expressions and ellipses. Familiar conversation partners (FCP) also tend to shift topics rather quickly without explicit transitions (Hornstein, 1985) and ask each other fewer questions (Kent, Davis, & Shapiro, 1981). A relatively high and formal level of speech in combination with polite language is used when the conversation partner is unfamiliar. In addition, speakers talking to a FCP use more terms that outsiders would not understand referring to shared experiences, events (Clark & Schaefer, 1987; Fleming & Darley, 1991), and/or mutually known people (Clark & Carlson, 1981) because of already established common ground (Clark & Marshall, 1981) and community co-membership (Clark & Carlson, 1981).

Boyle, Anderson, and Newlands (1994) investigated several influences on conversation, including the familiarity between the speakers. They used a task that involved speaking about a route on a map and found that when talking to a FCP, participants used more turns and more words than when talking to an unfamiliar conversation partner (UFCP). Futhermore, FCP interrupted each other less frequently and produced less overlapping speech.

Studies investigating the conversational behaviour of people with language impairments, for example, with aphasia, suggested that talking to a FCP made people feel more comfortable leading to fewer WFD and less disfluencies in general (Li, Williams, & Della Volpe, 1995) (see 2.2.4.2). This theory of comfort when talking to someone familiar was also investigated in the Bortfeld et al. (2001) study discussed above in section 2.2.1. The authors hypothesised that results could go into two directions: NHP revealed more disfluent speech either when talking to the UFCP because of being more anxious or when talking to the FCP because of planning problems and seeking their help. Neither hypothesis could be confirmed though, as NHP did not show a different conversational behaviour in either situation. The only difference between the two conversation partners that could be identified was an increased number of speech overlaps when talking to the FCP than when talking to the UFCP. Especially this last finding about speech overlap when talking to a FCP contradicts the findings of Boyle et al. (1994).

To summarise, the reviewed studies have found differences in the language used by participants when talking to familiar and unfamiliar conversation partners, for example, a more informal level of speech in a conversation with a FCP and more formal level of speech in one with a UFCP. Also, different conversation behaviour and turn-taking are obvious due to mutual knowledge and shared experiences. It is questionable though whether the familiarity of a conversation partner does have an influence on the fluency of speech and the word-finding behaviour; at least in participants without language impairment. The parameter of the conversation partner and the comfort of talking to someone familiar who has similar knowledge might be more important in conversations with people with impaired speech, as for example in aphasia (see 2.2.4.2).

2.2.3 Influence of conversation topic and partner on gesture production.

In the previous section about gesture (2.1) it became apparent that the production of gesture alongside speech plays an important role in everyday communication (Beattie & Coughlan, 1999; Kendon, 1997). With conversation being the most frequent communicative activity among people (Davidson et al., 2003), the use of gesture in conversation has become an important issue in gesture research. With gesture production being closely linked to language, the previously identified parameters (i.e., conversation topic and partner) having an influence on conversation are therefore expected to have an influence on gesture production as well. Unfortunately, no studies investigating these parameters in neurologically healthy conversation in particular could be identified.

Based on the studies conducted by Ulatowska and colleagues (e.g., Ulatowska et al., 1990; Ulatowska, Macaluso-Haynes, et al., 1981; Ulatowska, North, et al., 1981) comparing narrative and procedural topics, it is mainly the aim of the topic that defines the type of language that is produced (entertaining and informing versus explaining a process). In line with that and with gestures being closely linked to language, it is expected that procedural topics would elicit more object-related gestures than narrative topics. Referring to Kendon's continuum (McNeill, 1992, 2000), it is likely that especially the use of iconics and pantomimes is proportionally higher in procedural topics.

It is slightly more difficult to hypothesise about the influence of the conversation partner on gesture production in neurologically healthy speech. In line with the results of Bortfeld et al. (2001) and Boyle et al. (1994) and the effect of the conversation partner on language production (see 2.2.2), one can expect an influence on gesture production as well. Given the presence of shared knowledge, talking to a FCP might not require detailed speech and could therefore lead to fewer gestures. The study by Boyle et al. (1994), however, observed more words and more turns in friends' conversations than in conversations with a UFCP. And taking the theory of comfort investigated by Bortfeld et al. (2001), one may expect no influence of the conversation partner on gesture production at all.

To date there is no evidence about the influence of conversation topic and partner on gesture production. Implications can only be drawn from language analysis and the influence of the conversation topic onto gesture production. This clearly shows a gap in research. Studies investigating these parameters in aphasia will be reviewed in Chapter 3.

2.2.4 Influence of conversation topic and partner in aphasia.

The importance of conversation in everyday life is not diminished in aphasia (Kagan, 1995). Nevertheless, when communication competence fails, it can prevent participants with a language impairment, such as aphasia, from sharing their thoughts and ideas (Kagan, 1999). Depending on the type and severity of aphasia, conversation may be very difficult and PWA have to rely on other ways to express what they want to say, for example, by using gestures (see 2.1 and 2.4) or conversational props (Parr, Pound, Byng, Moss, & Long, 2008). Indeed, it has frequently been argued that the communicative ability of PWA may exceed their speaking abilities (Holland, 1977; Larfeuil & Le Dorze, 1997).

One way of investigating conversation in aphasia, is to compare participants' performance when (1) the conversation topic (2.2.4.1) and (2) the conversation partner (2.2.4.2) is varied. While studies investigating these parameters in NHP are sparse, there are a few more research studies investigated their influence on conversation in aphasia. The studies and their findings will be reviewed in the following subsections.

2.2.4.1 Conversation topic.

One of the first studies that compared narrative and procedural topics in aphasia was conducted by Ulatowska, North, et al. (1981). According to the authors, procedural language was thought to be syntactically simpler than narrative language. Procedural topics are also more constrained by temporal order than narrative topics as they describe a process that follows a specific sequence. Because of this and because of the different internal structure of procedural topics, Ulatowska, North, et al. (1981) hypothesised that PWA would behave differently on each topic, as well as in comparison to NHP. Both PWA and NHP were asked to complete several tasks, like talking about an experience (narrative) and explaining a process (e.g., brushing teeth and changing a tyre; procedural). Results revealed that PWA produced less complex language and fewer utterances in both topics than NHP. In procedural topics, this led to gaps between single steps. Interestingly, PWA did not perform differently in narrative and procedural topics in terms of information decrease overall. However, different types of information decrease specific to the topic were observed. While PWA used a reduced amount of evaluation in narrative topics, the overall amount of language was reduced in procedural topics. Here, PWA left out small steps in the procedure which led to the same result but with reduced detail. These results were confirmed by later studies of the same research team and colleagues (e.g., Ulatowska & Bond, 1983; Ulatowska, Doyel, Freedman-Stern, & Macaluso-Haynes, 1983; Ulatowska, Freedman-Stern, Doyel, & Macaluso-Haynes, 1983).

Two similar studies were conducted by Li et al. (1995) and S. E. Williams, Li, Della Volpe, and Ritterman (1994). In terms of differences between the performance of PWA and NHP, the results of both studies were in line with Ulatowska, North, et al. (1981): PWA produced fewer utterances and less complex language than NHP. Neither of the two studies commented on the different performance on narrative and procedural topics of PWA overall. Instead, they investigated the influence of topic familiarity on the performance of PWA in both topics. When talking about a familiar narrative topic, Li et al. (1995) observed that PWA were able to recall more actions than when talking about unfamiliar narrative topics. In procedural topics, the familiarity had an influence on how much optional detail was added to the description (i.e., the more familiar the more detailed). S. E. Williams et al. (1994) reported on familiarity influencing the amount of utterances in both topics: Familiar topics contained more T-units[7] than unfamiliar topics. In terms of familiarity influencing syntactic complexity, this effect was only found for procedural topics, with unfamiliar topics eliciting fewer but more complex utterances. These findings were similar for PWA and NHP.

The three mentioned studies agreed on participants behaving differently on narrative and procedural topics. While both Li et al. (1995) and Ulatowska, North, et al. (1981) also found differences between PWA and NHP, S. E. Williams et al. (1994) did not report on such an effect.

2.2.4.2 Conversation partner.

The influence of the familiarity of a conversation partner has shown to be limited to different levels of speech in neurologically healthy speech. Fluency of speech did not seem to be influenced by different conversation partners. Instead, Bortfeld et al. (2001) found a higher number of speech overlaps when NHP were talking to a FCP. Boyle et al. (1994), however, reported the opposite.

[7] According to S. E. Williams et al. (1994), a T-unit is defined as an independent clause, including the independent modifiers of that clause. In many cases, a T-unit is a sentence (Hunt, 1965).

One could argue that familiarity of the conversation partner did not have an influence on speech fluency because NHP did not have impaired language, as did PWA. One prominent feature of aphasic speech is WFD which could lead to misunderstandings and conversation breakdown. This is what one of the first studies about the influence of conversational partner familiarity in aphasia investigated. In the single-case study by Lubinski, Duchan, and Weitzner-Lin (1980), breakdowns in a conversation with a FCP of the PWA and in one with the speech and language therapist (SLT) who was the unfamiliar conversation partner were analysed. While both conversations revealed similar language difficulties, for example, word-finding difficulties, phonologic and semantic paraphasias, and topic shifts, there were more breakdowns in the conversation with the FCP than in the conversation with the SLT. The FCP, however, responded to the breakdowns by initiating repair while the SLT ignored them. It is questionable though whether this difference was really due to the familiarity of the conversation partner as the researchers also noted other confounding factors. In particular, the SLT was less attentive during the conversation than the FCP.

Gurland, Chwat, and Gerber Wollner (1982) investigated the role of the speaker (PWA) in conversation, again by comparing a conversation with a FCP and one with the SLT. Results revealed that the main difference between the conversations was the behaviour of the conversation partners: While the FCP made more comments on what the PWA said, the SLT made more requests in terms of clarification and rephrasing. It remains unclear though whether the authors also observed different conversational behaviours on the part of the PWA depending on the conversation partner.

In their studies, Li et al. (1995) and S. E. Williams et al. (1994) not only investigated the influence of the conversation topic (see 2.2.4.1) but also the influence of the conversational partner familiarity on the levels of speech as detailed by T. Herrmann (1983). Similar to studies conducted with NHP (see 2.2.2), S. E. Williams et al. (1994) did not find a difference between the conversation with the FCP and the one with the UFCP. Li et al. (1995), on the other hand, found an influence of the conversation partner but only in the narrative topic. Here, both PWA and NHP were more accurate in providing a setting for the story they were retelling when talking to the FCP. The authors based this effect on the more comfortable situation when talking to a FCP. Despite this finding, Li et al. (1995) did not identify differences in language formality either (cf., T. Herrmann, 1983).

Dalemans and Cox (2014) interviewed PWA about their favourite conversation partner(s) or who they preferred to converse with. Results revealed that PWA did not differentiate between familiar and unfamiliar conversation partners but between those that were familiar with their language impairment and those that were not. Dalemans and Cox (2014) reported that conversation partners who had experience with talking to PWA treated the participants with respect and provided support when necessary.

2.2.5 Summary.

The previous sections provided an overview of the literature investigating the influence of conversation partner and topic on both language and gesture production. While there was good evidence that the conversation topic influences speech production, findings with respect to the conversation partner were more equivocal for both PWA and NHP.

No studies could be identified that investigated the influence of conversation partner and topic on gesture production in neurologically healthy speech. Based on the close link between language and gesture, some hypotheses can be developed. These are stronger for the influence of the topic on gesture production than of the conversation partner. However, this topic has not been investigated yet.

More research on gesture production in conversation was conducted in aphasia. This literature is reviewed in section 2.4, followed by a systematic review on studies investigating the influence of conversation topic and conversation partner on gesture production in aphasia in Chapter 3.

2.3 Aphasia

Spontaneous gesture production plays a significant role in everyday conversation. As the production of gestures is closely related to speech, it is important to investigate gesture production in impaired language, for example, in aphasia, an acquired neurological language disorder due to brain damage.

2.3.1 Different types of aphasia.

Aphasia can affect all language modalities, including speaking, understanding, reading, and writing, although with varying presentations. A number of systems have been developed to classify different syndromes of aphasia. Often, these aphasia syndromes are used as guidance or to give a first impression of the underlying language impairment. The neoassociationist classification is the most widely classification system and is based on the anatomic disconnection model (Benson, 1979; Geschwind, 1967). According to this classification system, an impairment in a specific brain area results in a defined aphasia syndrome with typical symptoms showing in language production and comprehension (see accounts in Benson, 1979; Papathaniasou, Coppens, & Potagas, 2013).

Despite debates about syndrome classification (e.g., Ardila, 2010; Caramazza, 1984; Schwartz, 1984) it is broadly used in therapy and research environments, including in the evidence base about gesture production in aphasia. The neoassociationist classification system distinguishes between eight types of aphasia that can be divided into two groups based on the fluency of the speech production: Global aphasia, Broca's aphasia, transcortical motor aphasia, and mixed transcortical aphasia are characterised by non-fluent speech production while fluent speech production is typical for Wernicke's aphasia, conduction aphasia, anomic aphasia, and transcortical sensory aphasia. Other features of language production and comprehension, such as repetition, naming, speech comprehension, reading, and writing, classify the different aphasia types further.

Next to the language impairment, PWA often show additional impairments, such as hemiplegia, motor planning disorders (e.g., limb apraxia), dysarthria, and visual impairments. The co-occurrence of other impairments with aphasia is due to the close proximity between the language areas and other areas of the brain, such as the motor cortex, controlling both limb movement and motor planning processes.

Aphasia batteries have been developed to assess different parts of language, such as fluency of speech, naming, repetition, and comprehension. The Western Aphasia Battery-Revised (WAB-R; Kertesz, 2007) or the Boston Diagnostic Aphasia Examination (BDAE; Goodglass & Kaplan, 1983) are examples in English.

All PWA included in this study are initially assessed with the WAB-R (Kertesz, 2007), to screen for participants with poor language comprehension and to calculate the aphasia quotient (AQ) indicating the severity of the language impairment (see 5.3 for details). The AQ will then be used to find out more about the influence of the aphasia severity on the production of gestures.

2.3.2 Characteristics of aphasic language.

The aphasia batteries based on the neoassociationist classification system assess only a selection of language modalities very briefly, in order to categorise the type of aphasia. Further assessments are necessary to pin down the influence of specific language modalities influencing the production of gesture. Therefore, three characteristics of aphasic language are described in more detail as they potentially have an influence on gesture production and are investigated further in this study: (1) fluency of language production, (2) lexical retrieval, and (3) semantic skills. These characteristics of aphasic language and how they are addressed in this study will be described in the following subsections.

2.3.2.1 Fluency of language production and lexical retrieval.

The rate of speech fluency is often used to distinguish between non-fluent and fluent aphasia types (see 2.3.2.1). According to Huber, Poeck, Weniger, and Willmes (1983), non-fluent language production is caused by a reduced speech rate with many pauses and an average phrase length of less than five words. The speech production of participants with non-fluent aphasia is effortful. Fluent language production, on the other hand, is characterised by long sentence structures or by strings of speech that at least retain elements of sentence forms, such as prosody, comparable to the fluency of neurologically healthy speech.

In this study, participants' speech fluency is measured with the fluency measurement provided by the Western Aphasia Battery-Revised (WAB-R; Kertesz, 2007) in order to find out more about a potential relationship between the fluency of language production and the production of gestures (see 2.4.1.2.2 and 5.3).

One explanation for reduced fluency in aphasia are WFD which are a common characteristic of speech production in aphasia indicating an impaired lexical retrieval process (Benson & Ardila, 1996; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Goodglass & Wingfield, 1997). WFD also occur in neurologically healthy speech (see 2.1.3.3). However, there are differences between NHP and PWA: WFD of NHP often do not attract much attention as they can be resolved quickly. In the case of aphasia, WFD can be lengthy at times, which makes them stand out more of the fluent speech. It may even be the case that the speaker needs support from the conversation partner or that the WFD cannot be resolved at all (Goodglass & Wingfield, 1997; Herbert, Best, Hickin, Howard, & Osborne, 2003; Hickin, Herbert, Best, Howard, & Osborne, 2006; Lesser & Algar, 1995; Perkins, Crisp, & Walshaw, 1999). Furthermore, NHP experience mainly TOT states, a type of WFD in which the word meaning but not the word form can temporarily not be retrieved (e.g., Beattie & Coughlan, 1999; Burke, MacKay, Worthley, & Wade, 1991; Frick-Horbury & Guttentag, 1998; Goodglass, Kaplan, Weintraub, & Ackerman, 1976) (see 2.1.3.3), word retrieval in aphasia can be interrupted on either level (i.e., retrieving the word meaning or the word form) (Dell et al., 1997; Martin, 2013; Schneider, Wehmeyer, & Grötzbach, 2012).

Independent from the type of WFD, difficulty in retrieving a word usually leads to hesitations in language production. Instead of the target word, the speaker may produce filler words (e.g., *uh, um*), set phrases, word repetitions, or sentence interruptions. Trying to retrieve the correct word meaning often leads to semantic paraphasias, in which the produced word is semantically related to the target word (e.g., *elbow* instead of *knee*). Phonemic paraphasias usually occur during the process of word form retrieval (i.e., TOT). Here, the word is phonologically related to the target word but phonemes have been substituted, added or deleted (e.g., *bat* instead of *mat*, *bake* instead of *break*, but also *feletone* instead of *telephone*). PWA experiencing a problem in word form retrieval may be able to paraphrase the meaning of the word, depending on whether they can access the words they need to paraphrase (Best, 1996; Dell et al., 1997; Wheeler & Touretzky, 1997).

The difference between WFD and TOT states also becomes apparent in the two types of self-correcting processes that have been described: (1) conduite d'approche and (2) conduite d'écart. While the first process gradually leads to the retrieval of the target word (e.g., *trep* → *trezle* → *pretzel*), the second process describes gradually drifting off the target word (e.g., *trep* → *tretzle* → *trethle* → *trethles* → *ki* instead of *pretzel*) (Benson & Ardila, 1996; Saffran, 2000). Both processes can be either semantic or phonemic. Nevertheless, gradually retrieving or drifting off the target word is typically connected with a TOT state (Burke et al., 1991; Dell et al., 1997; Harley & MacAndrew, 2014).

The successful retrieval of words can be influenced by lexical-semantic parameters, such as frequency and imageability. High-frequent and high-imageable words are easier to retrieve than low-frequent and low-imageable words (Luzzatti et al., 2002; Zingeser & Berndt, 1988). These parameters do not only affect word retrieval in aphasia, but can also be observed in NHP by measuring reaction time (Martin, 2013)[8].

To investigate the influence of lexical production skills on gesture production, the word retrieval of nouns and verbs will be assessed (see 5.3).

2.3.2.2 Semantic skills.

Semantic processing, or the processing of word meaning plays an important role in both language production and comprehension (for an example of single-word-processing seeMeier, Lo, & Kiran, 2016). The heart of every language and gesture processing model

[8] The retrieval of low-frequent and/or low-imageable words usually leads to an increased reaction time in neurologically healthy language.

(e.g., de Ruiter, 2000; Ellis & Young, 1996; Krauss et al., 2000) is the semantic system in which the meanings of words are stored. In an intact semantic system, modality-specific features are activated and build a concept (Lambon Ralph, 2014) in order to produce and understand a multitude of verbal and non-verbal stimuli (e.g., words, pictures, objects) (Jefferies & Lambon Ralph, 2006). There is agreement that semantic processing is often, although not always, impaired in aphasia, particularly with respect to the processes that accomplish access to semantic information and control semantic knowledge (e.g., Almaghyuli, Thompson, Lambon Ralph, & Jefferies, 2012; Jefferies & Lambon Ralph, 2006; Jefferies, Patterson, Jones, & Lambon Ralph, 2009; Jefferies, Rogers, Hopper, & Lambon Ralph, 2010; Lambon Ralph, Lowe, & Rogers, 2007; Lambon Ralph, Snell, Fillingham, Conroy, & Sage, 2010; Noonan, Jefferies, Eshan, Garrard, & Lambon Ralph, 2013). The reason for this may be that core features relevant to produce or understand a word can temporarily not be activated or accessed in aphasia (e.g., Antonucci, 2014; Marques, Mares, Martins, & Martins, 2013; Mason-Baughman & Wallace, 2014; H. E. Thompson & Jefferies, 2013).

According to H. E. Thompson and Jefferies (2013) and H. E. Thompson, Robson, Lambon Ralph, and Jefferies (2015), the semantic impairment in aphasia leads to the following three performance patterns: (1) PWA perform well on matching tasks with items that are highly associated (e.g., *salt* and *pepper*) but they perform poorly on items that have weak associations (e.g., *salt* and *sugar*) (e.g., Noonan, Jefferies, Corbett, & Lambon Ralph, 2010). This is also in line with the study of Almaghyuli et al. (2012) who found that PWA performed better on imageable items than on abstract items. (2) Depending on the type of the task, PWA show different performance consistency patterns: On tasks with words or pictures only, they perform consistently, while on tasks with different executive demands, for example, in word-to-picture matching tasks and association judgements, performance is rather inconsistent (e.g., Jefferies & Lambon Ralph, 2006). Corbett and colleagues (2014; 2009), for example, investigated this notion of poor executive control further by investigating the relationship between participants' performance on semantic tasks and executive function tasks. Results indicated a link between the performance of the PWA on both tasks, such as that participants who performed poorly on the semantic tasks also performed poorly on the tasks of executive functions. Finally, (3) the performance of PWA can be influenced by cues activating the target but also by miscues activating the distracters in tasks, such as picture naming and demonstration of object use (e.g., Corbett, Jefferies, & Lambon Ralph, 2011; Jefferies, Baker, Doran, & Lambon Ralph, 2007; Noonan et al., 2010; Soni et al., 2009). As above, this could be explained with still intact semantic representations but poor executive control over semantic processing in aphasia and additionally temporal loss of access to the semantic features (Almaghyuli et al., 2012). Furthermore, studies showed that PWA performed better on highly imageable items than on abstract items. Imageability effects are thought to be related to the degree of elaboration in semantic representations. Highly imageably words have richer representations than abstract words, giving them an advantage.

While the parameters of frequency and imageability have an influence on word retrieval, different word classes, such as nouns, verbs and adjectives, entail different semantic features and vary in semantic complexity which may lead to a word-class-effect in aphasia (i.e., different word classes may be impaired to a different extent). Evidence from studies investigating Broca's aphasia (see 2.3.2.1), for example, revealed that nouns were typically better preserved than verbs (e.g., Bak & Hodges, 2003; Bastiaanse, 2011; Bastiaanse & Jonkers, 1998; Benson & Ardila, 1996; Bird, Howard, & Franklin, 2003; Marshall, 2003; Mätzig, Druks, Masterson, & Vigliocco, 2009). Verb deficits, however, are not restricted to Broca's aphasia. They can also be observed in fluent aphasia (e.g., Berndt, Haendiges, Mitchum, & Sandson, 1997; Berndt, Mitchum, Haendiges, & Sandson, 1997; Kohn, Lorch, & Pearson, 1989; S. E. Williams & Canter, 1987).

Impaired semantic skills are not restricted to the verbal modality (e.g., word comprehension, synonym judgement, or word-to-picture-matching). Often, PWA show an impairment of non-verbal semantic skills as well. Non-verbal semantic skills are important for understanding pictures and objects (e.g., Jefferies & Lambon Ralph, 2006). These can be assessed by linking to stimuli based on their overlapping semantic features. A third stimulus, the distractor, shares features with only one of the items. The Pyramids and Palm Trees Test is an example for assessing non-verbal semantic skills (PPTT; Howard & Patterson, 1992). Similar to verbal semantic skills, non-verbal semantic skills can be impaired differently among word classes (e.g., verbs vs. nouns) (e.g., Bak & Hodges, 2003).

Many gestures carry semantic information, especially iconic, metaphoric, pantomime, and emblem gestures (see 2.1.2). They depict certain features of lexical affiliates (Hadar, Wenkert-Olenik, et al., 1998) and are highly imageable. It is therefore of interest to find out whether semantic skills may influence the production of gesture. Therefore, in the current study assessments of verbal and non-verbal lexical semantic processing will be conducted. Participants' performance on these assessments will then be compared to the production of gestures.

2.4 Gesture in aphasia

2.4.1 Is gesture production impaired in aphasia?

Several research studies have sought to answer the question of whether gesture production is impaired in aphasia. There is no straightforward answer; as it depends on the focus of the study and the methodology used to examine gesture production. Past studies have shown great variability regarding their methodology: Different participant factors (e.g., severity of aphasia, type of aphasia, and whether or not limb apraxia[9] is present) and different settings for data collection have led to confounding findings. Researchers focusing on formal gesture tasks eliciting pantomime gestures agreed that PWA had a general impairment of gesture (e.g., J. R. Duffy & Watkins, 1984; R. J. Duffy & Duffy, 1981; R. J. Duffy, Duffy, & Pearson, 1975; Gainotti & Lemmo, 1976; Kadish, 1978; Pickett, 1974). This was not the case for other researchers who elicited production in a more naturalistic setting and examined gestures in different types of spontaneous speech (e.g., Behrmann & Penn, 1984; Carlomagno, Pandolfi, Marini, Di Iasi, & Cristilli, 2005; Cicone, Wapner, Foldi, Zurif, & Gardner, 1979; R. J. Duffy et al., 1984; Glosser et al., 1986; Hadar, Wenkert-Olenik, et al., 1998; M. Herrmann, Reichle, Lucius-Hoene, Wallesch, & Johannsen-Horbach, 1988; Hogrefe et al., 2012; Le May et al., 1988; Lott, 1999; Mol, Krahmer, & van de Sandt-Koenderman, 2013; Wilkinson, Beeke, & Maxim, 2010).

The following sections aim to give an overview of research studies and their results on gesture production and comprehension in aphasia. As the approach to gesture investigation in aphasia has changed over time, the focus will first be on studies using formal gesture tasks (2.4.1.1) before turning to those using more naturalistic settings (2.4.1.2). After that, several factors having an influence on gesture production will be investigated (2.4.2) before the functions of gesture production (2.4.4) will be discussed.

2.4.1.1 Formal gesture tasks.

Investigating gesture in aphasia with the help of formal tasks was especially common in the 1970s and early 1980s. Not all gestures can easily be investigated by formal tasks and so researchers mainly focused on pantomime and occasionally on emblem gestures (e.g., Gainotti & Lemmo, 1976; Goodglass & Kaplan, 1963; Pickett, 1974). As the current study does not focus solely on pantomime and emblem gestures but on gestures in

[9] Apraxia is a motor planning disorder often caused by brain injury, for example, after stroke. Limb apraxia is a type of apraxia, involving the impairment of goal-directed movements of the upper limb (Foundas, 2013; Patterson & Chapey, 2008; Reber, Allen, & Reber, 2009). Its role in gesture production and recognition will be explained in 2.4.1.1 and 2.4.2.2 in detail.

general (see 2.1.2 and 5.4.3), studies about formal gesturing tasks will be reviewed only briefly.

Formal gesture tasks fall into three categories: (1) gesture production, (2) gesture imitation, and (3) gesture comprehension. Gesture production tasks typically involve gesturing the use of an object (provided as a picture and/or as a real object) (e.g., R. J. Duffy & Duffy, 1981; Feyereisen, Barter, Goossens, & Clerebaut, 1988; Gainotti & Lemmo, 1976; Goodglass & Kaplan, 1963; Kadish, 1978; Pickett, 1974; Wang & Goodglass, 1992). In gesture imitation tasks the examiner provides a model gesture that has to be repeated by the person being tested (e.g., Feyereisen et al., 1988; Kadish, 1978; Pickett, 1974; Wang & Goodglass, 1992). In gesture comprehension tasks, participants are asked, for example, to identify the object that the examiner pretended to use. Participants are asked to point to a matching picture, for example, from a choice of three or four, which can enable the researcher to explore error patterns (e.g., Bell, 1994; Daniloff, Noll, Fristoe, & Lloyd, 1982; J. R. Duffy & Watkins, 1984; R. J. Duffy & Duffy, 1981; R. J. Duffy et al., 1975; Feyereisen et al., 1988; Gainotti & Lemmo, 1976; Kadish, 1978; Pickett, 1974; Seron, van der Kaa, Remitz, & van der Linden, 1979; Wang & Goodglass, 1992). While some studies focused solely on gesture comprehension (e.g., Daniloff et al., 1982; J. R. Duffy & Watkins, 1984; R. J. Duffy et al., 1975; Seron et al., 1979) others investigated all three types of gesture tasks (e.g., R. J. Duffy & Duffy, 1981; Feyereisen et al., 1988; Kadish, 1978; Pickett, 1974; Wang & Goodglass, 1992).

In many studies, participants' scores on the gesture tasks were compared with their performance on language test batteries, like the BDAE (Goodglass & Kaplan, 1983) (e.g., Bell, 1994; Goodglass & Kaplan, 1963; Kadish, 1978; Seron et al., 1979; Wang & Goodglass, 1992), the Western Aphasia Battery (WAB; Kertesz, 1982) (e.g., Bell, 1994), the Porch Index of Communicative Ability (PICA; Porch, 1971) (e.g., R. J. Duffy & Duffy, 1981; R. J. Duffy et al., 1975; Pickett, 1974; Wang & Goodglass, 1992), or the Aphasia Language Performance Scales (ALPS; Keenan & Brassell, 1975) (Daniloff et al., 1982). Almost all mentioned studies tested auditory comprehension and naming abilities of PWA with single word tasks (Bell, 1994; J. R. Duffy & Watkins, 1984; R. J. Duffy & Duffy, 1981; R. J. Duffy et al., 1975; Gainotti & Lemmo, 1976; Goodglass & Kaplan, 1963; Kadish, 1978; Pickett, 1974). Some studies applied testing for motor function as well (Bell, 1994; R. J. Duffy & Duffy, 1981; Feyereisen et al., 1988; Gainotti & Lemmo, 1976; Kadish, 1978), even though Bell (1994) and Gainotti and Lemmo (1976) did not investigate gesture production but focused on gesture comprehension only.

Depending on the study, the scores of different participant groups (i.e., PWA, PWBI (participant/s with brain injury), and/or NHP) were compared. All studies found that PWA scored lower on formal gesture tasks than comparator groups (i.e., PWBI and NHP). As this was the case for all different gesture tasks (e.g., J. R. Duffy & Watkins, 1984; Goodglass & Kaplan, 1963; Kadish, 1978; Pickett, 1974; Wang & Goodglass, 1992) and as the performance on gesture tasks was related to the performance on further language tasks, the authors concluded that PWA had a general impairment in gesture. Nevertheless, only Kadish (1978) observed a relationship between gesture performance and aphasia severity.

One problematic aspect about assessing gesture production skills in PWA by formal tasks only is the potential influence of limb apraxia on gesture production (see 2.4.2.2 and footnote 9 above). Many of the tasks included in these studies have since become part of limb apraxia assessments (see 5.3.1). A low score in any of these assessments could therefore point to a gesture impairment due to the aphasia or due to a motoric impairment. Glosser et al. (1986) also made the point that studies focused mainly on one type of gesture: pantomime. The authors noted that even though pantomime gestures are important in apraxia studies, they are not used very often by speakers in a natural conversation.

2.4.1.2 Gesture in spontaneous speech.

In the 1980s, the focus of gesture research moved away from formal gesture tasks and focused more on gestures produced in a more naturalistic context like discourse and/or conversation. Studies of formal gesture tasks observed low gesture production in PWA and concluded that gesture was impaired in aphasia (see 2.4.1.1). The results of the studies on gesture in spontaneous speech, however, were more equivocal. Even though most studies found a gestural impairment in aphasia as well, they observed PWA using more gestures than NHP in spontaneous speech, contradicting the results of the studies that used formal tasks only. Furthermore, they found that PWA exhibited gesture patterns that differed from those produced by control participants (i.e., PWBI and/or NHP).

An illustrative selection of studies is discussed here: Behrmann and Penn (1984); Borod, Fitzpatrick, Helm-Estabrooks, and Goodglass (1989); Carlomagno and Cristilli (2006); Carlomagno et al. (2005); Cicone et al. (1979); Cocks et al. (2011); Cocks, Dipper, et al. (2013); R. J. Duffy et al. (1984); Glosser et al. (1986); Hadar, Wenkert-Olenik, et al. (1998); M. Herrmann et al. (1988); Hogrefe et al. (2012); Kong, Law, Wat, and Lai (2015); Le May et al. (1988); Lott (1999); Macauley and Handley (2005); Mol et al. (2013); Pedelty (1987); Pritchard et al. (2013); Rose and Douglas (2003); Sekine and Rose

(2013); Sekine et al. (2013). The studies differ in their methodologies, particularly with respect to the type of spontaneous speech that was investigated. Discourse types included a monologue (Lott, 1999), an interview (Cicone et al., 1979; Lanyon & Rose, 2009; Rose & Douglas, 2003; Sekine et al., 2013), a conversation (Behrmann & Penn, 1984; Glosser et al., 1986; M. Herrmann et al., 1988; Kong et al., 2015; Le May et al., 1988; Macauley & Handley, 2005; Wilkinson et al., 2010), a picture description (Hadar, Wenkert-Olenik, et al., 1998; Kong et al., 2015; Lott, 1999), retelling a story or video clips (Carlomagno & Cristilli, 2006; Cocks et al., 2011; Cocks, Dipper, et al., 2013; Hogrefe et al., 2012; Hogrefe et al., 2013; Kong et al., 2015; Lott, 1999; Pedelty, 1987; Pritchard et al., 2013; Sekine & Rose, 2013), a referential communication task (Borod et al., 1989; Carlomagno et al., 2005; R. J. Duffy et al., 1984), and an assessment of total communication skills (Mol et al., 2013).

Most studies compared aphasic and neurologically healthy speech (Carlomagno & Cristilli, 2006; Carlomagno et al., 2005; Cicone et al., 1979; Cocks et al., 2011; Cocks, Dipper, et al., 2013; R. J. Duffy et al., 1984; Glosser et al., 1986; Hadar, Wenkert-Olenik, et al., 1998; M. Herrmann et al., 1988; Kong et al., 2015; Le May et al., 1988; Lott, 1999; Macauley & Handley, 2005; Mol et al., 2013; Pritchard et al., 2013; Sekine & Rose, 2013; Sekine et al., 2013). Some studies, however, focused on the speech of PWA only (Behrmann & Penn, 1984; Borod et al., 1989; Hogrefe et al., 2012; Hogrefe et al., 2013; Pedelty, 1987; Rose & Douglas, 2003). Motoric functions (e.g., limb apraxia) were tested by some studies only (Borod et al., 1989; Cocks et al., 2011; Cocks, Dipper, et al., 2013; R. J. Duffy et al., 1984; Hogrefe et al., 2012; Hogrefe et al., 2013; Kong et al., 2015; Macauley & Handley, 2005; Pritchard et al., 2013; Rose & Douglas, 2003).

In addition to the speech samples, language testing was conducted in most cases as well (Behrmann & Penn, 1984; Borod et al., 1989; Cocks et al., 2011; Cocks, Dipper, et al., 2013; R. J. Duffy et al., 1984; Glosser et al., 1986; Hadar, Wenkert-Olenik, et al., 1998; M. Herrmann et al., 1988; Hogrefe et al., 2012; Hogrefe et al., 2013; Kong et al., 2015; Le May et al., 1988; Lott, 1999; Macauley & Handley, 2005; Mol et al., 2013; Pedelty, 1987; Pritchard et al., 2013; Rose & Douglas, 2003; Sekine & Rose, 2013; Sekine et al., 2013). These studies aimed to investigate relationships between gesture production and the type and/or the severity of aphasia. In particular, they focused on the relationship between gesture production and the fluency of speech and/or the severity of the language impairment. The reasons for this are the theoretical implications one can draw from those relationships. For example, a reduced word-production-rate may lead to a reduced production rate of gestures in gesture processing. The link between gesture production and fluency of speech was frequently revealed while the relationship between gesture production and aphasia severity was less firmly established.

Studies in this section have addressed three main questions:

(1) Is there a difference in gesture production between PWA and NHP?
(2) Is gesture production influenced by aphasia type?
(3) Is gesture production influenced by aphasia severity?

These questions will be reviewed in turn.

2.4.1.2.1 Differences in gesture production between PWA and NHP.

The studies discussed in this section employed a range of methodologies (see above) (e.g., Carlomagno & Cristilli, 2006; Carlomagno et al., 2005; Cicone et al., 1979; Cocks et al., 2011; Cocks, Dipper, et al., 2013; R. J. Duffy et al., 1984; Glosser et al., 1986; Hadar, Wenkert-Olenik, et al., 1998; M. Herrmann et al., 1988; Kong et al., 2015; Le May et al., 1988; Lott, 1999; Macauley & Handley, 2005; Mol et al., 2013; Pritchard et al., 2013; Sekine & Rose, 2013; Sekine et al., 2013).

Most studies in this section found that PWA used more gestures than NHP (Carlomagno & Cristilli, 2006; Carlomagno et al., 2005; Cicone et al., 1979; Cocks, Dipper, et al., 2013; R. J. Duffy et al., 1984; Hadar, Wenkert-Olenik, et al., 1998; M. Herrmann et al., 1988; Kong et al., 2015; Le May et al., 1988; Lott, 1999; Macauley & Handley, 2005; Pritchard et al., 2013; Sekine & Rose, 2013; Sekine et al., 2013). Carlomagno et al. (2005) made the additional observation that iconic gestures were a particularly common category for PWA. In one of their studies, Carlomagno et al. (2005) found that the increased gesture use was not confined to co-speech gestures but also occurred in speech-replacing gestures. M. Herrmann et al. (1988) noted that PWA tended to use gesture in non-verbal communication sequences, which suggested that their participants were replacing speech with pantomimes.

These findings indicate that gesture may be resilient to aphasia and that it may perform a compensatory role (see 2.4.4.1). However, findings were not unanimous. Glosser et al. (1986) did not find any fundamental differences in gesture production between PWA and NHP. They asked their participants to have a conversation with a conversation partner (in this case the examiner) in two different settings: a face-to-face conversation in one session and a conversation with restricted visual access between the participant and the conversation partner in the other. Both participant groups used fewer gestures in the conversation with restricted visual access. The only difference between PWA and NHP was with respect to the quality of the gestures, with PWA using less complex and more unclear gestures than NHP. This was also dependent on the type and severity of the language impairment (see 2.4.1.2.2 and 2.4.1.2.3).

Differences in the quality of gestures produced by PWA were also found by Mol et al. (2013). They came to the conclusion that the gestures produced by NHP were more informative than those produced by PWA. Furthermore, they found that the semantic content of gestures tended to degrade with spoken language. They divided iconic gestures into three categories: (1) outlining/moulding gestures, (2) handling gestures, and (3) object/enact gestures. NHP produced more handling and object/enact gestures than PWA who used mainly outlining/moulding gestures making gestures less clear and informative (see above). This suggests a relationship between the type of the linguistic impairment and the clarity of gestures (see 2.4.1.2.2).

The notion that semantic knowledge is crucial for the production of gestures was the focus of studies by Cocks and colleagues (2011; 2013) who found a relationship between participants' semantic scores and the complexity of the produced gestures. Furthermore, their results supported the finding that PWA produced more iconic gestures than NHP and that this difference was due to increased gesturing during periods of WFD rather than during fluent speech. The increased number of WFD in PWA is a potential explanation for an increased gesture production overall (Pritchard et al., 2013) (see 2.4.3).

The high number of WFD in aphasia was also one of the explanations Macauley and Handley (2005) provided for an increased production of content gestures by PWA. They investigated the use of different types of gestures in a conversational setting in PWA and NHP. Not only did PWA produce significantly more gestures than NHP, they also produced different types of gestures. For example, PWA used almost four times as many filler gestures[10] and almost twice as many content gestures[11] than NHP. The authors argued that PWA were using more gestures than NHP in order to substitute for inaccessible words. Similar observations in terms of the use of different types of gestures used by PWA and NHP were made by Le May et al. (1988). Participants' gestures were elicited by an interview and coded into different gesture categories. Results indicated

[10] metaphoric gestures; "gestures that fill time but are not related in content of speech" (Macauley & Handley, 2005, p. 32)
[11] deictic, iconic, and emblem gestures

that PWA used more batons[12], ideographs[13], deictics, and kinetographs[14] which goes in hand with the findings by Macauley and Handley (2005) who observed that PWA used more filler gestures than NHP. Interestingly, Le May et al. (1988) did not find a significant difference between the two participant groups in the use of pictographs[15] (i.e., content gestures).

Hadar, Wenkert-Olenik, et al. (1998) found differences between PWA and NHP with respect to the timing of gestures, and hence the relationship between gestures and the accompanying speech. While the gesture and its lexical affiliate matched in healthy speech, some PWA were not able to "hold" the gesture onset until the matching word/phrase occurred in speech. This led to mismatches between speech and gesture.

With the exception of Glosser et al. (1986), the findings of the studies reported in this section support a difference in gesture production between PWA and NHP in both quantity and quality. An explanation for the increased use of gesture in aphasia was given by Le May et al. (1988) and Pritchard et al. (2013) who suggested that this was due to the increased number of WFD and a potential facilitative function in lexical retrieval (see 2.1.3.3 and 2.4.4.3). Interestingly, Hadar, Wenkert-Olenik, et al. (1998) who analysed the temporal relationship between gesture and its lexical affiliate observed that PWA were not able to hold the onset of the gesture long enough for the gesture to match speech. It is unclear though whether this was only the case during fluent speech (i.e., outside WFD). In terms of gesture quality, several studies came to the conclusion that the gestures of PWA were less semantically complex than those produced by NHP (Cocks et al., 2011; Cocks, Dipper, et al., 2013; Mol et al., 2013). Based on these findings, it is expected that both quantitative and qualitative differences in gesture production between PWA and NHP will be found in this study.

2.4.1.2.2 Gesture production and type of aphasia.

As already mentioned above, studies investigating the relationship between gesture production and the type of aphasia varied to a great extent in their methodology (e.g., Behrmann & Penn, 1984; Carlomagno & Cristilli, 2006; Carlomagno et al., 2005; Cicone et al., 1979; Cocks, Dipper, et al., 2013; R. J. Duffy et al., 1984; Le May et al., 1988; Lott, 1999; Mol et al., 2013; Pedelty, 1987; Sekine & Rose, 2013; Sekine et al., 2013). Despite this variety, all studies were in line with the findings of Hadar, Wenkert-Olenik, et al. (1998) and Mol et al. (2013) (see 2.4.1.2.1) indicating a link between gesture production

[12] beat gestures
[13] metaphoric gestures
[14] iconic gestures depicting a physical movement
[15] iconic gestures depicting a referrant

and the type of the linguistic impairment (i.e., in terms of different aphasia syndromes or different fluency levels of speech production; see 2.3 and 2.3.2.1).

Whether or not there was a relationship between speech fluency and gesture depended on the methods applied. If the overall number of gestures was computed in a given time frame, participants with non-fluent aphasia produced fewer gestures than the participants with fluent aphasia and the NHP, with the participants with fluent aphasia gesturing most often (e.g., Carlomagno et al., 2005; R. J. Duffy et al., 1984; M. Herrmann et al., 1988; Le May et al., 1988; Lott, 1999; Sekine et al., 2013). If however, the number of gestures produced was measured per number of words, the participants with non-fluent speech used more gestures that the other two participant groups (e.g., Carlomagno & Cristilli, 2006; Pedelty, 1987).

Participants with Broca's aphasia made frequent use of iconic, pantomime, and emblem gestures (Behrmann & Penn, 1984; Lanyon & Rose, 2009; Lott, 1999; Pedelty, 1987; Sekine & Rose, 2013; Sekine et al., 2013) but needed more time than other PWA to initiate a gesture and had longer pauses in between gestures (R. J. Duffy et al., 1984). Participants with Wernicke's aphasia were found to use more gestures than NHP, especially beat gestures (e.g., Sekine et al., 2013). In addition, their gestures tended to be vague and difficult to interpret without speech (Le May et al., 1988; Lott, 1999; Sekine & Rose, 2013; Sekine et al., 2013). In line with this, Cocks, Dipper, et al. (2013) found that people with poorer semantic skills produced semantically less informative gestures than those with intact semantics pointing towards an influence of semantic skills on gesture production (see 2.4.2.3).

Carlomagno et al. (2005), Sekine and Rose (2013) and Sekine et al. (2013) investigated the gesture production of participants with different types of aphasia and compared their performance to NHP. Regarding the number of gestures, Carlomagno et al. (2005) found that participants with anomic aphasia produced four times more iconic gestures per word than NHP. With respect to the type of gestures used, Sekine and colleagues (Sekine & Rose, 2013; Sekine et al., 2013) found similar patterns in participants with anomic aphasia and NHP. Furthermore, the study of Sekine et al. (2013) not only compared the gesture production of participants with Broca's aphasia, Wernicke's aphasia, and anomic aphasia to that of NHP, they also included participants with conduction aphasia and transcortical motor aphasia. Participants in the last two groups showed similar gesture production patterns as participants with Broca's aphasia; especially in terms of the number of gestures per 100 words and the type of gestures. All three groups showed a high number of semantically rich gestures. Sekine et al. (2013) concluded that fluency of speech was the best predictor of gesture production patterns, with participants with fluent aphasia producing more gestures per minute and participants with non-fluent aphasia producing more gestures per word in comparison to NHP.

An exception to the difference between non-fluent and fluent aphasia in terms of gesture production, was the study by Carlomagno and Cristilli (2006). They compared the production of gestures of 10 PWA (non-fluent and fluent) to 10 NHP. While all PWA produced significantly more gestures overall than NHP, the authors did not find a significant difference between participants with fluent and non-fluent aphasia. They found a qualitative difference between these two groups though, with participants with fluent aphasia producing more iconic gestures while non-fluent participants produced more deictic and metalinguistic gestures (i.e., beats) than the other two groups. In line with other studies, Carlomagno and Cristilli (2006) observed that despite the increased use of iconic gestures in participants with fluent aphasia, they conveyed concepts less clearly than participants with non-fluent aphasia and NHP, indicating that they mainly used vague gestures (cf., Le May et al., 1988; Lott, 1999; Sekine & Rose, 2013; Sekine et al., 2013).

To summarise, the studies in this section came to the conclusion that there was a strong link between the number and type of gestures used and the fluency of the speech output. While participants with fluent aphasia produced significantly more gestures per unit of time than NHP and other PWA, participants with non-fluent aphasia produced significantly more gestures per word. In addition to that, different characteristics of speech output in aphasia can be visible in gesture production as well: For example, participants with Wernicke's or fluent aphasia produced both vague speech and vague gestures while participants with Broca's and non-fluent aphasia produced many meaning-laden gestures (e.g., Carlomagno & Cristilli, 2006; Le May et al., 1988; Lott, 1999; Sekine & Rose, 2013; Sekine et al., 2013). Therefore, different gesture patterns in PWA are predicted, depending on the fluency of speech production.

2.4.1.2.3 Gesture production and severity of aphasia.

Only few studies have investigated the relationship between gesture production and aphasia severity (e.g., Behrmann & Penn, 1984; Borod et al., 1989; Glosser et al., 1986; Hogrefe et al., 2012; Hogrefe et al., 2013; Kong et al., 2015; Macauley & Handley, 2005; Mol et al., 2013; Pedelty, 1987; Rose & Douglas, 2003). These studies explored gesture production alongside a range of discourse types (see above). Depending on the study, different aspects of non-verbal communication, such as the overall number of gestures and different types of gestures, were analysed and related to aspects of the linguistic impairment.

These studies used a variety of methods to determine aphasia severity. While Behrmann and Penn (1984), Borod et al. (1989), Glosser et al. (1986), and Pedelty (1987) compared participants' gesture performance to the severity score of the BDAE (Goodglass & Kaplan, 1983), Hogrefe et al. (2012) used the severity scores of the Aachener Aphasie Test (AAT; Huber et al., 1983), Macauley and Handley (2005) used the WAB (Kertesz, 1982), and Kong et al. (2015) used the Cantonese version of the WAB (CAB; Yiu, 1992). In the study of Rose and Douglas (2003) participants were either assessed with the BDAE or with the WAB-R (Kertesz, 2007) to determine the aphasia severity. Mol et al. (2013) compared gesture performance of participants on the Scenario Test (van der Meulen, van de Sandt-Koenderman, Duivenvoorden, & Ribbers, 2010) to their performance on the Amsterdam-Nijmegen Test voor Alledagse Taalvaardigheden[16] (ANTAT; Blomert, Koster, & Kean, 1995). Unlike the BDAE and the AAT, the ANTAT/ANELT does not calculate an aphasia severity score.

The earliest study was conducted by Behrmann and Penn (1984). They included 11 participants of different aphasia severity and compared their gesture performance. Even though they came to the conclusion that there was no relationship between aphasia severity and gesture performance, they did not run statistical analyses on these factors. Instead, they focused on a qualitative analysis of the use of gesture in two participants. Different syntactic skills and aphasia severity scores led the authors to the conclusion that it was rather the type of the aphasia having an influence on gesture production rather than the severity.

Glosser et al. (1986) included 10 participants with mild and moderate aphasia in their study and compared their performance to five NHP. They found that participants with moderate aphasia used fewer semantically complex gestures than those with mild aphasia and NHP. Therefore, they concluded that the complexity of gestures decreased with the increase of aphasia severity. Interestingly, Hogrefe et al. (2012) did not find this relationship. They analysed the production of gestures in participants with severe aphasia only. Here, it was the semantic processing ability, rather than the aphasia severity score that predicted the diversity of hand gestures (see 2.4.2.3).

[16] The ANTAT (Amsterdam-Nijmegen Test voor Alledagse Taalvaardigheden) is the Dutch version of the ANELT (Amsterdam-Nijmegen Everyday Language Test; Blomert, Kean, Koster, & Schokker, 1994).

In a study by Borod et al. (1989), 41 PWA were assessed and took part in a referential communication task to score their use of gestures on a 4-point scale: 0 – no gesture production at all, 1 – occasional (low) production of gesture, 2 – occasional (high) production of gesture, and 3 – regular production of gesture. Gestures were rated in seven different contexts (e.g., gestures used to greet or used to point). This overall score (max. 21) was then correlated with the aphasia severity score of the BDAE and showed a significant relationship between these two ratings. Results revealed that participants with more severe aphasia gestured less. Borod et al. (1989) explained this link by the large group of participants with global aphasia (n = 9) as this correlation was no longer significant when these participants were excluded from the analysis. These results are in line with those of the study by Kong et al. (2015) who investigated the use of gesture in spontaneous speech of 48 PWA and 131 NHP. They found a link between the frequency of gesture use and the severity of the aphasia, indicating that participants with more severe aphasia gestured significantly more during discourse tasks than participants with mild or moderate aphasia. Furthermore, Kong et al. (2015) observed that an increase in complete utterances led to a decrease in gesture production underlining the influence of the severity on gesture production.

By using the ANTAT, Mol et al. (2013) divided the participants into two groups: participants with severe aphasia (ANTAT-score below 30) and participants with mild aphasia (ANTAT-score above 30). They compared the gesture performance of these two groups with two groups of NHP on performing the Scenario Test (van der Meulen et al., 2010). In this test, participants' communicative ability is tested in a dialogue setting. One group of NHP was allowed to speak, while the other group relied on gestural performance completely. PWA were allowed to use both gesture and speech. It was shown that participants with severe aphasia used less informative gestures than those with mild aphasia and the NHP. As mentioned above, Mol et al. (2013) divided the iconic gestures into three different categories: (1) outlining/moulding gestures, (2) handling gestures, and (3) object/enact gestures. While PWA mainly relied on outlining/moulding gestures, NHP produced a larger amount of handling and object/enactment gestures. This difference was even bigger when comparing the non-verbal healthy participants with the PWA. The authors therefore concluded that (1) the gestures used by PWA carried less information and (2) depending on the severity of the aphasia, PWA were not able to produce the whole range of gestures.

Macauley and Handley (2005), Pedelty (1987), and Rose and Douglas (2003) analysed the gesture production of PWA in a conversation. Correlating the number of gestures produced with the severity of the language impairment, neither of the three studies found a relationship between these two parameters. Instead, Rose and Douglas (2003) came to the conclusion that PWA were able to produce a wide range of meaning-laden gestures to convey information and that this was independent from both aphasia and apraxia severity (see 2.4.2.2).

One can conclude from these studies, that severity alone has not been clearly established as a predictor for gesture production: Only Glosser et al. (1986), Kong et al. (2015), and Mol et al. (2013) found a relationship between the number and complexity of gestures produced and aphasia severity, while the others did not. Borod et al. (1989) found this relationship only when participants with global aphasia were included. Instead of aphasia severity, it may rather be down to a more specific impairment in aphasia: While Behrmann and Penn (1984) and Kong et al. (2015) suggested syntactic skills having an influence on gesture production, Hogrefe et al. (2012) but also Kong et al. (2015) came to the conclusion that it was semantic processing that predicted the diversity of hand gestures. The impairment of semantic skills as an explanation for gesture impairment will be investigated in section 2.4.2.3 in more detail.

2.4.1.3 Relevance for this study.

The current study will further explore patterns of co-speech gesture in PWA compared to NHP. As in previous research (e.g., Carlomagno et al., 2005; Cicone et al., 1979; Cocks, Dipper, et al., 2013; R. J. Duffy et al., 1984; Hadar, Wenkert-Olenik, et al., 1998; M. Herrmann et al., 1988; Kong et al., 2015; Le May et al., 1988; Lott, 1999; Macauley & Handley, 2005; Pritchard et al., 2013; Sekine & Rose, 2013; Sekine et al., 2013), it is anticipated that the frequency of gesture production will be inflated in the PWA, possibly as a compensatory strategy (see 2.4.4.1). Because of the finding by Sekine et al. (2013) and many others that fluency of speech was the best predictor of gesture patterns (e.g., Behrmann & Penn, 1984; Carlomagno et al., 2005; Cicone et al., 1979; Cocks, Dipper, et al., 2013; R. J. Duffy et al., 1984; Le May et al., 1988; Lott, 1999; Mol et al., 2013; Pedelty, 1987; Sekine & Rose, 2013; Sekine et al., 2013), the relationship between fluency and gesture will be investigated. In accordance with studies that found that participants with non-fluent aphasia used fewer gestures over time unit than participants with fluent aphasia and NHP (e.g., Carlomagno et al., 2005; R. J. Duffy et al., 1984; M. Herrmann et al., 1988; Le May et al., 1988; Lott, 1999; Sekine et al., 2013), it is anticipated that there will be a correlation between the fluency of speech and the overall number of gestures (i.e., the higher the fluency score, the higher the overall number of gestures).

In order to explore the possible impact of aphasia severity found by Glosser et al. (1986), Kong et al. (2015), and Mol et al. (2013) (and partly by Borod et al. (1989)), the AQ of the WAB-R (Kertesz, 2007) will be correlated with the overall number of gestures produced. Since many of the studies that investigated the link between gesture production and aphasia severity did not find evidence for it (e.g., Behrmann & Penn, 1984; Hogrefe et al., 2012; Macauley & Handley, 2005; Pedelty, 1987; Rose & Douglas, 2003) and since this study does not include participants with global aphasia (see 5.2.1) a relationship between the aphasia severity and the gesture production patterns is not anticipated. Accordingly, links to the impairment of other, underlying, skills, such as semantics (e.g., Hogrefe et al., 2012; Kong et al., 2015) will be investigated (see 2.4.2.3).

2.4.2 Why is gesture production impaired in aphasia?

The previous sections showed that there are differences in gesture production and comprehension between PWA and NHP (e.g., Carlomagno et al., 2005; Cicone et al., 1979; Cocks et al., 2011; Cocks, Dipper, et al., 2013; J. R. Duffy & Watkins, 1984; R. J. Duffy et al., 1984; Glosser et al., 1986; Goodglass & Kaplan, 1963; Hadar, Wenkert-Olenik, et al., 1998; M. Herrmann et al., 1988; Kadish, 1978; Le May et al., 1988; Lott, 1999; Mol et al., 2013; Pickett, 1974; Pritchard et al., 2013; Sekine & Rose, 2013; Sekine et al., 2013; Wang & Goodglass, 1992). These differences were explained differently over the years. Roughly, one can distinguish between (1) language-related impairments, such as the central symbolic impairment (see 2.4.2.1) and the semantic impairment (see 2.4.2.3), (2) stroke-related impairments, like limb apraxia (see 2.4.2.2), and (3) other factors, such as cognition (see 2.4.2.4) that could influence gesturing either with PWA producing more or fewer gestures than NHP. These explanations will be reviewed in turn in the following subsections.

2.4.2.1 Central symbolic impairment.

The concept of a central symbolic impairment was first introduced by Finkelnburg (R. J. Duffy & Liles, 1979; Finkelnburg, 1870) about 150 years ago. Under the term *asymbolia* he proposed that PWA were generally unable to express or comprehend concepts through any kind of meaningful symbols (e.g., gestures, letters, money). Especially in the 1970s and the early 1980s, this proposal was investigated in relation to gesture production in aphasia (e.g., Bell, 1994; Cicone et al., 1979; Daniloff et al., 1982; J. R. Duffy & Watkins, 1984; R. J. Duffy & Duffy, 1981; R. J. Duffy et al., 1975; Gainotti & Lemmo, 1976; Goodglass & Kaplan, 1963; Kadish, 1978; Le May et al., 1988; Pickett, 1974; Seron et al., 1979; Thorburn, Newhoff, & Rubin, 1995; Varney, 1978, 1982; Wang & Goodglass, 1992). With the exception of the studies by Cicone et al. (1979) and Le

May et al. (1988) that were some of the first studies investigating gesture production in spontaneous speech (see 2.4.1.2), all studies investigated gesture production and comprehension by means of formal tasks (see 2.4.1.1).

Studies differed in both the methodology used to assess gesture and their outcomes. The majority of the studies that found evidence for a central symbolic impairment focused on gesture comprehension only (Bell, 1994; J. R. Duffy & Watkins, 1984; R. J. Duffy et al., 1975; Kadish, 1978; Varney, 1978). An exception was the study by Pickett (1974) which included both gesture production and comprehension. The authors of all studies reported poorer performance of PWA in comparison to control participants (e.g., PWBI and NHP; see 2.4.1.1) on gesture comprehension and pointing tasks in general. Furthermore, some studies found a relationship between gesture comprehension and the linguistic impairment, especially of verbal comprehension (Bell, 1994; J. R. Duffy & Watkins, 1984; Kadish, 1978). It was especially this finding that led the authors to the conclusion that symbols were generally impaired in aphasia.

Not all studies that investigated a central symbolic impairment found support for it. Instead, several studies either ruled out this explanation entirely or gave alternative explanations for a gestural impairment in aphasia. Again, most of these studies investigated gesture comprehension only (Daniloff et al., 1982; Gainotti & Lemmo, 1976; Seron et al., 1979; Thorburn et al., 1995; Varney, 1982; Wang & Goodglass, 1992). The studies by Cicone et al. (1979), Goodglass and Kaplan (1963), and Le May et al. (1988) focused on gesture production only while R. J. Duffy and Duffy (1981) included both gesture modalities (i.e., gesture production and comprehension) into their study. Furthermore, two studies investigated gesture in aphasia not by formal tasks but by spontaneous speech (Cicone et al., 1979; Le May et al., 1988). While the studies that found evidence for a central symbolic impairment took the relationship between gesture comprehension and linguistic impairment as a key finding (see above), it was the missing relationship between gesture performance and the severity of aphasia that led Goodglass and Kaplan (1963), Seron et al. (1979), and Wang and Goodglass (1992) to the conclusion that it was not a central symbolic impairment that is responsible for gesture impairment in aphasia. On that note, Seron et al. (1979) referred to a study by Hécaen (1978) who proposed that gesture could be impaired without having a linguistic impairment. Equally, Daniloff et al. (1982) reported that PWA performed better on gesture comprehension than on verbal comprehension tasks. R. J. Duffy and Duffy (1981) hypothesised that while the use of pantomimes was impaired, gesticulations could still be used (Critchley, 1939, 1975). Alternative explanations were, for example, limb apraxia (e.g., Goodglass & Kaplan, 1963; Wang & Goodglass, 1992) (see 2.4.2.2), the linguistic impairment in general (e.g., Daniloff et al., 1982; Gainotti & Lemmo, 1976; Seron et al., 1979) or other impairments (e.g., Cicone et al., 1979; R. J. Duffy & Duffy, 1981; Le May et al., 1988; Thorburn et al., 1995; Varney, 1982).

Most of the studies that argued for a central symbolic impairment used formal tasks for investigation. In line with section 2.4.1.1, many of these tasks have since become part of limb apraxia assessments (see 5.3.1). Performing poorly on any of these tasks could therefore be explained by either the aphasia or a motoric impairment (e.g., limb apraxia; see 2.4.2.2). The latter was also the explanation other studies gave for gestures being impaired (e.g., R. J. Duffy & Duffy, 1981; Goodglass & Kaplan, 1963; Wang & Goodglass, 1992). Moreover, the two studies investigating the central symbolic impairment as a possible explanation for the gesture impairment in aphasia in spontaneous speech did not find clear support for this assumption (Cicone et al., 1979; Le May et al., 1988). Instead, Cicone et al. (1979) observed that some PWA used gesture slightly better than spoken language. To explain this finding, Cicone et al. (1979) suggested that either gesture can take the lead (despite the central symbolic impairment) or the central organiser retained a certain amount of flexibility about which modality could be used to communicate. This interpretation was also used by Le May et al. (1988). They argued that that spoken language and gesture have a common origin, but if one channel is impaired, they can function independently (cf. *tradeoff hypothesis* in 2.1.3 and 2.4.4).

2.4.2.2 Limb apraxia.

In the previous section, several studies argued that it was not a central symbolic impairment but limb apraxia that caused PWA to perform more poorly on gesture tasks than control participants (e.g., R. J. Duffy & Duffy, 1981; Goodglass & Kaplan, 1963; Wang & Goodglass, 1992). The missing link between gesture performance and aphasia severity was the main reason for the researchers to exclude a central symbolic impairment as explanation for gesture being impaired in aphasia. Further support for the apraxia hypothesis came from the observation that PWA were impaired in both gesture production and gesture imitation (Goodglass & Kaplan, 1963; Wang & Goodglass, 1992). With limb apraxia being common in aphasia (De Renzi, Faglioni, Lodesani, & Vecchi, 1983; Goodglass & Kaplan, 1963; Kertesz, Ferro, & Shewan, 1984), this argument has important implications for gesture production. Again, many studies that investigated the influence of limb apraxia on gesture production used formal gesture tasks (see 2.4.1.1) and will be reviewed only briefly (e.g., Bell, 1994; R. J. Duffy & Duffy, 1981; Feyereisen et al., 1988; Gainotti & Lemmo, 1976; Goodglass & Kaplan, 1963; Kadish, 1978; Pickett, 1974; Wang & Goodglass, 1992). The focus of this section is on the studies that investigated the influence of limb apraxia on the spontaneous production of gestures (e.g., Borod et al., 1989; R. J. Duffy et al., 1984; Hogrefe et al., 2012; Hogrefe et al., 2013; Macauley & Handley, 2005; Pritchard et al., 2013; Rose & Douglas, 2003).

As before, the formal tasks to investigate gesture in aphasia fall into three categories: (1) gesture production, (2) gesture imitation, and (3) gesture comprehension (see 2.4.1.1). Four of the mentioned studies investigated all three gesture modalities (Feyereisen et al., 1988; Kadish, 1978; Pickett, 1974; Wang & Goodglass, 1992). Gesture production and comprehension was investigated in the study of R. J. Duffy and Duffy (1981) while Goodglass and Kaplan (1963) focused on gesture production and imitation. Bell (1994) and Gainotti and Lemmo (1976) included gesture comprehension tasks only.

Interestingly, only two studies concluded that limb apraxia caused a gestural impairment in aphasia (Goodglass & Kaplan, 1963; Wang & Goodglass, 1992). In both studies, the authors observed impaired gesture imitation in PWA. Wang and Goodglass (1992) even found links between gesture imitation and both gesture production and comprehension. They therefore argued that limb apraxia affected both gesture production and their recognition. Subsequently, this led them to the assumption that the gesture impairment in aphasia was due to limb apraxia. The other studies (1) interpreted their results differently, for example, that the gestural impairment could be explained by a central symbolic or a semantic impairment (Gainotti & Lemmo, 1976; Kadish, 1978), (2) did not find links between gesture production and both comprehension and imitation (Bell, 1994; Pickett, 1974), or (3) observed that participants with limb apraxia used gestures (R. J. Duffy & Duffy, 1981; Feyereisen et al., 1988).

Other studies analysed gesture production in spontaneous speech (see 2.4.1.2). Again, these studies varied in the type of discourse chosen to investigate gesture production. Discourse types included an interview (Rose & Douglas, 2003), a conversation (Macauley & Handley, 2005), retelling video clips (Hogrefe et al., 2012; Hogrefe et al., 2013; Pritchard et al., 2013), and a referential communication task (Borod et al., 1989; R. J. Duffy et al., 1984).

Borod et al. (1989) were the only researchers to argue that the gesture impairment was due to apraxia on the basis of data drawn from spontaneous speech samples. They analysed the gesture production of 41 PWA on a referential communication task. In addition to that, PWA completed a limb apraxia assessment, assessing gesture production only. Statistical results revealed a relationship between the overall use of gesture and the score on the limb apraxia task (cf., Wang & Goodglass, 1992).

Furthermore, for participants with global aphasia, there was a link between limb apraxia and aphasia severity.

Two other studies found that limb apraxia had an influence on gesture production in aphasia. According to these studies, limb apraxia could not be the only explanation for a gestural impairment in aphasia. Instead, the researchers found a significant influence of semantic skills as well. Hogrefe and colleagues (2012; 2013) investigated gesture production of participants with severe aphasia. In the first study (Hogrefe et al., 2012), 24 PWA were shown short video clips and asked to retell them immediately afterwards to the examiner. Additionally, participants were assessed on linguistic skills with the AAT (Huber et al., 1983), semantic skills, and limb apraxia. Gestures were transcribed according to their configuration (e.g., handshape and location). Comprehensibility of gestures was checked by asking NHP to match each narration (muted video clip) to its corresponding original video clip. Results showed that while the diversity of hand gestures was related to semantic skills (i.e., the less diversity in hand gestures, the lower the score on the semantic task), the comprehensibility of gestures was also linked to limb apraxia (i.e., the less comprehensible the gestures, the lower the score on the limb apraxia assessment). Hogrefe et al. (2012) therefore concluded that both non-verbal capacities (i.e., limb apraxia and semantic skills) had an influence on gesture production in aphasia. These results were replicated in a later study by the same research team (Hogrefe et al., 2013). Sixteen PWA were assessed on the same skills as in Hogrefe et al. (2012) and watched short video clips which they had to retell immediately after watching it. This time, however, retelling was divided into a verbal and a silent condition. While PWA were allowed to use both speech and gestures in the verbal condition, they had to rely on gestures only in the silent condition. In addition to the findings of the previous study (Hogrefe et al., 2012), Hogrefe et al. (2013) pointed out, that the link between gesture comprehensibility and limb apraxia was even stronger in the silent condition than in the verbal condition. A reason for this could be the increased use of more complex pantomime gestures that may be difficult to produce for participants with limb apraxia.

R. J. Duffy et al. (1984), Macauley and Handley (2005), Pritchard et al. (2013), and Rose and Douglas (2003) all came to the conclusion that limb apraxia did not have an influence on gesture performance in aphasia, especially not on spontaneous co-speech gestures (cf., R. J. Duffy & Duffy, 1981; Feyereisen et al., 1988). R. J. Duffy et al. (1984) investigated the gesture performance of two PWA who significantly differed in the fluency of their speech production (fluent vs. non-fluent). Their performance was compared to four NHP. All participants took part in a referential communication task. Their limb apraxia was not assessed separately. PWA completed the PICA in order to find out more about their aphasia instead. Despite the lack of assessing limb apraxia, R. J. Duffy et al. (1984) concluded that it could not be limb apraxia that caused PWA to perform lower than NHP. Instead, they observed that gesture production mirrored speech production: Fluent speech was combined with fluent and more complex gestures and non-fluent speech with non-fluent and simpler gestures (see 2.4.1.2.2).

The other three studies elicited spontaneous gestures by a conversation (Macauley & Handley, 2005), an interview (Rose & Douglas, 2003), and by retelling video clips (Pritchard et al., 2013). Macauley and Handley (2005) compared the performance of 12 PWA and eight NHP, Pritchard et al. (2013) conducted a single-case study and compared the performance of the PWA to 11 NHP, while Rose and Douglas (2003) investigated gesture production in seven PWA only. In addition to the different spontaneous speech samples, participants of all studies were assessed on limb apraxia. Correlation analyses revealed that there was no relationship between limb apraxia and the overall number of gestures produced which led the authors to conclude that limb apraxia did not have an influence on gesture production in aphasia. Macauley and Handley (2005) observed that even though participants with limb apraxia produced many gestures, they were often incorrect (either in movement or context of the conversation). Therefore, although the number of gestures was not affected by limb apraxia, accuracy may have been, as was proposed by Hogrefe and colleagues (2012; 2013).

The majority of the studies discussed here came to the conclusion that limb apraxia did not have an influence on gesture production, especially not on the production of spontaneous co-speech gestures. Variation in the findings could be due to the fact that participants had different aphasia severities: Both studies conducted by Hogrefe and colleagues (2012; 2013) included participants with severe aphasia only while the other studies included a more varied group. Previous studies found a link between aphasia severity and limb apraxia, as participants with severe aphasia often also displayed limb apraxia (e.g., Borod et al., 1989). In the study of Borod et al. (1989), the relationship between aphasia severity and limb apraxia was no longer significant if the participants with severe aphasia were excluded. The findings of Hogrefe and colleagues (2012; 2013) may have led to the observations that limb apraxia had an influence at least on the comprehensibility of gesture in severe aphasia. According to the authors, the semantic skills played an important role as well and will be discussed in more detail in 2.4.2.3 below.

Based on the findings of the studies investigating spontaneous gestures, it is not expected that limb apraxia will influence the overall number of produced gestures in the current study. Furthermore, participants are not drawn from the severe group who have revealed an association with apraxia but have range of different severities – from mild aphasia to severe aphasia (see 5.3.4).

2.4.2.3 Semantic impairment.

A number of researchers have argued that gesture impairments originate from a central semantic deficit. According to this view, PWA can manipulate the symbols, but the meanings of these symbols are underspecified. As a result, a core marker is the production of semantic errors, not only in linguistic but also in gestural tasks. This has been investigated by research studies applying formal gesture tasks and analysing participants' error patterns (e.g., Bell, 1994; Daniloff, Fritelli, Buckingham, Hoffman, & Daniloff, 1986; J. R. Duffy & Watkins, 1984; Gainotti & Lemmo, 1976; Thorburn et al., 1995; Varney & Benton, 1982). The influence of semantic skills on spontaneous gesture production has also been examined by either correlating semantic scores of verbal and non-verbal tests (e.g., word-to-picture matching tasks or odd-one-out tasks) with the number or type of gestures produced overall (e.g., Cocks, Dipper, et al., 2013; Fucetola et al., 2006; Hadar, Wenkert-Olenik, et al., 1998; Hogrefe et al., 2012; Hogrefe et al., 2013) or analysing the use of different types of gestures, like semantically rich gestures versus semantically empty gestures (e.g., Carlomagno & Cristilli, 2006; Glosser et al., 1986). These studies will be reviewed in this section before their data will be set into theoretical context about semantic processing in aphasia (e.g., Almaghyuli et al., 2012; Corbett et al., 2014; Corbett et al., 2009; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2010; Noonan et al., 2013).

To assess the role of semantics in the processing of gesture by formal gesture tasks, researchers asked participants to complete a variety of gesture comprehension tasks that were all set up in a similar way: The examiner produced a gesture (or sign; cf. Daniloff et al., 1986) and the participant had to choose the picture depicting the gestured object. Depending on the study, the participant had to choose between three or four pictures, either being unrelated, semantically related, or visually related to the target. An exception were the studies by Daniloff et al. (1986) who additionally investigated participants' ability to imitate gestures[17] and Bell (1994) and Gainotti and Lemmo (1976) who assessed limb apraxia either by an imitation task (Bell, 1994) or a production task

[17] In this case, gestures refer to either ASL signs or Amer-Ind gestures.

(Gainotti & Lemmo, 1976). In all studies, the performance of PWA was compared to control participants (i.e., PWBI and/or NHP).

All six studies that applied formal gesture comprehension tasks observed that PWA often produced semantic errors in gesture comprehension tasks. These error patterns were similar to the ones that were found in verbal comprehension tasks. Gainotti and Lemmo (1976), for example, investigated the relationship between gesture and verbal comprehension in 53 PWA, 75 PWBI, and 25 NHP. Results revealed that not only did PWA score lower on the gesture comprehension task than the other participants, but their score on this task was also related to the number of semantic errors produced on the verbal comprehension task. The authors therefore concluded that semantic skills had an influence on gesture comprehension. In addition to that, Gainotti and Lemmo (1976) reported a slight relationship between gesture production and comprehension in aphasia, indicating that PWA could also have a central symbolic impairment (see 2.4.2.1).

Other studies came to similar conclusions and reported that increased semantic errors in aphasia were associated with poorer gesture skills (e.g., Daniloff et al., 1986; J. R. Duffy & Watkins, 1984; Thorburn et al., 1995; Varney & Benton, 1982). According to Varney and Benton (1982), the performance of PWA was not due to a complete lack of gesture comprehension in aphasia. Instead, participants' poor performance was due to their impoverished understanding of the intended gesture meaning. This indicated that PWA who had difficulty with understanding gestures were not able to extract all semantic features they would have needed to identify the gestures correctly.

As in the studies above, Thorburn et al. (1995) compared nine PWA to nine NHP on gesture and symbol comprehension. Participants' reading skills were assessed as well. Overall, PWA performed similarly to NHP on the symbol recognition task but scored significantly lower on both gesture comprehension and reading tasks. Next to an increased rate of semantic errors on all tasks, the authors observed a high number of perceptual/visual errors (e.g., *ski pole* for *rowing*) in aphasia. Symbols and simple, mainly 2-dimensional, gestures were easier to understand for PWA than words and more complex pantomime gestures. Thorburn et al. (1995) did not provide any explanations for this finding and it remains unclear of whether the authors supported the semantic hypothesis or not based on their findings. Instead they referred to future research to find out more.

One of the studies investigating this issue, was the study by Bell (1994). Here, 23 PWA and 15 NHP were assessed on gesture, verbal, and reading comprehension. Additionally, all participants completed a limb apraxia test (here, gesture imitation only). Unlike Thorburn et al. (1995), Bell (1994) observed a high number of semantic errors on verbal comprehension tasks only. On gesture comprehension tasks, PWA predominantly produced perceptual errors. Analysing these error patterns, Bell (1994) came to the conclusion that more complex gestures, such as pantomimes with facial movement, were more difficult to comprehend than others (cf., Thorburn et al., 1995) indicating that limb apraxia may have an influence on gesture comprehension as well (cf., Wang & Goodglass, 1992) as there may be “a disturbance in the perception of the motoric features of the pantomimed stimuli” (Bell, 1994, p. 275) (see 2.4.2.2). Interestingly, there was no relationship between gesture comprehension and the score on the limb apraxia assessment itself. Nevertheless, Bell (1994) did not provide an explanation for these findings or a conclusion on whether the results of the study supported the semantic hypothesis.

A range of discourse types has been explored in studies that investigated the influence of semantic skills on gesture production in spontaneous speech: a conversation (Glosser et al., 1986), a picture description (Hadar, Wenkert-Olenik, et al., 1998), retelling news or video clips (Carlomagno & Cristilli, 2006; Cocks, Dipper, et al., 2013; Hogrefe et al., 2012; Hogrefe et al., 2013), and a functional communication task (Fucetola et al., 2006).

The study by Carlomagno and Cristilli (2006) investigated the use of different types of gestures and their semantic categories (e.g., object, number, and shape) in 10 PWA (fluent and non-fluent) and 10 NHP. All participants were asked to tell two pieces of news to the experimenter. Overall, PWA produced more gestures than NHP. In terms of the different semantic categories, the authors neither found a significant difference between PWA and NHP nor between participants with fluent and non-fluent aphasia. However, participants with fluent aphasia were more vague in conveying main story concepts, Carlomagno and Cristilli (2006) concluded that impaired verbal semantic processing in fluent aphasia could lead to mismatches between impaired speech and unimpaired gesture forms (cf., Butterworth & Hadar, 1989).

Glosser et al. (1986) focused on gestural behaviour in a conversation between the examiner and the participant (either PWA or NHP) in two settings: (1) a face-to-face conversation and (2) a conversation with restricted visual access between the two speakers. Besides observing that all participants (PWA and NHP) produced fewer gestures in the setting with the restricted visual access, there was no significant difference between PWA and NHP in terms of the number of gestures produced. Analysing the different types of gestures, Glosser et al. (1986) found that participants with moderate aphasia used fewer semantically complex gestures than participants with mild aphasia and NHP. In addition, they analysed the spoken language output of all participants and observed a similar behaviour, with participants with moderate aphasia producing fewer syntactically and semantically complex utterances than participants with mild aphasia and NHP. Thus, the authors concluded that gesture production was parallel to language production (see 2.4.1.2.2) and that semantic skills were also visible in gestures.

Further evidence for the semantic hypotheses came from studies that explored the relationship between gesture performance and scores on non-verbal semantic tasks. For example, Hadar, Wenkert-Olenik, et al. (1998) found that participants with low scores on the PPTT (Howard & Patterson, 1992), produced fewer gestures than those who scored higher. There were also differences in the quality of their gestures, in that they were more indistinct. Similar findings emerged from the work of Hogrefe and colleagues (2012; 2013), who used the Bogenhausener Semantik Untersuchung (BoSU; Glindemann, Klintwort, Ziegler, & Goldenberg, 2002) to assess non-verbal semantic processing in aphasia. Again, participants who scored poorly on this test were found to use a restricted range of gestures (Hogrefe et al., 2012), a finding that was replicated by Hogrefe et al. (2013). Furthermore, this study investigated the comprehensibility of gestures especially in severe aphasia. Participants were asked to retell several short video clips in two different conditions: (1) silent condition (i.e., gestures only) and (2) verbal condition (i.e., gesture and speech). To score the comprehensibility of gestures in both conditions, independent raters matched each video retell to the original video clip afterwards. Correlation analysis revealed a relationship between the comprehensibility of the gestures in the silent condition and the non-verbal semantic score (i.e., the lower the non-verbal semantic score, the lower the gesture comprehensibility).

Fucetola et al. (2006) examined the influence of several participant factors (e.g., aphasia severity, specific aspects of language, and working memory) on functional communication as assessed by the Communication Activities of Daily Living-2 (CADL-2; Holland, Frattali, & Fromm, 1998). In terms of semantic processing, they did not assess non-verbal semantic abilities (see above) but applied the semantic probe test of the BDAE-3 (Goodglass, Kaplan, & Barresi, 2001). In this test, participants were shown pictured objects and had to answer questions about their semantic properties (i.e., the function, category, or physical features). The score of this test was related to functional communication which included the use of gestures as well. This link therefore indicated that PWA with lower semantic scores received lower scores on the CADL-2 as well. The influence of semantic processing was even stronger than the influence of aphasia severity.

In their study about the impact of semantic knowledge on the spontaneous production of iconic gestures, Cocks, Dipper, et al. (2013) compared 29 PWA with 29 NHP. Similarly to the studies of Hogrefe and colleagues (2012; 2013), participants were shown short video clips that they were asked to retell to the examiner immediately after watching. Additionally, PWA completed non-verbal semantic tasks for nouns (PPTT; Howard & Patterson, 1992) and actions (Kissing and Dancing Test; KDT; Bak & Hodges, 2003). The data was first divided into gestures produced during fluent speech versus gestures produced during WFD. There was no relationship between the frequency and semantic skills in the former, although participants with better semantic skills produced more semantically rich gestures (i.e., manner) than semantically empty gestures (i.e., path)[18]. There was a relationship between semantic skills and frequency of iconic gestures in WFD, with participants with better semantic skills having a higher proportion of WFD accompanied by gesture. This was in the context of no relationship between semantic skills and either number of WFD or number of resolved WFD.

The results of these studies suggest that semantic processing plays a vital role in both gesture comprehension (formal gesture tasks) and gesture production (spontaneous speech). It seems that effects are particularly pronounced for semantically rich gestures. This is not surprising as semantically rich gestures (i.e., iconic, metaphoric, emblem, and pantomime gestures; see 2.1.2) depict semantic features of lexical affiliates (Hadar, Wenkert-Olenik, et al., 1998) and contain more imageable features than semantically empty gestures (i.e., beat and deictic gestures). These findings are in line with the assumption that when semantic access is intact, gesture processing can proceed, even during instances of WFD. If semantic representations can only be partially accessed, incomprehensible or impoverished gesture may result (cf., Cocks, Dipper, et al., 2013). Applied to gesture production tasks, this would subsequently lead to fewer and/or underspecified semantically rich gestures in participants with poor executive control over semantic processing abilities.

[18] This distinction was made based on the movements depicted by the gestures. As path gestures only indicated the movement of an object in space, they were considered to be semantically light (i.e., semantically empty). Manner gestures, however, depicted the way of the movement or the action. They often included path information as well and were therefore considered to be semantically heavy (i.e., semantically rich).

To find out more about the influence of participant factors on gesture production, PWA will complete a range of verbal and non-verbal semantic tasks in this study (see 5.3.1) which will be correlated against the number and different types of gestures. Gesture types will be grouped into semantically rich and semantically empty gestures, in order to pin down the influence of semantic skills onto different types of gestures. Based on the reviewed studies in this section (e.g., Hadar, Wenkert-Olenik, et al., 1998; Hogrefe et al., 2012; Hogrefe et al., 2013), a relationship between non-verbal semantic processing and the production of semantically rich gestures is expected.

The influences of executive functions and non-semantic cognitive processes on gesture production are reviewed in the following section.

2.4.2.4 Cognition.

Another hypothesis proposes that gesture production is impaired in aphasia because of impaired cognitive processing (e.g., Glosser & Goodglass, 1990; Purdy, 1992, 2002; Purdy et al., 1994; Purdy & Koch, 2006; Yoshihata et al., 1998). In the previous section, studies were reviewed that found an influence of semantic processing abilities on gesture production in aphasia. According to Jackendoff (1983), non-verbal semantic processing cannot clearly be assigned to either language or cognitive processing. In line with other researchers, Corbett et al. (2009) refer to non-verbal semantic processing also as semantic cognition not only in semantic dementia but also in aphasia (e.g., Jefferies & Lambon Ralph, 2006; Lambon Ralph et al., 2007; Rogers et al., 2004). In the current study, cognitive processing is understood to include skills relevant for language processing: (1) Executive function, (2) attention, (3) memory, and (4) visuo-spatial skills. Studies showed that these cognitive processes can be impaired in aphasia as well (e.g., Helm-Estabrooks, 2001; Helm-Estabrooks, 2002). according to Helm-Estabrooks (2002), executive functions are the most vulnerable cognitive functions in aphasia.

Corbett and colleagues (2014; 2009), for example, investigated the link between semantic processing and executive functions (e.g., problem-solving) in aphasia and semantic dementia. Like in semantic processing (see 2.4.2.3), PWA varied in their performance while PWSD remained stable. In fact, the authors found a relationship between executive functions and non-verbal semantic skills in aphasia. Indeed, the link between non-verbal semantic and cognitive processing was highlighted in studies before.

The relationship between gesture comprehension and/or gesture production and cognitive processes has not been studied in as much detail as, for example, limb apraxia or semantic skills. Many studies have investigated cognitive flexibility though, referring to the ability to switch between communication modalities, such as speaking and gesturing. From their results, one can speculate about the influence of cognitive processing on gesture comprehension and production in aphasia.

One of the studies investigating cognitive flexibility was conducted by Purdy et al. (1994) who trained 15 PWA on 20 symbols in three different modalities: (1) communication board (i.e., picture), (2) gesture, and (3) verbal (i.e., word). All symbols were taken from the CADL (Holland, 1980). After having completed the training, participants took part in a structural conversation and a referential communication task to test the symbols. Results revealed that while all participants successfully acquired 80% of the symbols in at least two modalities, they scored only 50% on both communication tasks. Following a cue, their performance could be increased to 85%. The authors concluded, that PWA were disadvantaged in the communication tasks because they were not able to switch between the different modalities. In fact, most frequently they only used the verbal modality to communicate, even though this was the modality participants were least successful on in the training. PWA switched modalities in only 39% of the time. After having switched the modality, in 75% of all cases PWA were successful in communicating their thoughts. The conclusion that Purdy et al. (1994) drew from these findings was that impairments in executive functions or other cognitive processes often prevented PWA from switching between modalities.

Purdy and Koch (2006) followed up on this point and re-analysed the data from their previous study (Purdy et al., 1994). This time, they also took participants' scores on the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948), a test that assesses cognitive flexibility, which is part of executive functioning, into consideration. They found a relationship between participants' ability to switch modalities and their score on the WCST. This supported the hypothesis that impaired executive skills inhibited switching between modalities.

One of the few studies that investigated other cognitive functions (than executive functions) was the single-case study by Bartolo, Cubelli, Della Sala, and Drei (2003). At the same time, this was one of the few studies investigating cognitive processes and the production of gestures. In this case, it was the influence of working memory on the production of gestures in one PWA and 11 NHP that was examined. Gesture production and comprehension were assessed by means of formal gesture production tasks involving pantomime gestures only (see 2.4.1.1). Digit span memory, a maze task, and a dual task consisting of digit span memory and a maze task at the same time were administered to assess participants' working memory. Results revealed that PWA generally scored lower on both gesture and working memory tasks, indicating a potential link between the ability to produce pantomime gestures and working memory skills (cf., Barquero & Logie, 1999; Pearson, Logie, & Gilhooly, 1999).

Investigating cognitive functions in aphasia is challenging as many cognitive assessments include language components that may confound participants' performance. This led Helm-Estabrooks (2002) to develop the Cognitive Linguistic Quick Test (CLQT; Helm-Estabrooks, 2001), a cognitive assessment specifically developed for PWA. This test consists of both linguistic and non-linguistic tasks that assess attention, memory, executive functions, language, and visuospatial skills. Correlation analyses on the standardisation data revealed no relationship between participants' performance on linguistic and non-linguistic subtests indicating that participants' cognitive skills could not be predicted by their linguistic skills.

The studies discussed in this section argued that cognitive skills can be impaired in aphasia, especially executive functions (e.g., Purdy, 1992; Purdy, 2002; Purdy et al., 1994; Purdy & Koch, 2006; Yoshihata et al., 1998). The difficulty of assessing cognitive functions in aphasia led to the development of the CLQT (Helm-Estabrooks, 2001, 2002). Participants in this study will be given the non-linguistic subtests of the CLQT (see 5.3.1). According to Helm-Estabrooks (2001, 2002), this selection of subtests assesses the visuospatial skills only. The tasks have been used in a number of studies involving PWA (e.g., Nicholas, Sinotte, & Helm-Estabrooks, 2005; Nicholas, Sinotte, & Helm-Estabrooks, 2011).

Based on the reviewed studies it is hypothesised that executive functions have an effect on gesture production, especially on successfully applying gestures as a compensatory method for language production in a conversation (see 2.4.4.1). Since measures of executive functions are included in the non-verbal subtests of the CLQT, a relationship between participants' score and their use of gestures is expected, in line with the studies investigating PWA's ability to switch between modalities. Based on the finding that PWA who scored higher on executive assessments were able to switch between modalities, a significant relationship is predicted between participants' score on the CLQT and the number of gestures produced during WFD, especially those that could be resolved (see 2.4.4.3).

2.4.2.5 Relevance for this study.

In this section, different explanations for gesture impairments in aphasia were reviewed and discussed. It included language-related impairments, stroke-related impairments, and other factors that could have an influence on gesture production. There was evidence both for and against all mentioned explanations. As spontaneous co-speech gestures are to be explored, an influence of limb apraxia is not expected, at least on the number of gestures produced. This would be in line with other studies analysing gestures in spontaneous speech (e.g., R. J. Duffy et al., 1984; Macauley & Handley, 2005; Pritchard et al., 2013; Rose & Douglas, 2003). Semantic and cognitive processing is hypothesised to affect gesture, given previous findings. Therefore, participants are assessed on verbal and non-verbal semantic tasks and on non-verbal cognition (i.e., visuospatial skills).

2.4.3 Word-finding difficulties.

Another aspect of language impairment that influences gesture production is impaired word finding. Generally, WFD are a very prominent symptom of aphasia (see 2.3). With gesture playing an important role in the facilitation of TOT states in healthy speech (see 2.1.3.3), several studies have focused on gesture production in aphasic speech in relation to WFD. Different aspects of gesture production in WFD have been investigated, such as (1) increase in gesture production due to WFD and (2) different types of gestures during WFD.

A selection of studies is discussed in this section in order to highlight these aspects (Ahlsén & Schwarz, 2013; Carlomagno et al., 2005; Cocks et al., 2011; Cocks, Dipper, et al., 2013; Hadar, 1991; Hadar, Burstein, Krauss, & Soroker, 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994; Lanyon & Rose, 2009; Pritchard et al., 2013). Even though all studies investigated gesture production in relation to WFD by means of discourse, they employed a range of different types of discourse to elicit gesture production: a semi-structured interview (Hadar, 1991; Hadar & Yadlin-Gedassy, 1994; Lanyon & Rose, 2009), an informal interaction (Ahlsén & Schwarz, 2013), retelling video clips (Cocks et al., 2011; Cocks, Dipper, et al., 2013; Pritchard et al., 2013), a picture description (Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998), and a referential communication task (Carlomagno et al., 2005). Except the study of Lanyon and Rose (2009) who focused on PWA only, all studies compared the performance of PWA to the performance of control participants (i.e., PWBI and/or NHP).

Almost all of these studies came to the conclusion that PWA produced significantly more gestures than NHP due to an increased number of WFD. An exception was the study by Ahlsén and Schwarz (2013) who did not find such an increase. Their study will be discussed in more detail below. That the increase of WFD in aphasia led to an increase in the production of gestures was demonstrated by Cocks, Dipper, et al. (2013) and Pritchard et al. (2013). Cocks, Dipper, et al. (2013) investigated gesture production of 29 PWA and compared their performance to 29 NHP. Next to extensive language tests, participants watched short video clips that they were asked to retell immediately afterwards to the examiner. Overall, they found that PWA produced significantly more gestures than NHP. If, however, one was to take out all gestures that occurred during a WFD[19], there was no longer a significant difference between PWA and NHP. This indicated that the inflated production of gestures in the PWA were largely due to WFD. The authors did not find a relationship between the production of gestures and resolved WFD, indicating that gestures could not facilitate lexical retrieval. These findings are in line with a previous study by Cocks et al. (2011) and were replicated in the study by Pritchard et al. (2013).

Similar findings were produced by Lanyon and Rose (2009) to show that PWA generally used more gesture during a WFD than during fluent speech, hinting towards an important role of gesture production during WFD (see 2.4.4.3). The gestures that occurred during a WFD were most often semantically rich gestures, in this case either iconic, pantomime, or emblem gestures. This is in line with the results of the previously reviewed studies (Cocks et al., 2011; Cocks, Dipper, et al., 2013; Pritchard et al., 2013). Even though semantically rich gestures occurred more often in resolved WFD than in unresolved WFD, this finding was not significant (cf., Cocks et al., 2011; Cocks, Dipper, et al., 2013; Pritchard et al., 2013).

Another aspect of gesture production during WFD is the timing of gesture and the lexical affiliate. This was investigated in the study of Ahlsén (1991). Ten PWA and 10 NHP were included into their study to compare their spontaneous use of gesture with nouns and verbs and in relation to WFD in an informal interaction. Overall, PWA and NHP used similar amounts of gestures with verbs and nouns and the authors did not find a significant difference between PWA and NHP in terms of gesture timing. Instead, they reported that 18% of gesture strokes[20] for PWA and 17% for NHP occurred prior to the

[19] In order to identify a WFD, the Cocks, Dipper, et al. (2013) and Pritchard et al. (2013) applied the definition of a word searching behaviour by Murray and Clark (2006). This definition is used in the current study as well and can be found in 5.4.2.

[20] A gesture stroke is the core of a gesture that carries the meaning. It is the only obligatory part of the different gesture phases: (1) preparation, (2) stroke, (3) hold, and (4) retraction (e.g., McNeill, 1992; McNeill, 2000, 2005).

lexical affiliate indicating a potential facilitative function of gestures. Ahlsén and Schwarz (2013) did not comment on this finding in any detail. In terms of semantic features being captured by gestures, PWA tended to produce more gestures with nouns than with verbs. It is unclear though, whether this (and any other findings) was significant, as statistical tests were not run.

Hadar, Wenkert-Olenik, et al. (1998) (in line with Hadar, 1991; Hadar, Burstein, et al., 1998; Hadar & Yadlin-Gedassy, 1994) explored the role of conceptual processing in gesture production in aphasia. They included 12 PWA into their study. Depending on participants' performance on sentence comprehension, word and phrase repetition, and naming, and their error pattern (e.g., semantic or phonological errors), participants were assigned to one of three groups: (1) a group with conceptual impairments, (2) a group with semantic impairments, and (3) a group with phonological impairments. These three groups were compared to 12 NHP on a picture description task. In general, the groups with primarily semantic and phonologic impairments produced more gestures than the group with primarily conceptual deficits and NHP. According to the authors, the increase in gesture production in the non-conceptual groups (i.e., participants with predominantly semantic and phonologic impairment) could be explained by the high number of WFD experienced by these groups; that is, gestures were produced during WFD in an attempt to facilitate production or convey information in another way (see 2.4.4.3). Hadar and colleagues hypothesised that participants with primarily conceptual deficits were less aware of their WFD and therefore did not always gesture to compensate and/or facilitate when these happened (see 2.4.4.2 and 2.4.4.3).

Part of the reasoning put forward by Hadar and colleagues, was picked up by Carlomagno et al. (2005). In this study, 11 PWA and 25 participants with Alzheimer's type dementia (PWAD) were compared to 18 NHP on completing a referential communication task. The PWA and all PWAD produced significantly more gestures than NHP. The gesture pattern (i.e., the distribution of gesture types) of PWA and the two PWAD who had primarily a lexical-sematic impairment affecting word finding was also the same. This increased gesture rate could be explained as an attempt to use gestures to facilitate lexical retrieval as already suggested by Hadar and Butterworth (1997) and Hadar, Wenkert-Olenik, et al. (1998) (see 2.4.4.3).

The majority of the reviewed studies in this section observed an increase in gesture production in aphasia that was related to an increased number of WFD in comparison to NHP. The studies offer different explanations for this finding. Hadar and colleagues, followed by other researchers (e.g., Ahlsén & Schwarz, 2013; Hadar, 1991; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994; Lanyon & Rose, 2009), argue that gestures facilitate lexical retrieval. In contrast, Cocks and colleagues (Cocks et al., 2011; Cocks, Dipper, et al., 2013; Pritchard et al., 2013) found that the resolution of WFD was unrelated to gesture production.

As the current study is not about training gestures, for example, to overcome WFD, only non-intervention studies were reviewed in this section. Nevertheless, a number of studies have investigated the therapeutic effect of gesture on lexical production. There is cumulative evidence that including gesture cues in word-finding treatment brings about positive outcomes (see Rose, Raymer, Lanyon, and Attard (2013) for a review). Crosson et al. (2007), for example, investigated the effect of gesture production on naming in comparison to watching a visually presented stimulus prior to naming. They came to the conclusion that the first condition led to greater improvement from one treatment phase to the next, suggesting gesture to play a fundamental role in lexical retrieval. Other studies, however, did not find an effect of gesture training and the resolution of WFD. When gesture is treated in isolation rather than in combination with other word-finding cues, benefits for speech production have not been reported (e.g., Caute, 2013; Daumueller & Goldenberg, 2010).

Given previous findings, in this study PWA are expected to experience more WFD than NHP and this is expected to be related to increased gesture production. All WFD will be coded according to their co-occurrence with gesture and their resolution. This will be used to find out more about a potential facilitative function of gestures in WFD (see 2.1.3.3 and 2.4.4.3).

2.4.4 What functions do gestures play in aphasia?

The previous sections discussed the impairments that may increase gesture production in aphasia. In what follows, the functions of gesture in aphasia will be reviewed. 2.1.3 reviewed gesture function in the context of neurologically healthy speech. This highlighted three potential roles of gesture: (1) augmentative, (2) compensatory, and (3) facilitative. These roles will be discussed in relation to aphasia.

2.4.4.1 Augmentative – Gestures accompany speech.

According to the *hand-in-hand hypothesis* (de Ruiter et al., 2012) gestures are produced alongside speech to add information and to supplement communication. Evidence for this account comes from several research studies analysing the gesture production alongside both neurologically healthy language and aphasia. A selection of studies, covering a variety of spontaneous speech samples, such as conversations, referential communication tasks, and video retelling, are reviewed in this section to shed light on the different functions of gesture in aphasia (Ahlsén, 2005; Behrmann & Penn, 1984; Carlomagno et al., 2005; Carlomagno, Zulian, Razzano, De Mercurio, & Marini, 2013; Cicone et al., 1979; Cocks et al., 2011; Cocks, Dipper, et al., 2013; Dipper, Cocks, Rowe, & Morgan, 2011; Glosser et al., 1986; Glosser, Wiener, & Kaplan, 1988; Hadar, Burstein, et al., 1998; Helasvuo, 2004; Hogrefe et al., 2013; Johnson, Cocks, & Dipper, 2013; Klippi, 2015; Kong et al., 2015; Lanyon & Rose, 2009; Le May et al., 1988; Lott, 1999; Mol et al., 2013; Pritchard et al., 2013; Pritchard, Dipper, Morgan, & Cocks, 2015; Rose & Douglas, 2003; Rousseaux, Daveluy, & Kozlowski, 2010; Sekine & Rose, 2013; Sekine et al., 2013; van Nispen, van de Sandt-Koenderman, Mol, & Krahmer, 2014; Wilkinson et al., 2010). Most studies compared the gesture performance of PWA to NHP (Carlomagno et al., 2005; Cicone et al., 1979; Cocks et al., 2011; Cocks, Dipper, et al., 2013; Dipper et al., 2011; Dipper et al., 2015; Glosser et al., 1986, 1988; Hadar, Burstein, et al., 1998; Johnson et al., 2013; Kong et al., 2015; Le May et al., 1988; Lott, 1999; Mol et al., 2013; Pritchard et al., 2013; Pritchard et al., 2015; Rousseaux et al., 2010; Sekine & Rose, 2013; Sekine et al., 2013; van Nispen et al., 2014) and/or others (i.e., PWBI and PWAD) (Ahlsén, 2005; Carlomagno et al., 2005; Hadar, Burstein, et al., 1998). Only a small number of studies did not include any control participants (Behrmann & Penn, 1984; Carlomagno et al., 2013; Helasvuo, 2004; Hogrefe et al., 2013; Klippi, 2015; Lanyon & Rose, 2009; Pedelty, 1987; Rose & Douglas, 2003; Wilkinson et al., 2010).

Almost all studies reported that PWA, like NHP and other control participants, used gestures alongside speech both to augment and to supplement speech. Furthermore, many researchers came to the conclusion that gestures conveyed information that was not conveyed in speech already (e.g., Cocks et al., 2011; Hadar, Burstein, et al., 1998; Kong et al., 2015; Lott, 1999; Pritchard et al., 2015; Wilkinson et al., 2010). In the study of Lott (1999), for example, gesture production of 15 PWA was compared to the gesture production of 15 NHP in a variety of tasks, including an interview with the examiner and a story completion task. Results revealed that especially participants with non-fluent aphasia (e.g., Broca's aphasia) produced gestures to supplement and to complete speech. This is in line with the findings of Wilkinson et al. (2010) who investigated gesture production in conversations with PWA only. They found that PWA used gestures to construct understandable contributions consisting of both speech and gestures. By expressing part of the utterance through gesture, the linguistic structure of the utterance could be simpler than would otherwise be required to communicate a specific thought.

Exceptions to these findings are those of the study by Cicone et al. (1979). In their study, the production of gestures in four PWA and four NHP was compared in an interview situation. Despite observing gesture production alongside speech, the authors did not find additional information being communicated by gesture. In fact, they reported that one of the PWA preferred to switch to writing instead of gesturing when he was not able to verbally articulate his thoughts. Moreover, they came to the conclusion that while speech continued to carry the dominant role in communication in aphasia, gestures only carried secondary reflections over the speech properties. Evidence for this conclusion comes, for example, from observations that PWA preferred to communicate by writing rather than by gesturing when experiencing a WFD.

Some studies also focused on the semantic relationship between gesture and speech (e.g., Carlomagno et al., 2013; Cocks et al., 2011; Cocks, Dipper, et al., 2013; Dipper et al., 2011; Dipper et al., 2015; Sekine & Rose, 2013). Cocks, Dipper, and colleagues (Cocks et al., 2011; Cocks, Dipper, et al., 2013; Dipper et al., 2011; Dipper et al., 2015), for example, investigated the semantic content of iconic gestures in both PWA and NHP. In their studies, participants were shown short video clips that they were asked to retell immediately afterwards to the examiner. Gestures were marked as *path*, *manner*, *shape outline*, or *other*, depending on their action depicted. The authors observed similar semantic form in both gesture and speech for both participants. The most frequent gestures of PWA contained either path or manner information, providing additional information to what was being communicated verbally.

In order to find out more about the motivation for producing gestures, Glosser et al. (1986, 1988) investigated gesture production in PWA and NHP in different conversation settings: (1) Speakers could see each other (e.g., face-to-face conversation or video conference) and (2) speakers could not see each other (e.g., opaque screen between speakers or talking on the phone). In general, they did not find any differences between PWA and NHP (see 2.4.1.2.1). For both groups, gesturing increased when speakers could see each other. This finding led Glosser et al. (1986, 1988) to the conclusion that gestures were primarily produced to transmit information to the conversation partner and only played a secondary role for the speaker himself.

The results of the reported studies in this section are consistent with those of neurologically healthy language, indicating that gestures play an important role in accompanying and augmenting speech. One may argue that this is the primary function of gesture production.

2.4.4.2 Compensatory – gestures replace speech.

An alternative to the *hand-in-hand hypothesis* is the *tradeoff hypothesis* (de Ruiter et al., 2012) according to which, gesturing increases if speaking gets more difficult and vice versa. Studies investigating the compensatory function of gesture production in neurologically healthy language (see 2.1.3.2) came to the conclusion that gesture could take over a certain amount of communication (e.g., gesture system developed by the sawmill workers in British Columbia; Kendon, 1997; Meissner & Philpotts, 1975). Evidence for compensatory gesture production in NHP is sparse, potentially because participants mainly rely on spoken language as long as they can, using gesture only to augment the co-occurring speech. In aphasia, however, the verbal language output may be impaired, leading PWA having to find alternative ways of communication.

A large body of research studies investigated the compensatory functions of gesture production in aphasia applying different methods of natural language production. A selection of these studies is reviewed in this section (Ahlsén, 2005; Ahlsén & Schwarz, 2013; Auer & Bauer, 2011; Beeke, Wilkinson, & Maxim, 2001; Behrmann & Penn, 1984; Carlomagno et al., 2005; Carlomagno et al., 2013; Damico, Wilson, Simmons-Mackie, & Tetnowski, 2008; Dipper et al., 2011; Dipper et al., 2015; Glosser et al., 1986; Helasvuo, 2004; M. Herrmann et al., 1988; Hogrefe et al., 2012; Hogrefe et al., 2013; Johnson et al., 2013; Klippi, 2015; Kong et al., 2015; Lanyon & Rose, 2009; Le May et al., 1988; Lott, 1999; Macauley & Handley, 2005; Mol et al., 2013; Pedelty, 1987; Pritchard et al., 2015; Rose & Douglas, 2003; Rousseaux et al., 2010; Sekine & Rose, 2013; Sekine et al., 2013; van Nispen et al., 2014; Wilkinson, 2013; Wilkinson et al., 2010).

The use of compensatory gestures of PWA was compared to that of NHP (Ahlsén & Schwarz, 2013; Carlomagno et al., 2005; Dipper et al., 2011; Dipper et al., 2015; Glosser et al., 1986; M. Herrmann et al., 1988; Johnson et al., 2013; Kong et al., 2015; Le May et al., 1988; Lott, 1999; Macauley & Handley, 2005; Mol et al., 2013; Pritchard et al., 2015; Rousseaux et al., 2010; Sekine & Rose, 2013; Sekine et al., 2013; van Nispen et al., 2014) and/or other control participants (Ahlsén, 2005; Carlomagno et al., 2005). Again, some studies did not include any control participants at all and focused on PWA only (Auer & Bauer, 2011; Beeke et al., 2001; Behrmann & Penn, 1984; Carlomagno et al., 2013; Damico et al., 2008; Helasvuo, 2004; Hogrefe et al., 2012; Hogrefe et al., 2013; Klippi, 2015; Lanyon & Rose, 2009; Pedelty, 1987; Rose & Douglas, 2003; Wilkinson, 2013; Wilkinson et al., 2010).

The majority of these studies came to the conclusion that gestures could be produced to replace speech in aphasia. Investigating the different types of gestures, it was mainly emblem and pantomime gestures (i.e., gestures that usually occurred without speech; see 2.1.2) that PWA used to communicate their thoughts without speaking (e.g., Beeke et al., 2001; M. Herrmann et al., 1988; Lanyon & Rose, 2009; Sekine & Rose, 2013). Nevertheless, other types of gestures that usually occurred with speech, were used by PWA to replace speech, such as iconic gestures[21] (e.g., Lott, 1999; Wilkinson, 2013).

Wilkinson (2013) conducted a single-case qualitative study applying conversation analysis. By investigating the compensatory use of iconic gestures only, he reported that gestures could function both collaboratively and context-bound. For example, the meaning of a certain gesture may only be able to understood within its sequential context. Furthermore, Wilkinson (2013) observed that conversation partners verbalised their interpretation of the gesture produced by the speaker. These findings led to the conclusion that gestures were an alternative to speech. These findings are in line with those of Pedelty (1987) who investigated the production of gesture in nine PWA in a conversational setting. She found that PWA used gestures to covey ideas or images that could not be conveyed by verbal language. In fact, some of these gestures might actually present richer or more accurate representations of the communicated items than speech and could therefore stand in place of the inaccessible word. The substitution of speech with gesture was further investigated by Auer and Bauer (2011). In their single-case study applying conversation analysis they observed gestures replacing speech as well. However, they came to the conclusion that gestures could not be used like words. In fact, the production of gestures was only successful if they were embedded into a collaborative framework during which the underspecified meaning was established together with the conversation partner, usually by "hinting-and-guessing" (cf., Wilkinson, 2013). Therefore, gestures could not be regarded as a pure substitute for speech.

Hogrefe et al. (2013) suggested that gesture may not be underspecified when they occurred without speech. In their study, 16 participants with severe aphasia were shown short video clips that they were asked to retell to the examiner immediately after watching. Gestures were elicited in two conditions: (1) silent condition and (2) verbal condition. While participants had to communicate the video message by gesture only in the silent condition, they were allowed to use both speech and gestures in the verbal condition. NHP rated the comprehensibility of the gestures by matching the original video clip to the retold video. Interestingly, the gestures produced in the silent condition were significantly easier to comprehend than the gestures in the verbal condition, indicating

[21] By definition, iconic gestures have to co-occur with speech production. In this context, however, iconic gestures are distinguished from pantomime gestures. While iconic gestures are single gesture movements, pantomime gestures can consist of a sequence of gestures depicting a certain situation (Sekine & Rose, 2013; Sekine et al., 2013).

that PWA were indeed able to use gestures for compensation. Furthermore, PWA produced a greater variety of gestures in the silent condition, representing their gesture potential. The fact that gestures were poorly understood in the verbal condition is interesting, particularly as speech production was very impaired for this group. These findings could point towards a problem with integrating gesture production into the production of verbal language. This could be related to an impairment of executive functions preventing PWA from switching between tasks (see 2.4.2.4).

Like Glosser et al. (1986, 1988) who reported a primarily augmentative function of gesture production (see 2.4.4.1), other studies only found limited evidence for a compensatory function of gesture (e.g., Dipper et al., 2011). In their study, Dipper et al. (2011) investigated the semantic content of iconic gestures in one PWA. Analysing the produced gestures in video retell, they observed that gestures often mirrored the semantic content of speech but did not give further information. According to the authors, gestures should carry additional information in order to function as compensatory gestures.

Limited evidence for the *trade-off-hypothesis* also comes from the study by Mol et al. (2013) who investigated the gesture production of 26 PWA and 17 NHP by means of the Scenario Test (van der Meulen et al., 2010). Even though PWA produced both speech accompanying and replacing gestures, these were less informative and complex than the gestures by NHP. Based on this, the authors came to the conclusion that PWA were not able to compensate for their language impairment and that gesture and speech broke down together.

To summarise the findings on gesture compensating for speech, many studies found evidence for PWA being able to replace speech with gesture, at least to some extent. Participants with severe aphasia who have to rely on ways of communication other than speech, were particularly shown to use compensatory gestures, although, these gestures were not always effective (cf., Hogrefe et al., 2013). Based on these observations, it seems to be the case that gesture can serve more than one function, in both impaired and healthy speech. In fact, gesture may even support the speaker. The potential facilitative function of gesture in WFD will be reviewed in the next section.

2.4.4.3 Facilitative – gestures resolve word-finding difficulties.

Many researchers have proposed a facilitative function of gesture, especially in WFD, for both PWA and NHP. Investigating the influence of gesture production in lexical retrieval was proven to be challenging in the past: Many studies applied a restrictive methodology preventing participants from gesturing to hypothesise about the function of gestures (see 2.1.3.3). Only a small number of studies investigated the facilitative function of gesture production in spontaneous speech. One way of finding out more about a potential facilitative function of gesture, is to investigate the temporal relationship between gesture and speech (e.g., Butterworth & Beattie, 1978; de Ruiter, 1998; Kendon, 1972, 1975; McNeill, 1987; Morrel-Samuels & Krauss, 1992; Schegloff, 1984). Researchers applying this methodology in neurologically healthy language observed that the gesture was initiated either before or at the same time of the onset of the lexical affiliate.

Another way of investigating the facilitative function of gestures is to investigate their function in WFD. PWA experience more (obvious) WFD than NHP that may be resolved with the help of gesture. A selection of studies investigating this gesture function in spontaneous speech will be reviewed in this section (Ahlsén, 2005; Ahlsén & Schwarz, 2013; Behrmann & Penn, 1984; Cocks et al., 2011; Cocks, Dipper, et al., 2013; Glosser et al., 1986; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994; Helasvuo, 2004; Kong et al., 2015; Lanyon & Rose, 2009; Le May et al., 1988; Pedelty, 1987; Pritchard et al., 2013).

There is disagreement between researchers as to whether gestures facilitate lexical retrieval or not. While the majority of the studies above agree on gesture being facilitative, only a few studies investigated WFD in aphasia in detail (Ahlsén & Schwarz, 2013; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994; Kong et al., 2015; Lanyon & Rose, 2009). With the exception of Lanyon and Rose (2009), these studies primarily focused on the temporal relationship between gesture and speech (see 2.1.3.3). They concluded that gestures that immediately preceded their lexical affiliates (similar to the findings in NHP) lead to successful lexical retrieval. In addition to this, Hadar, Wenkert-Olenik, et al. (1998) investigated three groups of PWA, all showing either a primarily phonological deficit, a semantic deficit, or a conceptual deficit. In 66% of all WFD that were observed, the gesture immediately preceded the word. However, this was only the case for participants with phonological and semantic deficits. The participants with conceptual deficits produced their gestures even earlier (3-4 words before the lexical affiliate depicted by gesture) but were not able to hold them. The authors therefore concluded that only immediately preceding gestures could successfully facilitate lexical retrieval.

Lanyon and Rose (2009) did not investigate the temporal relationship between gesture and speech. Instead, they analysed the rate of resolution of WFD and whether instances of WFD were accompanied by a gesture in 18 PWA. Results revealed that PWA produced significantly more gestures during WFD than during fluent speech. Moreover, resolved WFD were significantly more often accompanied by a gesture. According to Lanyon and Rose (2009), this meant that gestures served as cross-modal prime and facilitated lexical retrieval.

These findings could not be replicated in the studies of Cocks, Pritchard, and colleagues (Cocks et al., 2011; Cocks, Dipper, et al., 2013; Pritchard et al., 2013) though. While all PWA gestured during WFD, co-occurring gestures did not automatically lead to the resolution of the WFD. In fact, PWA produced a large number of WFD that could not be resolved despite producing a co-occurring gesture. The authors therefore concluded that gesturing during WFD was not a successful strategy to overcome difficulties in lexical retrieval.

Researchers do not agree on whether there is a facilitative function of gesture in lexical retrieval in aphasia. Many researchers found an increased number of gesture production due to WFD in aphasia (see 2.4.3) which could indicate a facilitative function in gesture production. Furthermore, studies investigating the temporal relationship between gesture and speech observed that gestures either occurred with the word or immediately prior to it. This led them to conclude that gesture production supported the speaker by facilitating lexical retrieval (e.g., Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994). But only Lanyon and Rose (2009) found a positive relationship between gesture production and the resolution of WFD.

2.4.4.4 Summary.

Similar to the studies investigating the functions of gesture in neurologically healthy language (see 2.1.3), the studies including PWA found evidence for gesture supporting speech (augmentative gestures) and replacing speech (compensatory gestures). Difficult to test was the facilitative function of gesture in lexical retrieval and only one of the reviewed studies found evidence that gestures helped to resolve WFD. In order to find out more about gesture function, in this study, semantically rich gestures will be coded into three categories: (1) Augmentative gestures that occur during fluent speech, (2) compensatory gestures that occur without speech, and (3) facilitative gestures that occur during resolved WFD. A fourth category will be introduced to cover gestures that occurred during unresolved WFD, these are communicative gestures (see 5.4.3.2 for more details).

Based on the findings of previous studies, it is expected that both augmentative and compensatory gestures will be produced by PWA and NHP. The number of compensatory gestures is expected to be higher in PWA than in NHP. The distribution of facilitative and communicative gestures is challenging to predict. It is expected that NHP will produce fewer communicative gestures (i.e., during unresolved WFD) than PWA.

2.4.5 Gesture processing in aphasia.

In the previous sections, gesture production in aphasia, its potential impairment and functionality in spontaneous speech were discussed. As mentioned earlier (see 2.1), gestures play an important role in everyday language and are used frequently by speakers with neurologically healthy language. Gestures can, for example, add information to what is said, that is, they augment speech (de Ruiter et al., 2012; Kendon, 2000; McNeill, 2000; So et al., 2009). Gestures can also increase when speaking gets more difficult, for example, in a noisy environment. In that case, gestures can compensate or even replace speech (Bangerter, 2004; de Ruiter, 2006; de Ruiter et al., 2012; Melinger & Levelt, 2004; van der Sluis & Krahmer, 2004, 2007). Finally, gestures can help to facilitate lexical retrieval, for example, during WFD (Krauss et al., 2000). These functions indicate a close relationship between gesture and speech, a relationship that has been delineated by different processing models. de Ruiter and de Beer (2013) suggested that one can roughly distinguish between two hypotheses/models: (1) the **Interface Hypothesis** (de Ruiter, 2000; Kita & Özyürek, 2003; McNeill, 1992; McNeill & Duncan, 2000) and (2) the **Lexical Facilitation Model** (Krauss et al., 2000). These two models were described briefly with data of NHP in 2.1.4. Nevertheless, some functions of healthy language and gesture often remain unknown or disputed. One way to illuminate disputed areas is to investigate speech and gesture production in those with impaired language, such as aphasia. Here, the functioning of one half of the system (i.e., the gesture stream) can be explored when the other half (i.e., the language formulator) is impaired. Evidence of preserved gesture, for example, might underscore the independent operation of the gesture stream and illuminate the degree to which the augmentative and compensatory functions of gesture are retained when language is impaired. Despite potential independency of gesture and language production, it may be the case that impaired language may have an influence on the way gestures are implemented into speech. Earlier studies, for example, came to the conclusion that PWA used more gestures instead of speech (i.e., compensatory gestures) than NHP (e.g., Goodwin, 1995; Goodwin, 2000; M. Herrmann et al., 1988; Rousseaux et al., 2010; Wilkinson et al., 2010). The type of gesture produced may also be influenced by impaired language. PWA may, for example, use more semantically rich gestures to augment and compensate than NHP. Conversely, in cases of impaired semantics (see 2.4.2.3) or cognition (see 2.4.2.4), they may not be able to successfully implement gesture into their speech. PWA experience more frequent and prolonged WFD than NHP, and it is likely that their WFD are more difficult to resolve. Here, the relationship between gesture and WFD resolution may be more transparent, for example, because there are more instances to analyse or because resolution is a lot less automatic.

2.5 Summary

The majority of the studies reviewed in this chapter came to the conclusion that the spontaneous production of gestures alongside speech is a prominent feature of healthy communication. People use different types of gestures to facilitate, supplement, and/or replace speech. Additionally, speakers adapt their language depending on the topic they are talking about and depending on their conversation partner. For example, all participants used more formal language when talking to an unfamiliar conversation partner than when talking to someone familiar. Studies showed that participants with impaired language processing, such as in aphasia, use spontaneous gestures to communicate as well. Nevertheless, they found quantitative and qualitative differences between the gesture production of PWA and NHP. Overall, PWA produce more gestures than NHP. However, the fluency of speech does also have an influence on the number of gestures. This overall increase in gesture production may be due to impaired lexical access in aphasia. PWA may use gestures to facilitate lexical retrieval. Qualitative differences between the gestures produced by PWA and NHP could be explained by impaired semantics, making PWA unable to retrieve all necessary sematic features in order to produce clear gestures. Impaired cognition may also affect gesture production, for example, by impairing their ability to switch between modalities. This is necessary in order to successfully use gestures as a compensatory modality.

Chapter 3 Systematic literature review

3.1 Background

The narrative review of the literature has established main themes relating to gesture production in aphasia. It has further enabled the formulation of preliminary research questions and hypotheses. The systematic literature review aimed to determine the degree to which these preliminary questions have been addressed in previous literature. Questions addressed by the review were:

(1) Did studies investigate different conversation partners of PWA?
(2) Did studies use different types of conversation/discourse to investigate gesture production?
(3) If studies investigated the effect of conversation partner and/or topic on gesture production, did they have an influence on the number or type of gesture produced?
(4) Did studies investigate the functions of gesture? Did they find evidence that gestures facilitated lexical retrieval, augmented speech, and/or compensated for the language impairment?

3.2 Methods

This review follows established methods for conducting and reporting systematic literature reviews (Liberati et al., 2009; Mohrer, Liberati, Tetzlaff, Altman, & Group, 2009).

3.2.1 Eligibility criteria.

For a study to be eligible for inclusion in the systematic review, it had to report research data on the use of gesture in aphasia after stroke, in the context of conversation or discourse. Only studies in English, German, and Dutch were included. Participants had to be at least 18 years old; no other exclusion criteria such as severity or type of aphasia, co-morbidities, age, sex, or setting were applied, nor was there any restriction on publication date, geographical location, or study design.

3.2.2 Sources of information and search strategy.

Electronic searches of the following databases were conducted in the beginning of August 2015 using the EBSCOhost platform: Academic Search Complete, CINAHL Plus with Full Text, Communication Source, eBook Collection (EBSCOhost), E-journals, MEDLINE Complete, PsycARTICLES, PsycINFO, and SocINDEX with Full Text.

Search terms were: (gestur* OR multimodal communication OR total communication) AND (stroke OR aphas* OR dysphas*) AND (conversation* AND discours*).

3.2.3 Data collection.

Irrelevant articles were excluded by screening titles and abstracts. The remaining studies were fully reviewed. As this systematic review was part of a PhD project, there were no resources to re-review a percentage of the papers by another person.

A codified critical appraisal framework, such as the CASP (Critical Appraisal Skills Programme; 2013) did not work for the reviewed papers, as the range of the study designs could not be captured by one checklist. Instead, the study design and type of data analysis are simply described in 3.3.2.

3.2.4 Data coding.

Almost every study used their own terminology in terms of the conversation partner, the topic of the spontaneous speech sample, the types of gestures investigated and of the role that gestures could take. Therefore, all relevant studies were coded on these four parameters in order to be able to compare them.

The conversation partner (CP) was classified in terms of the familiarity with the participant. Therefore, coding distinguished between familiar conversation partners (FCP) and unfamiliar conversation partner (UFCP). Family members (e.g., partner and son/daughter) or friends were categorised as FCP. Any other conversation partner who was neither family member nor friend was categorised as UFCP. Conversation partners that could not be allocated to either group were coded as *other*.

For the topic of the conversation/discourse, studies were either coded as narrative (N) or procedural (P) or both. Narrative speech samples were defined as “spoken or written account of connected events” or as “story” according to the Concise Oxford English Dictionary (Soanes & Stevenson, 2004). A procedural topic was described as “series of actions conducted in a certain order or manner” (Soanes & Stevenson, 2004). The topic of studies which included spontaneous speech samples that could not be coded as either N or P was described as *unspecified*[22].

The types of gestures explored in the studies were categorised as either semantically rich gestures (SR) or semantically empty gestures (SE). Semantically rich gestures were gestures that directly depicted semantic content (e.g., iconic, metaphoric, emblem, and pantomime gestures) while semantically empty gestures did not. Instead, they could stress parts of the utterance (e.g., beat gestures) or refer to a location (e.g., deictic/pointing gestures). Gesture types that could not be defined or which were unspecified in the paper, were coded as *other* or *unspecified*.

In terms of different functions of gestures, studies were either coded as: A (augmentative), C (compensatory), or F (facilitative) or a combination. Augmentative gestures were gestures that occurred co-speech and either added to or complimented what was said verbally. They supplemented speech. Compensatory gestures also added information but occurred without speech. They were produced to replace speech; in the case of aphasia, they were produced to compensate for the language impairment. Finally, facilitative gestures facilitated speech production, for example, they occurred during a WFD and helped the speaker to retrieve the word. Not all studies investigated and/or reported on gesture functions that fit the above categories. These studies were coded as *other*.

3.3 Results

3.3.1 Results of the search.

All searches were at abstract level. 250 references were found; after automatic deduplication 100 references remained and after manual deduplication a further of seven studies were excluded, leaving 93 references. 27 studies were additionally identified through other sources (e.g., hand-searching). Therefore, 120 studies were screened according to their title and abstract (see Figure 3.1).

[22] This also included unconstrained conversations, such as analysing the conversation of PWA and SLT during a therapy session (Damico et al., 2008).

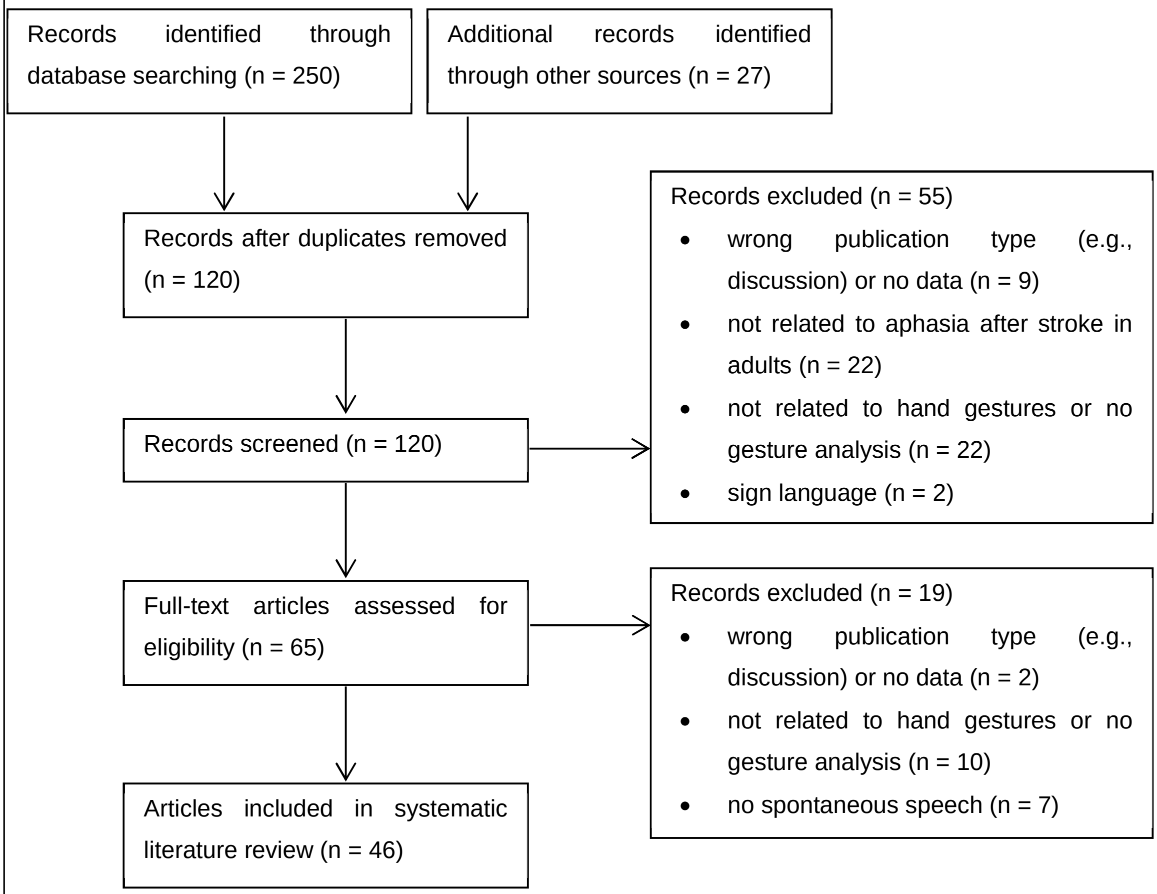

Figure 3.1. ***Flowchart of the review process.***

Fifty-five studies (45.83%) were excluded as they (1) were of the wrong publication type or did not present data (n = 9), (2) were not related to aphasia after stroke (n = 22), (3) did not investigate hand gestures or did not include a gesture analysis (n = 22), or (4) investigated sign language (n = 2). For the remaining 65 studies, full text articles were retrieved and screened against the inclusion criteria. Further articles were excluded because they (1) were of the wrong publication type or did not present data (n = 2), (2) did not investigate hand gestures or did not include a gesture analysis (n = 10), or (3) did not investigate spontaneous speech samples (n = 7). This left 46 studies to be included into the review.

3.3.2 Study characteristics.

Of the remaining 46 studies, 95.66% (n = 44) were published in peer-reviewed journals while two studies were part of PhD-projects (Lott, 1999; Pedelty, 1987). Most peer-reviewed studies were published in *Aphasiology* (n = 8; 17.39%), followed by those published in *Clinical Linguistics and Phonetics* and *Brain and Language* (both n = 5; 10.87%).

Only 32.61% (n = 15) of the studies were published between 1979 and 1999 (n = 15) while the majority (n = 41; 67.39%) were published between 2001 and 2015, with 23.91% (n = 11) being published in 2013 alone.

In terms of the number of PWA investigated, there was huge variation with mainly low participant numbers. Most studies recruited <11 participants (n = 29; 63.04%) with seven studies investigating individual PWA only (15.22%). The remaining studies analysed gesture production in 11-20 PWA (n = 7; 15.22%) and more than 20 PWA (n = 10; 21.74%). This goes in line with the different designs that were applied to conduct the studies. 16 studies (34.78%) used a small group design (SG; <11 PWA), 12 studies (26.09%) a medium group design (MG; 11-40 PWA), and five studies (10.87%) a large group design (LG; >40 PWA). Seven papers (15.22%) used single case studies (SC; 1-2 PWA depending on the data analysis) to investigate gesture production and conversation analysis (CA; 1-7 PWA) was used to analyse the data of seven studies (15.22%). One study (Carlomagno et al., 2005) conducted a medium group study before using a single case design to describe individuals in more detail. In line with these study designs, one can distinguish between quantitative and qualitative data analysis. All group studies (SG, MG, LG) and single-case studies applied quantitative data analysis while the studies with CA used qualitative analysis to find out more about gesture production in aphasia. Of the 39 studies using quantitative data analysis, 35 studies (76.09%) applied statistical analysis as well. The remaining four studies described their collected data descriptively without any statistical analysis (8.79%). This was mainly due to a small sample size.

Thirty-one studies (67.39%) assessed language skills of PWA in addition to gesture production, 39.13% (n = 18) included motor skills assessments as well. Cognitive skills were only assessed by 8.70% (n = 6). Ten studies (21.74%) did not include assessments of any kind.

The majority of the studies compared gesture production of PWA with gesture production of NHP (n = 31; 67.39%) while 10 studies (21.74%) did not include any comparison. 10.87% (n = 5) compared the gesture performance of PWA to participants with other forms of brain damage (e.g., traumatic brain injury and Alzheimer’s type dementia). Four studies (8.70%) compared gesture production in PWA to both NHP and participants with other brain damage.

These characteristics alongside the answers to the questions of this review (see 3.1) are summarised in Table 3.1:

Table 3.1. *Systematic literature review.*

Study	PWA	Comparisons		Assessments			Design	Ana-lysis	Statis-tics	Task/s	Questions			
	N	PWA NHP	PWA Other	Lang.	Mot.	Cog.					CP	Topic/s	Gesture type/s	Gesture function
Cicone et al. (1979)	4	✓	X	x	x	x	SG	quant	✓	interview	UFCP	N, P	SR, SE	A
Prinz (1980)	3	✓	X	✓	x	x	SG	quant	x	conversation, reaction	UFCP	N	SR, SE	*unspeci-fied*
Feyereisen (1982)	10	✓	✓	x	x	x	SG	quant	✓	conversation	UFCP	N	SR, SE	Other
Feyereisen (1983)	10	✓	✓	x	x	x	SG	quant	✓	conversation	UFCP	N	SR, SE	A, C, F
Behrmann and Penn (1984)	11	x	x	✓	x	x	MG	quant	x	conversation, process description	UFCP	N, P	*unspecified*	A, C (F)
Glosser et al. (1986)	10	✓	x	✓	x	x	SG	quant	✓	interview	UFCP	N	SR, SE	A, not C, not F
Pedelty (1987)	9	x	x	✓	✓	✓	SG	quant	✓	conversation	UFCP	N	SR, SE	A, C, F
Glosser et al. (1988)	10	✓	x	✓	x	x	SG	quant	✓	interview	UFCP	N	SR, SE	A
M. Herrmann et al. (1988)	7	✓	x	✓	x	x	SG	quant	✓	conversation	FCP	N	SR	C
Le May et al. (1988)	7	✓	x	✓	x	x	SG	quant	✓	conversation, picture description	UFCP	N	SR, SE	A, C, F
Hadar and Yadlin-Gedassy (1994)	2	✓	x	✓	x	x	SG	quant	✓	interview	UFCP	N	SR	F
Foundas et al. (1995)	8	✓	x	✓	✓	x	SG	quant	✓	conversation	UFCP	N, P	SR, SE	Other
Hadar, Burstein, et al. (1998)	4	✓	✓	✓	✓	✓	SG	quant	✓	conversation, picture description	UFCP	N	SR, SE	A, F

Table 3.1. *Systematic literature review* (*continued*).

Study	PWA	Comparisons		Assessments			Design	Analysis	Statistics	Task/s	Questions			
	N	PWA NHP	PWA Other	Lang.	Mot.	Cog.					CP	Topic/s	Gesture type/s	Gesture function
Hadar, Wenkert-Olenik, et al. (1998)	12	✓	x	✓	x	✓	MG	quant	✓	conversation, picture description	UFCP	N	SR, SE	F
Lott (1999)	15	✓	x	✓	x	x	MG	quant	✓	interview, storytelling, picture description, story completion	UFCP	N	SR, SE	A, C
Beeke et al. (2001)	2	x	x	x	x	x	CA	qual	x	conversation	FCP, UFCP	N	SR	C
Rose and Douglas (2003)	7	x	x	✓	✓	x	SG	quant	✓	conversation	UFCP	N	SR	A, C
Helasvuo (2004)	5	x	x	x	x	x	CA	qual	x	conversation, therapy session	FCP, UFCP	N	SR, SE	A, C, F
Ahlsén (2005)	1	x	✓	✓	x	x	SC	quant	x	role-play	UFCP	N	SR	A, C, F
Carlomagno et al. (2005)	11	✓	✓	x	x	x	MG, SC	quant	✓	referential communication task, picture description	UFCP	N	SR, SE	A, F (C)
Macauley and Handley (2005)	12	✓	x	✓	✓	x	MG	quant	✓	conversation	UFCP	N	SR, SE	A, C, F
Carlomagno and Cristilli (2006)	10	✓	x	x	x	x	SG	quant	✓	news retelling	UFCP	N	SR, SE	*unspecified*
Damico et al. (2008)	1	x	x	x	x	x	CA	qual	x	therapy session	UFCP	*unspecified*	SR, SE	C
Lanyon and Rose (2009)	18	x	x	✓	✓	x	MG	quant	✓	interview	UFCP	N	SR, SE	A, C, F

Table 3.1. ***Systematic literature review*** *(continued)***.**

Study	PWA	Comparisons		Assessments			Design	Analysis	Statistics	Task/s	Questions			
	N	PWA NHP	PWA Other	Lang.	Mot.	Cog.					CP	Topic/s	Gesture type/s	Gesture function
Rousseaux et al. (2010)	63	✓	x	✓	x	x	LG	quant	✓	interview, discussion, PACE	UFCP	N, P	SR, SE	A, C
Wilkinson et al. (2010)	4	x	x	x	x	x	CA	qual	x	conversation	FCP, UFCP	N	SR	A, C
Auer and Bauer (2011)	1	x	x	x	x	x	CA	qual	x	conversation	FCP	N	SR, SE	C, other
Cocks et al. (2011)	1	✓	x	✓	✓	x	SC	quant	✓	video retelling	UFCP	N	SR	A, not F
Dipper et al. (2011)	1	✓	x	✓	✓	x	SC	quant	x	video retelling	UFCP	N	SR	A (C)
Hogrefe et al. (2012)	24	x	x	✓	✓	x	MG	quant	✓	video retelling	UFCP	N	other	C
Ahlsén and Schwarz (2013)	10	✓	x	✓	x	x	SG	quant	x	conversation, narration	UFCP	N	SR, SE	C, F
Carlomagno et al. (2013)	2	x	x	✓	x	x	SC	quant	✓	PACE, referential communication task	UFCP	N	SR, SE	A, C
Cocks, Dipper, et al. (2013)	29	✓	x	✓	✓	x	MG	quant	✓	video retelling	UFCP	N	SR	A, not F
Hogrefe et al. (2013)	16	x	x	✓	✓	x	MG	quant	✓	video retelling	UFCP	N	*unspecified*	A, C
Johnson et al. (2013)	3	✓	x	✓	✓	✓	SG	quant	✓	process descriptions	UFCP	P	SE	C (A)
Kong, Law, Wat, and Lai (2013)	48	✓	x	x	✓	x	LG	quant	✓	monologue, process description, story telling	UFCP	N, P	SR, SE	*unspecified*
Mol et al. (2013)	26	✓	x	✓	X	x	MG	quant	✓	Scenario test	UFCP	N	SR, SE	A (C)
Pritchard et al. (2013)	1	✓	x	✓	✓	x	SC	quant	✓	video retelling	UFCP	N	SR	A, not F

Table 3.1. *Systematic literature review* *(continued)*.

Study	PWA	Comparisons		Assessments			Design	Analysis	Statistics	Task/s	Questions			
	N	PWA NHP	PWA Other	Lang.	Mot.	Cog.					CP	Topic/s	Gesture type/s	Gesture function
Sekine et al. (2013)	46	✓	x	✓	x	x	LG	quant	✓	interview	UFCP	N	SR, SE	A, C
Sekine et al. (2013)	46	✓	x	✓	x	x	LG	quant	✓	interview	UFCP	N	SR, SE	A, C
Wilkinson (2013)	1	x	x	✓	x	x	CA	qual	x	conversation	UFCP	N	SR (without speech)	C
van Nispen et al. (2014)	1	✓	x	✓	✓	x	SC	quant	✓	video retelling	UFCP	N	SR, SE	A, C
Dipper et al. (2015)	29	✓	x	✓	✓	x	MG	quant	✓	video retelling	UFCP	N	SR	A, C, not F
Klippi (2015)	7	x	x	✓	x	x	CA	qual	✓	conversation	UFCP, other	N	SE	A, C
Kong et al. (2015)	48	✓	x	✓	✓	x	LG	quant	✓	story retelling, process description	UFCP	N, P	SR, SE	A, C, F
Pritchard et al. (2015)	29	✓	x	✓	✓	x	MG	quant	✓	process description	UFCP	P	SR	A, C

Note. N = number or participants; PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; Lang. = language; Mot. = motor; Cog. = cognition; SG = small group; MG = medium group; LG = large group; SC = single case; CA = conversation analysis; quant = quantitative; qual = qualitative; CP = conversation partner/s; FCP = familiar conversation partner; UFCP = unfamiliar conversation partner; N = narrative; P = procedural; SR = semantically rich gestures; SE = semantically empty gestures; A = augmentative; C = compensatory; F = facilitative.

3.3.3 Questions.

There were four parameters that were of interest:

1. *Conversation partner*: FCP or UFCP
2. *Type of topic*: narrative or procedural
3. *Types of gestures*: semantically rich or semantically empty gestures
4. *Functions of gestures*: augmentative, compensatory, or facilitative

3.3.3.1 Conversation partner

Forty-four studies included an unfamiliar conversation partner (95.65%) with either the examiner/researcher or a speech and language therapist (SLT) playing this role. Only five studies investigated gesture production in a conversation with a familiar conversation partner (10.87%). One study included a group setting as well (2.17%). Only three studies included both a familiar and an unfamiliar conversation partner (6.52%) (Beeke et al., 2001; Helasvuo, 2004; Wilkinson et al., 2010)[23]. None of these studies investigated the influence of different conversation partners on gesture production.

3.3.3.2 Type of topic

Almost all studies (n = 43; 93.48%) investigated narrative topics (i.e., conversations about stroke or everyday life and video/story retelling). A small number of studies analysed procedural topics (n = 8; 17.39%) (e.g., describing how to make a cup of tea or how to change a tyre) (Behrmann & Penn, 1984; Cicone et al., 1979; Foundas et al., 1995; Johnson et al., 2013; Kong et al., 2013, 2015; Pritchard et al., 2015; Rousseaux et al., 2010). Damico et al. (2008) examined gesture production of a PWA during a therapy session. They did not specify the type of discourse that took place during that session. Therefore, this was coded as *unspecified*. Six studies (13.04%) investigated both types of topics and examined the influence on gesture and language production (Behrmann & Penn, 1984; Cicone et al., 1979; Foundas et al., 1995; Kong et al., 2013, 2015; Rousseaux et al., 2010). No studies compared the influence of the two different topics on gesture production.

3.3.3.3 Types of gestures

Only Wilkinson (2013) focused on gestures that only occurred without speech while all other studies (n = 45; 97.83%) included co-speech gestures as well. Of all studies, 89.13% (n = 41) investigated semantically rich gestures. Semantically empty gestures

[23] Please note that adding up the percentages often goes beyond 100% due to studies investigating more than one option.

were explored by 63.04% (n = 29). Only three studies followed another classification system (n = 1; 2.17%) or did not give any details on gesture classification (n = 2; 4.35%). A large number of studies (n = 28; 60.87%) investigated both semantically rich and semantically empty gestures. Of these studies, eight (17.39%) reported that PWA used more semantically rich than semantically empty gestures (Ahlsén & Schwarz, 2013; Carlomagno et al., 2005; Cicone et al., 1979; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Lanyon & Rose, 2009; Sekine & Rose, 2013; van Nispen et al., 2014), three (6.52%) found the opposite (i.e., PWA used more semantically empty than semantically rich gestures) (Kong et al., 2015; Macauley & Handley, 2005; Mol et al., 2013), and two (4.35%) did not find a difference between the two gesture groups (Carlomagno et al., 2013; Lott, 1999). Twelve studies (26.09%) did not include a comparison of semantically rich and semantically gestures at all. The remaining three studies (6.52%) compared the use of semantically rich and semantically empty gestures in different participant groups, like PWA versus NHP (Glosser et al., 1986) and/or participants with different types of aphasia (Pedelty, 1987; Sekine et al., 2013). While Glosser et al. (1986) observed similar gesture production in PWA and NHP, Sekine et al. (2013) found that PWA produced more gestures than NHP. Furthermore, they found different patterns of gesture production within the PWA, depending on the type of the aphasia. For example, participants with Broca's aphasia produced many iconic, pantomime, and emblem gestures. This finding was in line with Pedelty (1987).

3.3.3.4 Functions of gestures

Augmentative gestures occurred alongside fluent speech and added information to what is expressed verbally. They were identified in 31 studies (67.39%). Almost as many studies (n = 29; 63.04%), especially those including participants with severe and/or non-fluent aphasia, identified compensatory gestures that replaced speech (e.g., M. Herrmann et al., 1988; Hogrefe et al., 2012; Lanyon & Rose, 2009; Rose & Douglas, 2003). 41.30% of all studies (n = 19) investigated the facilitative function of gesture production, especially in lexical retrieval. While 13 studies (28.26%) found gestures to be facilitative, four studies (8.70%) did not find a significant difference between resolved and unresolved WFD that were accompanied by gesture (n = 4) (Cocks et al., 2011; Cocks, Dipper, et al., 2013; Dipper et al., 2015; Pritchard et al., 2013). The authors of the remaining two studies (4.35%) that investigated the facilitative function of gesture production, either excluded this function of gesture due to gesture indicating a central symbolic impairment (see 2.4.2.1; n = 1) (Glosser et al., 1986) or produced inconclusive findings and hence called for further research (Behrmann & Penn, 1984). About half of all studies (n = 25; 54.35%) identified more than one function that gestures took in spontaneous speech, with eight (17.39%) studies identifying all three functions of gestures (Ahlsén, 2005; Feyereisen, 1983; Helasvuo, 2004; Kong et al., 2015; Lanyon & Rose, 2009; Le May et al., 1988; Macauley & Handley, 2005; Pedelty, 1987). The results of two studies (4.35) could not be classified, as no gesture functions were described (n = 2) (Feyereisen, 1982; Foundas et al., 1995) and three further studies (6.52%) did not give enough information in order to do so (n = 3) (Carlomagno & Cristilli, 2006; Kong et al., 2013; Prinz, 1980).

3.4 Discussion

3.4.1 Summary of main findings.

The reviewed studies included a variety of conversation partners, although most involved a UFCP who was either the examiner/researcher or a SLT. Some of the studies involved more than one conversation partner but did not compare their influence on gesture production. Gesture production was investigated by means of different topics, with the majority focusing on narrative conversations or discourses. Some studies used procedural discourses but only few of them did both. Again, the influence of the topic on gesture production was not investigated. Almost every study classified semantically rich gestures (i.e., gestures that depicted speech content). Semantically empty gestures were investigated by a large number of studies too. In order to compare the results of the studies, function of gestures was coded into augmentative, compensatory, facilitative, and other/unspecified. Most studies reported uses of gestures that supplemented speech, that is, they served an augmentative function. A similar number of studies identified compensatory gestures that replaced spoken language. Fewer studies explored the facilitative function of gestures in spontaneous speech (n = 19; 41.30%) and even fewer studies concluded that this was occurring (n = 13; 28.26%). About half of all studies reported more than one gesture function.

3.4.2 Quality of the evidence.

Limited details on the characteristics of the participants, especially of the PWA made it difficult to compare these studies. For example, there was wide variation in the time post-stroke, from one week to several years. The studied participants also varied in the severity of their language impairment (very severe to residual aphasia) and in whether co-morbidities (i.e., motor and cognitive skills) were assessed.

Inter-rater reliability of the coding used in this review could not be checked, giving rise to a potential risk of bias.

Despite these issues, this systematic review highlighted a number of issues which are of interest and need to be explored further. The results of this review will be discussed against the four parameters that were of interest: (1) conversation partner, (2) type of topic, (3) type of gestures, and (4) functions of gestures.

3.4.2.1 Conversation partners

This review shows that the influence of the CP in gesture production has not been explored. Language analyses have shown that a FCP elicits less formal and elaborated speech than a UFCP (e.g., T. Herrmann, 1983; S. E. Williams et al., 1994). Given the tight interrelationship between speech and gesture, a similar impact of conversation partner on gesture production might be hypothesised. For example, a FCP may elicit fewer gestures or a different distribution of gesture types than a UFCP. Shared knowledge between familiar partners may also affect gesture production. To date, these predictions have been tested only in NHP, with null results (Bortfeld et al., 2001) (see 2.2.2 and 2.2.3). The case for aphasia has not been explored (see 2.2.4).

3.4.2.2 Types of topic

The majority of studies investigated narrative topics in conversation and/or discourse and none compared narrative and procedural topics with respect to gesture performance. Analyses of these different discourse types (e.g., Ulatowska et al., 1990; Ulatowska & Bond, 1983) suggest, that there will be a difference in gesture production. Since procedural topics mainly aim to inform and to instruct, they elicit more object-related, concrete language than narrative topics. With gesture and language production being closely related (see 2.1.4) it is expected that procedural topics would elicit more semantically rich gestures (see below) than narrative topics (see 2.2.1).

3.4.2.3 Types of gestures

Except Wilkinson (2013), who investigated speech-replacing gestures only, all studies distinguished between different types of gestures that occurred with and without speech. But gestures cannot only be divided according to their occurrence with or without speech. They can also be grouped according to their semantic meaning, for example, semantically rich versus semantically empty gestures. Distinguishing between semantically rich and semantically empty gestures sheds light on the impairment of the semantic system and its influence on gesture production in aphasia. The influence of semantic skills (both verbal and non-verbal) on the production of semantically rich gestures has been in the focus of many recent research studies (e.g., Cocks, Dipper, et al., 2013; Dipper et al., 2015; Hogrefe et al., 2012; Hogrefe et al., 2013). These studies found that participants with lower semantic skills also produced fewer semantically rich gestures than those with higher semantic skills and NHP. Other studies have identified fewer semantically complex gestures in PWA in general but did not correlate that with participants' semantic skills (e.g., Ahlsén & Schwarz, 2013; Auer & Bauer, 2011), while another group of studies came to the conclusion that PWA were not able to produce the full range of gestures, including semantically rich gestures (Mol et al., 2013; van Nispen et al., 2014).

In this review, almost all studies investigated semantically rich gestures, with fewer identifying semantically empty gestures. Nevertheless, over half of all reviewed studies distinguished between gestures that were semantically rich and semantically empty. Not all of these compared participants' performance on these different gesture types though. When the comparison was made, most studies agreed that PWA produced more semantically rich than semantically empty gestures (n = 8; 17.39%). The fact that these studies came to the same result despite the varying participant characteristics (i.e., severity and type of aphasia) makes this finding even more striking.

3.4.2.4 Functions of gestures

All studies in this review identified at least one reason why PWA and (in some cases) NHP used gestures. Gestures can accompany speech in which case they typically add information to what is said or augment speech. This gesture function was most reliably confirmed. Thirty-one studies (67.39%) found that PWA used gesture in this way and none contested the augmentative function of gesture. Gestures can also replace speech and consequently compensate for the language impairment in aphasia. Similar to the augmentative function of gesture production, studies widely agreed on this function as well. Twenty-nine studies (63.04%) described gestures being used in this way. An exception was the study by Glosser et al. (1986) who found no evidence that gestures were compensating for the language impairment. This was in line with their hypothesis that gesture and language in aphasia break down together so that one cannot take over the role of the other (cf. central symbolic impairment; see 2.4.2.1). Finally, 19 studies (41.30%) investigated the facilitative function of gestures, but only 13 studies (28.26%) found evidence for gestures facilitating speech production. Interestingly, most studies that investigated the facilitative function in detail, for example, by examining the co-occurrence of gesture with WFD and whether or not those difficulties were resolved excluded this role (Cocks et al., 2011; Cocks, Dipper, et al., 2013; Dipper et al., 2015; Pritchard et al., 2013). Exceptions are the studies of Hadar and colleagues (Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994). They explored facilitation by examining the temporal relationship of gesture and speech production. The authors found that gestures often preceded speech and concluded therefore that gesture facilitated lexical retrieval.

3.5 Conclusions

The current review revealed huge methodological variation in terms of how to elicit spontaneous gesture production and which participants to include (based on severity and type of aphasia). Studies included different conversation partners and different topics. Nevertheless, none of the studies investigated the influence of familiarity of the conversation partner or the conversation topic on gesture production. Both these factors influence verbal language, but the question remains as to whether there are similar effects on gesture production.

Coding the different types of gestures according to their semantic value allowed for comparisons across studies. While only a few studies compared the use of these different types of gestures, most of them came to the conclusion that semantically rich gestures played an important role in spontaneous speech in aphasia. As few studies have addressed this question, further data are needed to confirm this finding. Findings with respect to gesture functions varied. Augmentative and compensatory gestures were identified in most studies. Fewer studies investigated the potential facilitative function of gestures, and these produced equivocal results.

The review pointed to a lack of evidence on a number of the parameters, and hence the need for more studies into the spontaneous use of gesture in aphasia. If gestures and their functions are investigated further, and in a more consistent manner, they and their relationship with language could be understood better. Further insights could also illuminate potential uses of gesture in speech and language therapy. These issues motivated the design of the following study.

Chapter 4 Research questions and hypotheses

This study is conducted in order to answer the following five research questions.

4.1 RQ 1: Overall number of gestures.

To what extent do PWA and NHP employ gestures in conversation? What influence does the conversation partner (i.e., familiar vs. unfamiliar conversation partner) have on the use of gesture? Do different conversation topics (i.e., narrative vs. procedural) elicit a different number of gestures?

<u>Hypotheses</u>

Studies have found evidence for a difference between PWA and NHP in terms of the overall number of gestures employed in conversation with PWA producing significantly more gestures than NHP (e.g., Carlomagno & Cristilli, 2006; Carlomagno et al., 2005; Cicone et al., 1979; Cocks, Dipper, et al., 2013; R. J. Duffy et al., 1984; Hadar, Wenkert-Olenik, et al., 1998; M. Herrmann et al., 1988; Kong et al., 2015; Le May et al., 1988; Lott, 1999; Macauley & Handley, 2005; Pritchard et al., 2013; Sekine & Rose, 2013; Sekine et al., 2013).

No study has yet investigated the influence of the conversation partner on gesture production in both PWA and NHP. It is therefore difficult to hypothesise about the outcomes. Based on the findings of studies investigating the influence of the conversation partner on speech production for both PWA and NHP, results may go in two directions: Either (1) the UFCP elicits more gestures because speech with unfamiliar conversation partners tends to be more formal and detailed and thus includes more information in both speech and gesture production (e.g., Boyle et al., 1994; T. Herrmann, 1983) especially in narrative topics (e.g., Li et al., 1995) or (2) there is no difference in terms of the overall number of gestures between the FCP and the UFCP (e.g., Bortfeld et al., 2001; S. E. Williams et al., 1994).

There has been no investigation of the influence of conversation topic on gesture production in both PWA and NHP yet either. Based on language analysis, it is expected that the overall number of gestures produced in narrative and procedural topics will differ (e.g., Ulatowska et al., 1990; Ulatowska & Bond, 1983). This is because procedural topics typically elicit more object-related, concrete language than narrative topics, and such language is likely to be accompanied by gesture.

Investigating the influence of the familiarity of the conversation partner and the topic of the conversation helps, for example, to illuminate pragmatic influences onto gesture and language production. If gesture production is influenced by conversation topic and/or conversation partner, this may lead to a revision of gesture and language processing models. For example, additions might have to be made showing how these pragmatic influences might feed into the gestuary or the conceptualiser. The knowledge of gesture being influenced by the setting of the conversation may also help clinicians to assess the gesture status of PWA in a less time-consuming way, by only using the topic eliciting most gestures, for example.

4.2 RQ 2: Different types of gestures.

To what extent do PWA and NHP use different types of gestures (i.e., semantically rich gestures that convey information about the co-occurring word and/or concept (iconic, metaphoric, pantomime, emblem, and air writing & number gestures) vs. semantically empty gestures (deictic, beat, and other gestures)) in conversation? Does the conversation topic (i.e., narrative vs. procedural) have an influence on the use of different gesture types?

<u>Hypotheses</u>

It is expected that there will be significant difference in the number of semantically rich and semantically empty gestures. In particular, PWA are expected to produce significantly more semantically rich than semantically empty gestures to supplement and/or replace speech (e.g., Ahlsén & Schwarz, 2013; Carlomagno et al., 2005; Cicone et al., 1979; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Lanyon & Rose, 2009; Sekine & Rose, 2013; van Nispen et al., 2014).

The conversation topic is expected to elicit different types of gestures. Since procedural topics elicit more object-related, concrete language than narrative topics (e.g., Ulatowska et al., 1990; Ulatowska & Bond, 1983), it is expected that there will be significantly more semantically rich gestures in procedural topics than in narrative topics. This is expected for both participant groups.

The distribution of gesture types may illuminate whether a specific type of gesture is more impaired in aphasia. Conversely, frequent use of a gesture type might indicate that his is particularly central to aphasic communication. Investigating the influence of conversation partner and topic on the different types of gestures may illuminate pragmatic influences on gesture production even further (see above).

4.3 RQ 3: Word-finding difficulties.

Do gestures help to resolve word-finding difficulties?

Hypotheses

As WFD are a prominent feature of aphasic language (see 2.3), it is expected that PWA will experience significantly more WFD than NHP. NHP are expected to resolve significantly more WFD than PWA, independent of a co-occurring gesture.

The relationship between the production of gesture and the resolution of the WFD will be investigated by examining every instance of WFD and coding whether or not a gesture is produced and whether or not the difficulty is resolved.

It is difficult to make a prediction about the influence of gesture production on the resolution of WFD based on the different findings of research studies. Results may go into two directions: Either (1) participants may produce significantly more gestures during resolved WFD than during unresolved WFD, indicating a facilitative function of gesture in lexical retrieval (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, Dipper, et al., 2013; Pritchard et al., 2013). Evidence from the intervention literature (see 2.4.3) is also equivocal. While gesture cues may contribute to positive outcomes in word-finding therapy, this is typically when they are used in combination with other types of facilitation, and not when used alone. The independent contribution of gestures is thus difficult to determine, making it difficult to predict the influence of gesture production on the resolution of WFD in the current study.

Investigating gesture production in the context of WFD and whether or not they could be resolved may illuminate a potential facilitative role of gestures. It is challenging to investigate the facilitative role of gestures as it is difficult to determine whether it was indeed the gesture that led to the resolution. Nevertheless, comparing resolved and unresolved WFD and whether or not they were accompanied by gestures may point towards a potentially important role of gesture during lexical retrieval. This may lead to more research on gesture processing models, even in neurologically healthy speech.

Furthermore, it may give information to clinicians of whether or not the production of gestures may be used in a more consistent manner in aphasia therapy. Evidence of a relationship between gesture production and the resolution of WFD is of potential value to clinicians. For example, it is a further rationale for deploying gesture in therapy and would argue against proposals for gesture suppression during speech production (e.g., Maher et al., 2006; Meinzer, Djundja, Barthel, Elbert, & Rockstroh, 2005; Pulvermüller & Berthier, 2008; Pulvermüller et al., 2001).

4.4 RQ 4: Functions of semantically rich gestures.

What different functions can semantically rich gestures play in conversation? Are there different patterns in PWA and NHP?

Hypotheses

Four potential roles will be explored in relation to speech: facilitative, communicative, augmentative, and compensatory gestures. It is difficult to hypothesise about the distribution of the different functions of semantically rich gestures.

Based on the findings of previous studies, it is expected that both augmentative and compensatory gestures will be produced in PWA and NHP (e.g., Alibali et al., 1997; Bangerter, 2004; Bavelas et al., 2008; Beattie, 2004; Beattie & Shovelton, 2002; Beeke et al., 2001; Broaders & Goldin-Meadow, 2010; Cassell et al., 1998; Cocks et al., 2011; de Ruiter, 2006, 2007; Goldin-Meadow, 2003; Goldin-Meadow et al., 1993; Hadar, Burstein, et al., 1998; M. Herrmann et al., 1988; Kendon, 1997, 2000; Kong et al., 2015; Lanyon & Rose, 2009; Lott, 1999; McNeill, 1992, 2000; Melinger & Levelt, 2004; Pritchard et al., 2015; Sekine & Rose, 2013; So et al., 2009; van der Sluis & Krahmer, 2004, 2007; Wilkinson, 2013; Wilkinson et al., 2010). PWA are expected to show more compensatory gestures than NHP because of their language impairment. NHP are expected to produce more augmentative gestures than PWA, as they have more fluent speech and fewer WFD.

Gestures may be used when WFD are unresolved, in order to convey the intended target. Such communicative gestures are expected to be used more by PWA than NHP, as they are likely to experience more unresolved WFD.

According to gesture processing models, gestures can take different functions. Because of their language impairment, PWA are expected to use gestures differently from NHP.

Investigating different functions of gestures in both impaired and neurologically healthy language may shed light on the diverse way of combining gesture with language. It may also help to choose between gesture production models. The *Lexical Facilitation Model* (Krauss et al., 2000), for example, does not account for gesture functions other than facilitative while the Sketch Model (de Ruiter, 2000) can accommodate other functions as well.

4.5 RQ 5: Participant factors.

What participant factors (i.e., severity of aphasia, fluency of speech, lexical production skills, verbal semantic skills, non-verbal semantic skills, cognitive skills, and motor skills) have an influence on overall gesture production and the production of semantically rich gestures?

<u>Hypotheses</u>

NHP are expected to perform at ceiling on cognitive and motor assessments. Therefore, a relationship between the production of gestures and these assessments does not apply.

The severity of the aphasia is not expected to be linked to the overall production of gestures based on the findings of previous studies (e.g., Behrmann & Penn, 1984; Borod et al., 1989; Hogrefe et al., 2012; Hogrefe et al., 2013; Macauley & Handley, 2005; Pedelty, 1987; Rose & Douglas, 2003). Instead, it is expected that there will be a relationship between the fluency of speech and the overall number of gestures; that is, participants with fluent aphasia will produce more gestures per time unit than participants with non-fluent aphasia (e.g., Carlomagno & Cristilli, 2006; Le May et al., 1988; Lott, 1999; Sekine & Rose, 2013; Sekine et al., 2013).

Previous studies have argued that WFD in aphasia stimulate increased gesture production (e.g., Ahlsén & Schwarz, 2013; Carlomagno et al., 2005; Cocks et al., 2011; Cocks, Dipper, et al., 2013; Hadar, 1991; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994; Lanyon & Rose, 2009; Pritchard et al., 2013). It is therefore expected that there will be a link between lexical production skills and the overall number of gestures, with participants with better lexical production skills producing fewer gestures than those with poorer lexical production skills (e.g., Carlomagno et al., 2005; Cocks et al., 2011; Cocks, Dipper, et al., 2013; Hadar, 1991;

Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994; Lanyon & Rose, 2009; Pritchard et al., 2013).

Verbal and non-verbal semantic skills are expected to be related to the number of semantically rich gestures, that is, participants with better semantic skills will produce more semantically rich gestures than participants with poorer semantic skills (e.g., Carlomagno & Cristilli, 2006; Cocks, Dipper, et al., 2013; Fucetola et al., 2006; Glosser et al., 1986; Hadar, Wenkert-Olenik, et al., 1998; Hogrefe et al., 2012; Hogrefe et al., 2013).

Based on previous studies, it is expected that there will be a relationship between executive functions[24] and the overall number of gestures. It has been argued that retained executive skills enable speakers to switch modality, so promote the use of gesture during communication failures (e.g., Glosser & Goodglass, 1990; Purdy, 1992, 2002; Purdy et al., 1994; Purdy & Koch, 2006; Yoshihata et al., 1998). A relationship is therefore expected between participants' scores on cognitive measures and their use of gesture during WFD.

In previous studies, limb apraxia was proven not to have an influence onto the production of gestures in spontaneous speech (e.g., Borod et al., 1989; R. J. Duffy et al., 1984; Macauley & Handley, 2005; Pritchard et al., 2013; Rose & Douglas, 2003). Exceptions were the studies by Hogrefe and colleagues (Hogrefe et al., 2012; Hogrefe et al., 2013) who included participants with severe aphasia only. The current study included participants with a range of aphasia severity. Therefore, a relationship between motor skills and the overall number of gestures is not expected.

The influence of participant factors may augment insights into gesture processing, as they give an indication about which skills are needed in order to effectively produce gestures in spontaneous speech. For example, if semantic scores are predictive this adds to the evidence that semantic skills are deployed during gesture production.

[24] The non-verbal subtests of the CLQT are applied as cognitive assessment in this study. Since the majority of these subtests are used to assess executive functions as well, it is likely to find a link between participants' cognitive skills and the overall number of gestures.

Chapter 5 Methodology and design

This section describes the methodology of the study, including information about the ethical approval (5.1) and about the different participant groups involved in this study (5.2). It gives an overview of the materials and the procedures being used in order to collect assessment and conversation data (5.3). Finally, the different levels of analysis being performed are described (5.4).

5.1 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.

5.2 Participants

The following subsections give detailed information about the recruitment process and the participants being involved in the study.

5.2.1 Participants with aphasia.

The recruitment of PWA was done through a joint aphasia recruitment drive that was set up by the researchers of the aphasia team in autumn 2012. Building up this network included (1) setting up a voicemail and an email address with a rota for checking regularly, (2) creating a general PowerPoint presentation, (3) creating a general procedure for contacting people and getting their contact details, and (4) contacting stroke, aphasia and communication groups in and around London (e.g., Connect, Stroke Association, Speakability). In the beginning, nine projects were presented to people attending stroke groups. Over time, other referrals via phone, email, and SLT that heard about the research going on at City University were received. At the moment, the database contains details of over 100 PWA who are interested in taking part in research.

Twenty PWA (9 female, 11 male) were recruited 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 (level 4 to level 7), nine PWA had reached and finished secondary education (level 2 and level 3) (*M* = 3.85, *SD* = 1.387). All PWA were (originally) right-handed, 11 PWA had right hemiplegia.

Inclusion criteria for the study were: (1) a left hemispheric stroke, (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, (5) meeting pre-determined screening cut-offs (see 5.3.1.1), and (6) nomination of a family member or friend as their FCP. 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.

Demographic data of the PWA, including age, gender, level of education (i.e., (1) no formal education, (2) GCSE/O levels, (3) A levels/apprenticeship, (4) Bachelor's degree, (5) Diploma/College degree, (6) Master's degree, and (7) Doctoral degree), pre-stroke/retirement profession, months post stroke, type/location of stroke, and conversation partners (i.e., FCP and UFCP) are summarised in Table 5.1:

Table 5.1. ***Demographics of PWA.***

ID	Gender	Age	Level of education	Profession prior to stroke/ retirement	Months post stroke	Type/location of stroke	Conversation partners	
							FCP	UFCP
1A	female	71	3	dental nurse, mental nurse	38	CVA, ischemia, left	1F; daughter, 54	1UF; student, 36
2A	female	79	3	estate agent	50	CVA, ischemia, left posterior putamen, insular cortex, and corona radiata	2F; friend, 67	2UF; student, 41
3A	male	40	3	photographer, marketing assistant	43	*no information available;* left	3F; researcher, 32	3UF; student, 23
4A	male	75	3	marketing assistant, consultant	83	CVA, ischemia, left MCA	4F; wife, 71	4UF; student, 25
5A	male	73	2	carpenter	19	CVA, ischemia, left MCA, frontal lobe	5F; wife, 73	5UF; researcher, 32
6A	female	64	2	cashier	11	CVA, ischemia, left MCA	6F; niece, 32	6UF; student, 28
7A	male	64	7	lecturer	65	CVA, ischemia, left, basal ganglia	7F; friend, 69	7UF; student, 33
8A	male	79	6	staff of UN	31	CVA, ischemia, left MCA	*no consent*	8UF; student, 42
9A	male	58	5	salesman	40	CVA, ischemia, left MCA	9F; wife, 58	9UF; student, 24
10A	female	54	6	secretary, artist, lawyer, solicitor	55	CVA, ischemia, left MCA	10F; friend, 58	10UF; student, 20
11A	male	56	4	civil engineer	23	CVA, ischemia, left MCA	11F; wife, 38	11UF; student, 26
12A	female	54	4	designer	65	CVA, ischemia, left MCA	12F; partner, 50	12UF; student, 23
13A	female	65	5	teacher, civil servant	72	*no information available*; left	13F; husband, 70	13UF; researcher, 39
14A	female	47	3	student	117	CVA, ischemia, left MCA	14F; daughter, 16	14UF; student, 41
15A	male	77	4	electrical engineer	36	*no information available*; left	15F; support worker, 25	15UF; student, 27
16A	male	56	4	salesman	56	CVA, ischemia, left MCA	16F; ex-wife, 43	16UF; researcher, 33
17A	male	83	4	civil engineer, director	44	CVA, ischemia, left MCA	17F; son, 50	17UF; researcher, 33
18A	female	23	3	student	58	CVA, ischemia, left MCA	18F; mother, 54	18UF; student, 26
19A	female	54	2	park ranger, driver	60	*no information available*; left	19F; partner, 47	19UF; researcher, 28
20A	male	40	4	computer engineer	42	CVA, ischemia, left MCA	20F; researcher, 33	20UF; researcher, 35

Note. PWA = participant/s with aphasia; FCP = familiar conversation partner/s; UFCP = unfamiliar conversation partner/s; CVA = cerebrovascular accident; MCA = middle cerebral artery.

5.2.2 Neurologically healthy participants.

PWA were compared to NHP who were recruited through an existing database stored in the Department of Psychology at City University[25] and through personal links of the examiner. In the end, 21 NHP (12 female, 9 male) took part in the study. NHP were between 27 and 89 years old (*M* = 60.19, *SD* = 20.764). Seventeen NHP had completed tertiary education (level 4 to level 7), 4 had reached and finished secondary education (level 2 and level 3) (*M* = 4.62, *SD* = 1.596). Four NHP were left-handed.

Inclusion criteria for participation were: (1) fluent users of English, (2) normal or corrected-to-normal vision and hearing, (3) meeting predetermined assessment screening cut-offs (see 5.3.1.1), and (4) nomination of a family member or friend as their FCP. 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). Exclusion criteria were: (1) history of neurological illness or insult and (2) any other serious medical condition.

Table 5.2 summarises demographic data of the NHP, including gender, age, level of education, profession (practised or pre-retirement) and conversation partners (i.e., FCP and UFCP):

[25] All participants in this database had previously given consent to be contacted about other research projects taking place at City University.

Table 5.2. ***Demographics of NHP.***

ID	Gender	Age	Level of education	Profession (practised or prior to retirement)	Conversation partners (ID, relationship, age)	
					FCP	UFCP
1C	male	68	4	electrical engineer	21F; wife, 69	21UF; student, 33
2C	female	78	4	marketing & desk researcher	22F; daughter-in-law, 56	22UF; student, 25
3C	female	89	4	psychotherapist	23F; friend, 71	23UF; researcher, 29
4C	female	70	7	museum curator	24F; friend, 63	24UF; researcher, 35
5C	female	75	4	research assistant, medical epidemiology	25F; friend, 69	25UF; student, 33
6C	male	73	2	office boy, social worker, musician	26F; friend, 66	26UF; student, 23
7C	female	73	7	lecturer	27F; friend, 30	27UF; student, 31
8C	male	71	3	marketing executive	28F; friend, 64	28UF; student, 42
9C	female	86	2	secretary	29F; friend, 83	29UF; researcher, 26
10C	male	89	2	tailor, cutter, designer	30F; wife, 85	30UF; student, 42
11C	female	70	5	nurse, librarian	31F; friend, 70	31UF; researcher, 31
12C	female	31	6	music teacher	32F; husband, 31	32UF; researcher, 35
13C	female	67	6	Psychoanalyst	33F; friend, 70	33UF; researcher, 49
14C	female	39	5	health regulator	34F; friend, 38	34UF; student, 25
15C	male	35	4	software engineer	35F; partner, 33	35UF; student, 23
16C	female	32	5	teacher	36F; friend, 33	36UF; student, 25
17C	female	27	6	music publisher	37F; husband, 35	37UF; student, 23
18C	male	36	6	SLT, researcher	38F; friend, 32	38UF; researcher, 29
19C	male	36	7	medical secretary	39F; partner, 46	39UF; researcher, 33
20C	male	62	4	teacher	40F; wife, 62	40UF; researcher, 32
21C	male	57	4	building surveyor	41F; partner, 56	41UF; researcher, 29

Note. NHP = neurologically healthy participant/s; FCP = familiar conversation partner/s; UFCP = unfamiliar conversation partner/s.

5.2.3 Familiar conversation partners.

PWA and NHP nominated one FCP each (family member/friend; 30 female, 9 male) [26]. They were between 16 and 85 years old (*M* = 53.85, *SD* = 17.089). Thirty FCP had completed tertiary education (level 4 to level 7), 9 had reached and finished secondary education (level 2 and level 3) (*M* = 4.4, *SD* = 1.483). FCP were included if they met the assessment screening cut-offs. Meeting these cut-offs means that they had no physical, cognitive, and linguistic deficit influencing the research.

Demographic data of all 39 FCP, including gender, age, level of education, profession, details about participant (PWA or NHP), and their relationship to the participant (e.g., husband/wife, son/daughter, friend) are given in Appendix B: Demographics of conversation partners.

5.2.4 Unfamiliar conversation partners.

Twenty-eight UFCP[27] were included into the study (all female). UFCP were either SLT students in their final year at City University of London or researchers working within the department. They were between 20 and 49 years old (*M* = 30.93, *SD* = 6.960). Twenty-six UFCP had completed tertiary education (level 4 to level 7), only two had reached and finished secondary education (level 2 and level 3) (*M* = 4.93, *SD* = 1.184). None of them had a self-reported history of neurological illness, insult, or any other serious medical condition. Appendix B: Demographics of conversation partners gives a summary of the demographic data of all UFCP, including gender, age, level of education, profession (if applicable), and details about participant/s (PWA or NHP).

5.3 Materials and procedures

The following sections describe the assessments included in the screening and data collection processes (5.3.1), give an overview of the whole data collection process (5.3.3), summarise the assessment results of PWA (5.3.4), explain the process of

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[26] One potential familiar conversation partner (8F) did not give consent to data collection. Due to limited availability of the PWA (8A), there was no time to find an alternative. Therefore, his data were not included into the analyses investigating the difference between the conversation partners. As percentage scores were used for the majority of the other analyses (see 5.4.5), this restricted set of data could be used.
Another participant (20F/35F) served as FCP for two participants (20A and 15C).

[27] Ten participants served as unfamiliar conversation partners for two or three participants. In addition, two participants served as both FCP and UFCP for different participants. Details are given in Appendix B: Demographics of conversation partners.

collecting conversation data (5.3.5), and describe pilot participants and their assessment performance (5.3.2).

5.3.1 Assessments.

All participants completed a number of assessments. Assessments are described according to their purpose for the study. Participants underwent a screening process in order to make sure they met the inclusion criteria (5.3.1.1). Following this, suitable participants completed further assessments described in 5.3.1.2.

5.3.1.1 Screening.

Each group completed a different set of screening assessments. Table 5.3 gives an overview of the different groups and the skills that were tested:

Table 5.3. ***Skills assessed in screening process.***

	PWA	NHP	FCP	UFCP
Language skills	x	n/a	n/a	n/a
Cognitive skills	x	x	x	n/a
Motor skills	x	x	x	x

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; FCP = familiar conversation partner/s; UFCP = unfamiliar conversation partner/s.

The following sections provide more information about the different screening assessments.

5.3.1.1.1 Language skills.

PWA were screened to define the severity of aphasia, and the presence of comprehension and naming impairments. These were determined by the score on the Western Aphasia Battery – Revised (WAB-R; Kertesz, 2007), the performance on the auditory word-to-picture-matching task of the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA #47; Kay, Lesser, & Coltheart, 1992), and the naming ability, assessed using list A of the Object and Action Naming Battery (OANB; Druks & Masterson, 2000).

The WAB-R (Kertesz, 2007) is an aphasia impairment level test based on the neoassocianist model (Benson, 1979; Geschwind, 1967) and widely used in English-speaking countries (e.g., Bakheit, Carrington, Griffiths, & Searle, 2005), and in line with previous studies investigating gesture production in aphasia (e.g., Cocks, Dipper, et al., 2013; Cocks, Sautin, Kita, Morgan, & Zlotowitz, 2009; Dipper et al., 2011; Hadar, Wenkert-Olenik, et al., 1998; Lanyon & Rose, 2009; Pritchard et al., 2013; Raymer et al., 2006; Rose, Raymer, et al., 2013; Sekine & Rose, 2013). The WAB-R assesses four different language domains: (1) spontaneous speech, (2) auditory verbal comprehension, (3) repetition, and (4) naming and word finding. On the basis of the scores of each domain, the Aphasia Quotient (AQ) is calculated and indicates the severity of the aphasia. Severity ratings are based on Kertesz (2007) and given in Table 5.4:

Table 5.4. ***WAB-R – AQ severity rating.***

	Very severe	Severe	Moderate	Mild	WNL
Score	0 – 25.9	26.0 – 50.9	51.0 – 75.9	76.0 – 93.7	> 93.8

Note. WAB-R = Western Aphasia Battery – Revised; AQ = aphasia quotient; WNL = within normal limits.

In order to take part in the study, PWA had to score lower than 93.8 on the AQ as this is the cut-off score according to Kertesz (2007). Additionally, they had to score lower than 10 on fluency and lower than 9 on naming to exclude participants with residual aphasia only.

The PALPA (Kay et al., 1992) is a test battery consisting of 60 tests to assess language processing in aphasia. It is divided into four sections: (1) auditory processing, (2) reading and spelling, (3) picture and word semantics, and (4) sentence comprehension. To ensure sufficient comprehension skills, PWA were tested with PALPA #47 (auditory word to picture matching). The task consists of 40 items. For each item, a spoken word had to be matched to a picture in the presence of four distractors, three of which are semantically or visually related to the target. To be included into the study, PWA had to score at least 20% to ensure sufficient comprehension skills.

The OANB (Druks & Masterson, 2000) consists of drawings for 162 objects and 100 actions. It is divided into two lists that are both matched for frequency and imageability of the stimuli. Because of the extent of other language testing, PWA were only presented with list A of the OANB (i.e., 81 objects and 50 actions). To confirm WFD that were outside normal limits, but not too severe for the participant to be involved in conversation, PWA had to score between 15% and 90% on the objects and below 90% on the actions. A lower limit score was not applied for actions, as verbs are often a site of particular difficulty in aphasia (i.e., Bastiaanse, Bouma, & Post, 2009; Mätzig et al., 2009).

The cut-offs of these tests are summarised in Table 5.6 in 5.3.1.1.5.

5.3.1.1.2 Cognitive skills.

To rule out any major cognitive impairment, all participants except UFCP (i.e., PWA, NHP, and FCP) were given the non-linguistic subtests of the CLQT (Helm-Estabrooks, 2001). Since all UFCP were either students in their final year or researchers working at City University of London, it was assumed that they did not have any cognitive impairments.

The CLQT was developed specifically for people with acquired neurological disorders to assess correlations between linguistic and non-linguistic skills (Helm-Estabrooks, 2002). It consists of ten subtests in order to assess (1) attention, (2) memory, (3) executive functions, (4) language, and (5) visuospatial skills.

Participants were only given the non-linguistic subtests of the CLQT: (1) symbol cancellation, (2) symbol trails, (3) design memory, (4) mazes, and (5) design generation, which is consistent with other studies (e.g., Nicholas et al., 2005; Nicholas et al., 2011). The only cognitive domain that is assessed thoroughly with these tests is that of the visuospatial skills which is normed with weighted scores. For screening purposes, these weighted scores were calculated in order to categorise participants' cognitive skills. The CLQT language subtests were not administered as the language skills of PWA were assessed more fully elsewhere (see 5.3.1.1.1 and 5.3.1.2.1) and as the NHP were expected to perform at ceiling.

Each cognitive domain (i.e., attention, memory, executive functions, language, and visuospatial skills) has normed severity rating. Severity ratings are adjusted depending on the age of the participant (see Table 5.5):

Table 5.5. ***CLQT – visuospatial skills severity rating.***

Severity	18 – 69 years[28]		70 – 89 years	
	Score	%	Score	%
WNL	≥ 82	≥ 78.1%	≥ 62	≥ 59.0
Mild	52 – 81	49.5% – 77.1%	37 – 61	35.2% – 58.1%
Moderate	42 – 51	40.0% – 48.6%	22 – 36	21.0% – 34.3%
Severe	≤ 41	≤ 39.0%	≤ 21	≤ 20.0

Note. CLQT = Cognitive Linguistic Quick Test; WNL = within normal limits.

[28] An exception was made for 16F who was 16 years old and therefore did not fall within in the normed age range. According to the norms of the younger group (18-69 years), she scored WNL.

To make sure that participants did not have any major cognitive impairments and therefore had to be excluded from the study, PWA had to score at least as mild or WNL. NHP and FCP had to score WNL.[29]

5.3.1.1.3 Motor skills.

As the focus of this study is gesturing during conversation, it had to be ensured that all participants were able to use at least one arm/hand without difficulty. This was assessed with the Action Research Arm Test (ARAT; McDonnell, 2008). The ARAT consists of four different categories: (1) grip, (2) grasp, (3) pinch, and (4) gross movement. The first task in each category is administered. Only if the participant is not able to perform this task, this category is investigated in more detail. Otherwise, the participant receives a full score and the examiner moves on to the next category. Only the dominant or non-hemiplegic arm in case of hemiplegia was assessed.

5.3.1.1.4 Analysis.

For PWA and NHP, the results of the assessments conducted for screening purposes also went into the analysis in order to answer RQ 5 (participant factors). In the case of the NHP, only the scores of the CLQT were relevant for the analysis. For PWA however, all screening results and the results of additional assessments went into the analysis. An exception was the score of the ARAT; as all participants scored 100%, this score was not relevant for the analysis and was therefore excluded. Further details are given in 5.3.1.2.

5.3.1.1.5 Summary.

To ensure that all participants met the inclusion criteria and were therefore suitable to take part in the study, they were screened with different assessments. There were language assessments for PWA, motor assessment for PWA, NHP, FCP, and UFCP, and cognitive assessment for PWA, NHP, and FCP. All screening cut-offs are summarised in Table 5.6:

[29] An exception was 2F who scored only 1% below WNL in the younger group (18-69) as she was 67 years old. At the same time, she was at the upper end of the age range and based on her language skills in everyday life, she was considered to be WNL.

Table 5.6. ***Summary of screening cut-offs.***

Test	Cut-off for inclusion
WAB-R	AQ < 93.8, fluency < 10, naming < 9
PALPA #47	> 20%
OANB-A	Objects: > 15% and < 90%; Actions: < 90%
ARAT	100%
CLQT	PWA: WNL and mild; NHP and FCP: WNL

Note. WAB-R = Western Aphasia Battery – Revised; AQ = aphasia quotient; PALPA = Psycholinguistic Assessments of Language Processing in Aphasia; OANB = Object and Action Naming Battery; ARAT = Action Research Arm Test; CLQT = Cognitive Linguistic Quick Test; PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; FCP = familiar conversation partner/s; WNL = within normal limits.

5.3.1.2 Further assessments.

If the participants met the criteria of the study based on the screening outcomes, further assessments were carried out. These included assessments to test language (PWA only) and motor skills (PWA and NHP) in more detail, in order to answer RQ 5 which concerned the relationship between participants' language, motor, and cognition profiles and the use of gesture.

5.3.1.2.1 Language skills.

PWA were given an auditory synonym judgement task of the PALPA #49 (Kay et al., 1992), two further synonym judgement tasks for verbs and adjectives that were created for this project (see Appendix A: Synonym judgement tasks), and the verb comprehension subtest of the Verb And Sentence Test (VAST; Bastiaanse, Edwards, & Rispens, 2002) to assess verbal lexical-semantic skills. Non-verbal lexical-semantic skills were tested with the Pyramids and Palm Trees Test (PPTT; Howard & Patterson, 1992) and the Kissing and Dancing Test (KDT; Bak & Hodges, 2003).

Like PALPA #47 (Kay et al., 1992) which was part of the screening process (see 5.3.1.1), PALPA #49, an auditory synonym judgement task, was administered to assess comprehension skills in more detail. The task consists of 60 word pairs (nouns) matched for imageability of which 30 are synonyms. There are currently no norms available.

Two further auditory synonym judgement tasks for verbs and adjectives were created for this study to get an overall picture of semantic processing over different word classes. These two tasks were based on PALPA #49 and extended the comprehension and verbal semantic processing data of PWA. Like the PALPA #49, the synonym judgement task for verbs consisted of 60 word pairs, while the synonym judgement task for adjectives only consisted of 56 word pairs. Each word pair was matched for imageability. Imageability values were taken from Cortese and Fugett (2004) and Schock, Cortese, and Khanna (2012) for the verbs and from the MRC database (Wilson, 1987) and Bird, Franklin, and Howard (2001) for the adjectives. Half of the word pairs were synonyms. Synonyms were collected in a norming study, in which 77 native British English speakers took part. Control data were collected by asking all NHP, FCP and UFCP to complete these synonym judgement tasks as well for standardisation purposes. In total, 89 healthy participants completed the tasks, scoring between 51 and 60 (M = 58.74, SD = 1.634) on the verb task and between 50 and 56 (M = 54.60, SD = 1.320) on adjectives. There was a significant difference between the performance of PWA and NHP on tests (verbs: U = 118.500, z = -6.547, p < .001; adjectives: U = 118.500, z = -6.500, p < .001).

More details on norming and standardising the synonym judgement tasks (e.g., demographics of norming participants and the final version of the two tasks) can be found in Appendix A: Synonym judgement tasks.

The VAST (Bastiaanse et al., 2002) comprises two sections that assess (1) the comprehension and (2) the production of verbs and sentences. Each section has a number of different subtests that can be conducted individually to get a clearer picture of any language processing deficit. In the context of this study, PWA were given the verb comprehension task of the VAST only. This task consists of 40 items. For each item the PWA hears a spoken verb that has to be matched to one of four pictures, showing the target and three other semantically related distractors. According to Bastiaanse et al. (2002), participants scoring 95% and higher are WNL. Difference in performance on PALPA #47 and verb comprehension test of the VAST may indicate a word-class-effect (see 2.3.2.2).

The PPTT (Howard & Patterson, 1992) assesses the ability to derive semantic information non-verbally from object pictures. It consists of 52 object pictures, presented with one semantically related picture and one distractor. The task is to identify the picture that is semantically related to the target.

The KDT (Bak & Hodges, 2003) is based on the PPTT and assesses semantic skills non-verbally from action pictures. For both assessments, the authors state that if participants score above 90% they are WNL. Comparing these two semantic assessments may indicate whether semantic information can be derived more readily from objects than from actions.

5.3.1.2.2 Motor skills.

In addition to the ARAT (5.3.1.1) (McDonnell, 2008), the Birmingham Praxis Screen (BCoS-Praxis), a subsection of the Birmingham Cognitive Screen (BCoS; Bickerton et al., 2012) was conducted with both PWA and NHP. The BCoS-Praxis is divided into four parts: (1) object use, (2) pantomime production, (3) pantomime recognition, and (4) meaningless gesture imitation. Subtests (2)-(4) test the cognitive processes that are involved in motor planning whilst subtest (1) additionally tests “the ability to select an appropriate object among distractor objects” (Bickerton et al., 2012, p. 515). The BCoS-Praxis was included into the battery to assess motor planning difficulties. Depending on the age of the participant, cut-offs to score WNL are adjusted. Participants reaching that score or a higher one on each subtest are not considered as having limb apraxia. Table 5.7 summarises the cut-offs:

Table 5.7. *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.

5.3.1.2.3 Summary.

Participants were given further assessments to test language (PWA only) and motor skills (PWA and NHP) in more detail. All further assessments and their cut-offs for scoring with normal limits are summarised in Table 5.8:

Table 5.8. *Summary of further assessment cut-offs.*

Test	**Cut-off for WNL**
PALPA #49	*not available*
Synonym judgement task verbs	≥ 95%
Synonym judgement task adjectives	≥ 95%
VAST-verb comprehension	≥ 95%
PPTT	≥ 90%
KDT	≥ 90%
BCoS-Praxis	see Table 5.7

Note. WNL = within normal limits.; PALPA = Psycholinguistic Assessments of Language Processing in Aphasia; VAST = Verb And Sentence Test; PPTT = Pyramids and Palm Trees Test; KDT = Kissing and Dancing Test; BCoS-Praxis = Birmingham Cognitive Screen – Praxis.

5.3.1.3 Composite scores.

The results of the language and motor assessments described above (see 5.3.1.1 and 5.3.1.2) did not go directly into the analysis but were used to calculate five different composite scores to represent different processes: (1) lexical production skills, (2) verbal semantic skills, (3) non-verbal semantic skills, (4) motor skills, and (5) cognitive skills (see Table 5.9). Calculating composite scores allows for profiling of different cognitive domains and reduces the number of statistical analyses and therefore the potential type I error. In order to derive composite scores, the results for all assessments were converted into percentage scores. The composite scores depict the average percentage score of the relevant assessments. For example, the composite score for lexical production skills corresponds to the average percentage score of the OANB objects and the OANB actions. Percentage averages were used as the number of items in different tests often varied.

Table 5.9. ***Composite scores.***

Composite score	Assessment
Lexical production skills	OANB objects (list A)
	OANB actions (list A)
Verbal semantic skills	PALPA #47
	PALPA #49
	Synonym judgement task for verbs
	Synonym judgement task for adjectives
	VAST-verb comprehension
Non-verbal semantic skills	PPTT
	KDT
Motor skills	BCoS-Praxis
Cognitive skills	CLQT (non-verbal skills)

Note. OANB = Object and Action Naming Battery; PALPA = Psycholinguistic Assessments of Language Processing in Aphasia; VAST = Verb And Sentence Test; PPTT = Pyramids and Palm Trees Test; KDT = Kissing and Dancing Test; BCoS-Praxis = Birmingham Cognitive Screen – Praxis; CLQT = Cognitive Linguistic Quick Test.

Composite scores are given in percentages and were calculated using the percentage score of each test divided by the number of tests. Exceptions were made for (1) motor skills and (2) cognitive skills. Motor skills were derived from just one score (BCoS-Praxis), so was not a composite. The composite score for cognitive skills was based on the non-linguistic subtests of the CLQT. Here the weighted scores of the subtests were added up and entered into the analysis, following the criteria of the test.

5.3.2 Pilot participants.

Two PWA, two FCP, and two UFCP were involved in the piloting process. Piloting was conducted for two main reasons: (1) to ensure, the data collection procedure elicited the required data and (2) to trial the proposed language and gesture analysis (see 5.4.2 and 5.4.3).

5.3.2.1 Demographics.

Both pilot PWA were more than six months post-stroke (nine months and 23 months). They were 95 and 72 years old. One PWA had completed tertiary education, the other had reached and finished secondary education.

All conversation partners had no history of neurological illness, insult, or any other serious medical condition. The FCP furthermore met the assessment screening cut-offs, meaning that they had no physical, cognitive, and linguistic deficit influencing the research. Conversation partners were between 25 and 81 years old. Three of them had completed tertiary education and one had reached and finished secondary education.

Demographic data of the all pilot participants, including age, gender, level of education[30], pre-stroke/retirement profession, months post-stroke (for PWA), type/location of stroke (for PWA), and FCP and UFCP are summarised in Table 5.10:

5.3.2.1 Assessment data.

Test scores of all pilot participants are given in Table 5.11 and Table 5.12 below. They include the language scores for PWA, cognition scores for PWA and FCP, and motor skills scores for all pilot participants. See 5.3.1 for details about the assessments.

[30] (1) no formal education, (2) GCSE/O levels, (3) A levels/apprenticeship, (4) Bachelor's degree, (5) Diploma/College degree, (6) Master's degree, and (7) Doctoral degree

Table 5.10. ***Demographics of pilot participants.***

ID	Gender	Age	Level of education	Profession (prior to stroke/ retirement)	Months post stroke	Type/location of stroke	Conversation partners
1PA	female	95	7	GP, psychoanalyst	9	CVA, ischemia, pons and right parietal lobe	2PF, 1PUF
2PA	male	72	2	shipper, cleaning business	23	CVA, ischemia, left	1PF, 2PUF
1PF	female	69	3	clerk	n/a	n/a	2PA
2PF	female	81	4	teacher	n/a	n/a	1PA
1PUF	female	26	4	student	n/a	n/a	1PA
2PUF	female	25	4	student	n/a	n/a	2PA

Note. PA = pilot participant/s with aphasia, PF = pilot familiar conversation partner/s, PUF = pilot unfamiliar conversation partner/s; CVA = cerebrovascular accident.

Table 5.11. ***Language and semantic skills scores of PWA pilot participants.***

ID	WAB-R				Lexical production composite score in %	Verbal semantic composite score in %	Non-verbal semantic composite score in %
	AQ	Severity	Syndrome	Fluency			
1PA	94.4	WNL	Anomic aphasia	10	86.70%	95.00%	86.60%
2PA	40	severe	Wernicke's aphasia	8	12.05%	85.00%	91.40%

Note. PA = pilot participant/s with aphasia; WAB-R = Western Aphasia Battery – Revised; AQ = aphasia quotient; WNL = within normal limits.

Table 5.12. ***Cognition and motor skills scores of pilot participants.***

ID	CLQT non-linguistic skills (max. score)			BCoS-Praxis (max. score)						
	Weighed score (105)	%	Severity	Score (42)	%	Subtest scores				Apraxia yes/no
						Object use (12)	Pantomime (12)	Recognition (12)	Imitation (12)	
1PA	95	90.5%	WNL	39	92.9%	12	10	5	12	no
2PA	88	83.8%	WNL	30	71.4%	11	7	5	7	yes
1PF	94	89.5%	WNL	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2PF	98	93.3%	WNL	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1PUF	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2PUF	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Note. PA = pilot participant/s with aphasia, PF = pilot familiar conversation partner, PUF = pilot unfamiliar conversation partner; CLQT = Cognitive Linguistic Quick Test; BCoS-Praxis = Birmingham Cognitive Screen – Praxis; WNL = within normal limits.

The piloting process revealed that the data collection procedure elicited the required data in both cases. Trialling language and gesture coding on the conversation samples confirmed this. Therefore, the tasks and procedures remained unchanged. Both pilot PWA were excluded from the main study as they did not meet the inclusion criteria[31] (see 5.2.1).

5.3.3 Data collection process.

This section gives a brief overview of the different steps of data collection. There were two phases. In the first phase, PWA were recruited, screened and assessed, two conversation sessions with PWA and FCP/UFCP took place and FCP and UFCP were assessed. Depending on the stamina of the PWA and the severity of their aphasia, this took between four and eight sessions. In the second phase, this protocol was repeated with the NHP who were age, gender, and education matched with the PWA. This time, however, data collection only took two sessions per participant. Figure 5.1 depicts these steps:

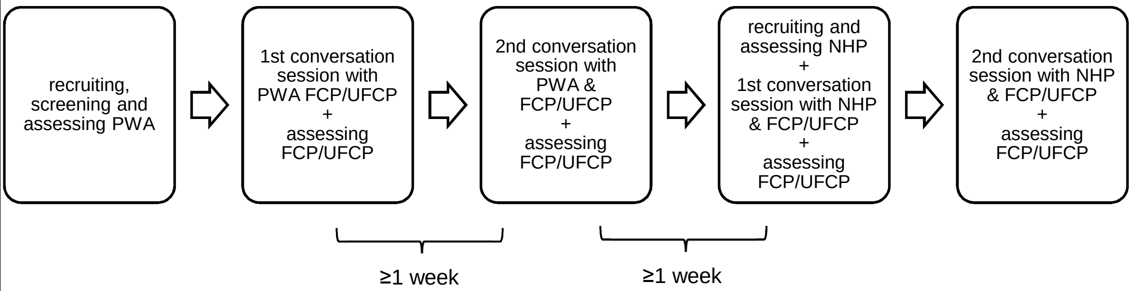

Figure 5.1. ***Five steps of data collection, including recruiting, screening, assessing PWA, NHP, FCP, and UFCP, and the conversation sessions.***

The sessions with PWA took place either at City University of London or in participants' homes, depending on the participants' preferences. All NHP came to City University of London for their sessions. Participants were blinded to the focus of the study (i.e., gesture). They were told that the study was about conversation in aphasia. This was to prevent participants from changing their normal gestural behaviour.

The first session was used to give participants extensive information about the project and their possible participation. After the all questions have been answered by the researcher, the participant had at least 24 hours to think about it and consult with family

[31] 1PA was WNL on the WAB-R and scored 10 on the WAB-R fluency measurement. 2PA did not meet screening criteria on the lexical production skills (Table 5.11).

member/s or friends, before consent was elicited. Following this, screening started. As soon as the PWA showed signs of being tired, assessments were stopped and the session was rescheduled, which meant that screening took approximately one to two sessions and further assessments took two to four sessions, depending on the severity of the aphasia and participants' levels of fatigue. Further testing was only carried out if screening cut-offs were met. The last two sessions were the two conversation sessions. To avoid confounding familiarity with the order if testing, 13 PWA had the first conversation with the FCP and seven with the UFCP (see Appendix G: Conversation order). Prior to each conversation, the conversation partners were screened and tested in order to make sure that they met the inclusion criteria (see 5.3.1.1). Each conversation session consisted of four different topics, two narrative topics and two procedural topics. The order of the topics was semi-randomised, i.e. five PWA were asked to start with the first narrative topic, five with the second narrative topic, five with the first procedural topic and five with the second procedural topic. Details about the topics and the order can be found in 5.3.5 and Appendix G: Conversation order. Since there was no change in conversation topics between the first and the second conversation session, at least one week was left between each conversation session to reduce practice effects.

In the second phase of the study, 21 NHP were recruited. They were age, gender, and education matched to the PWA. Participants were given information prior to the first session (e.g., by emailing or posting information sheets) and were asked to give consent after all questions have been answered by the researcher. Immediately afterwards, participants were screened. If screening cut-offs were met, the conversation partner was screened and the first conversation took place. NHP were asked to do the second conversation with the other conversation partner about a week later to reduce practise effects. Like in the first phase of the project, the order of conversation partners was counterbalanced, 11 started with the FCP and 10 with the UFCP. Additionally, the order of conversation topics was semi-randomised as described above. More details about the conversation order can be found in Appendix G: Conversation order.

5.3.4 Assessment data.

The following sections give details about the assessment results of the PWA. More detailed results and assessment results of NHP, FCP, and UFCP are given in Appendix C: Detailed results of PWA.

Table 5.13 and Table 5.14 display the results of PWA in all assessments including WAB-R, WAB-R fluency, and the composite scores of lexical production, verbal semantics, non-verbal semantics, cognition, and motor skills. Additionally, detailed results of the BCoS-Praxis are presented, including the presence of limb apraxia.

Table 5.13. ***Language and semantic skills scores of PWA.***

ID	WAB-R				Lexical production composite score in %	Verbal semantic composite score in %	Non-verbal semantic composite score in %
	AQ	Severity	Syndrome	Fluency			
1A	68.2	moderate	Conduction aphasia	4	80.70%	87.68%	96.15%
2A	86.6	mild	Anomic aphasia	9	74.15%	92.42%	91.85%
3A	62.7	moderate	Broca’s aphasia	4	57.15%	82.92%	90.40%
4A	75.6	moderate	Conduction aphasia	5	88.55%	96.46%	96.15%
5A	76.6	mild	Transcortical Motor aphasia	4	71.65%	77.82%	91.35%
6A	82.9	mild	Anomic aphasia	9	77.50%	91.76%	83.20%
7A	90.8	mild	Anomic aphasia	9	85.45%	90.16%	89.90%
8A	66.9	moderate	Conduction aphasia	6	40.00%	91.42%	75.95%
9A	68.6	moderate	Conduction aphasia	5	76.95%	93.06%	96.15%
10A	84.2	mild	Anomic aphasia	5	86.70%	94.74%	91.35%
11A	81.1	mild	Anomic aphasia	5	84.60%	97.08%	95.20%
12A	76.6	mild	Conduction aphasia	5	86.55%	92.88%	98.10%
13A	36.7	severe	Broca’s aphasia	2	40.60%	80.30%	80.75%
14A	37.2	severe	Broca’s aphasia	2	40.60%	72.58%	77.90%
15A	63	moderate	Broca’s aphasia	4	34.30%	71.34%	74.05%
16A	31.6	severe	Broca’s aphasia	2	6.15%	72.26%	83.65%
17A	77.2	mild	Transcortical motor aphasia	4	75.40%	89.14%	92.30%
18A	64.1	moderate	Broca’s aphasia	4	84.60%	96.12%	96.20%
19A	53	moderate	Broca’s aphasia	4	45.45%	85.32%	91.80%
20A	77.8	mild	Transcortical motor aphasia	4	80.15%	88.50%	88.25%

Note. PWA = participant/s with aphasia; WAB-R = Western Aphasia Battery – Revised; AQ = aphasia quotient.

Table 5.14. ***Cognition and motor skills scores PWA.***

ID	CLQT non-linguistic skills (max. score)					BCoS-Praxis (max. score)				
	Weighed score (105)	%	Severity	Score (42)	%	Subtest scores				Apraxia yes/no
						Object use (12)	Pantomime (12)	Recognition (12)	Imitation (12)	
1A	93	88.6%	WNL	37	88.1%	12	10	5	10	no
2A	90	85.7%	WNL	38	90.5%	12	11	5	10	no
3A	96	91.4%	WNL	34	81.0%	12	8	5	9	yes
4A	68	64.8%	WNL	38	90.5%	12	11	6	9	no
5A	75	71.4%	WNL	37	88.1%	12	12	5	9	no
6A	70	66.7%	mild	31	73.8%	11	9	5	6	yes
7A	75	71.4%	mild	34	81.0%	12	10	4	8	yes
8A	43	41.4%	mild	31	73.8%	12	8	5	6	yes
9A	92	87.6%	WNL	32	76.2%	12	6	5	9	yes
10A	81	77.1%	mild	33	78.6%	12	8	6	7	yes
11A	97	92.4%	WNL	41	97.6%	12	11	6	12	no
12A	99	94.3%	WNL	39	92.9%	12	12	6	9	no
13A	52	49.5%	mild	30	71.4%	12	6	5	7	yes
14A	58	55.2%	mild	11	26.2%	12	4	1	6	yes
15A	41	39.0%	mild	30	71.4%	12	8	4	6	yes
16A	77	73.3%	mild	30	71.4%	12	6	3	9	yes
17A	85	81.0%	WNL	37	88.1%	12	10	4	11	no
18A	97	92.4%	WNL	38	90.5%	12	9	5	12	yes
19A	90	85.7%	WNL	36	85.7%	12	11	5	8	yes
20A	98	93.3%	WNL	38	90.5%	12	10	6	10	no

Note. PWA = participant/s with aphasia; CLQT = Cognitive Linguistic Quick Test; BCoS-Praxis = Birmingham Cognitive Screen – Praxis.

As can be seen in Table 5.13, the severity of the language impairment varied from mild to severe. According to the WAB-R fluency measurement, nine PWA were considered as being fluent, and 11 as being non-fluent.

Maximum score, mean (*M*), range, and standard deviation (*SD*) achieved on all assessments are summarised in Table 5.15:

Table 5.15. ***Assessments and composite scores.***

Assessments and composite scores	Max. score	*M*	Range	*SD*
WAB-R (AQ)	100	68.08	31.60-90.08	16.946
WAB-R fluency score	10	4.08	2-9	2.093
Lexical production composite score in %	100%	65.86%	6.15%-88.55%	23.326
Verbal semantic composite score in %	100%	86.69%	71.34%-97.08%	8.419
Non-verbal semantic composite score in %	100%	88.58%	75.05%-98.10%	7.032
CLQT visuospatial skills in %	100%	75.09%	39.00%-94.30%	17.608
BCoS-Praxis in %	100%	80.37%	26.20%-97.60%	15.140

Note. *M* = mean; *SD* = standard deviation; WAB-R = Western Aphasia Battery – Revised; AQ = aphasia quotient; CLQT = Cognitive Linguistic Quick Test; BCoS-Praxis = Birmingham Cognitive Screen – Praxis.

5.3.5 Conversation data.

Conversation data was collected from two conversation settings (FCP and UFCP) and four different topics.

5.3.5.1 Setup/material.

Participants, their conversation partners and the camera were set up in a triangle. PWA/NHP and FCP/UFCP 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 partners were not allowed to have anything on their laps, in their hands and next to their chairs. Figure 5.2 outlines the setup:

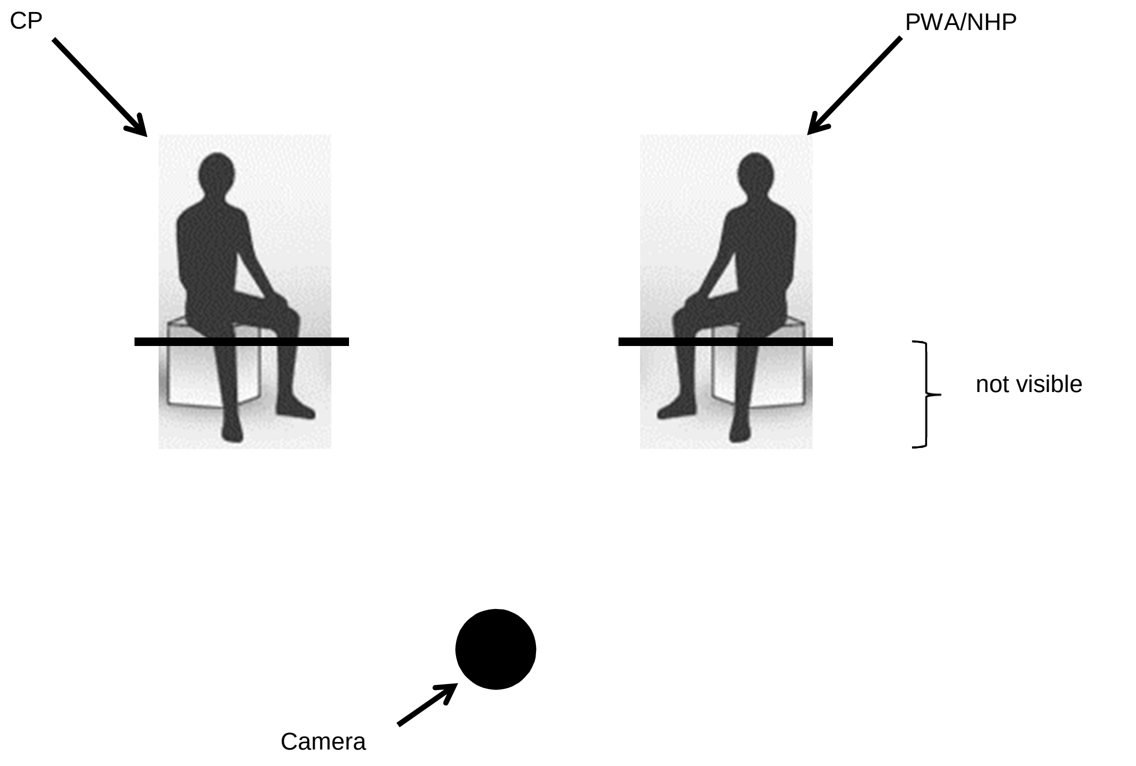

Figure 5.2. ***Setup of the conversation session.***

The view of the camera is given in Figure 5.3. 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.

Figure 5.3. ***Example of the camera view.***

5.3.5.2 Conversation topics.

As shown by Ulatowska and colleagues (e.g., Ulatowska et al., 1990; Ulatowska & Bond, 1983) (see 2.2.1). Different types of conversation contain different kinds of information which can affect gesture use. To get as many different co-speech gestures as possible (cf., McNeill et al., 1994), two different types of conversation were elicited: (1) narrative and (2) procedural. A narrative conversation is about something happening, either real or imagined, for example, a story about a holiday. Procedural conversation is the description of how something is done, for example, how to change a tyre or where to find the next supermarket. The process is described in a specific order and the account is goal-oriented (Ulatowska, North, et al., 1981).

In order to collect enough conversation data, two topics per conversation type were given. Therefore, participants were asked to have four different conversations per conversation partner. Table 5.16 gives details about the different topics and the way participants were instructed:

Table 5.16. ***Conversation types, topics, and instructions.***

Type	Topic	Instructions
N1	Happy memory	*Can you think of a happy memory? Please try to include as much detail as possible. For example, "what happened" and "how did you feel". Imagine the conversation partner does not know about it. Can you tell it to him/her?*
N2	Busy weekend	*Can you think of a recent busy or interesting weekend/week/day. Please try to include as much detail as possible. For example, "what happened" and "how did you feel". Imagine the conversation partner does not know about it. Can you tell it to him/her?*
P1	How to wrap a parcel	*Can you explain how to wrap a box for a present? Imagine your conversation partner does not know how to do it. You have to describe it to him/her. Please try to be very specific and include as much detail as possible.*
P2	How to make scrambled eggs[32]	*Can you explain how to make scrambled egg? Imagine your conversation partner does not know how to do it. You have to describe it to him/her. Please try to be very specific and include as much detail as possible.*

Note. N = narrative, P = procedural.

At least 02:30 minutes of conversation for each topic was targeted but the examiner did not stop the conversation. As soon as the conversation came to a natural stop, the camera was stopped as well. Only the middle 02:00 minutes of the conversation sample were used for analysis.

In the case of the procedural discourse topics, participants tended to switch into a more narrative style after having described the process. To ensure that the majority of the analysed 02:00 min reflected procedural language (and gesture), additional criteria for the endpoint of the conversation were defined:

(1) Natural stop: Both participant and CP agree on having covered the topic, for example, *I think that's it; the end*, or the floor shifts to the conversation partner, for example, they describe how they would wrap a parcel or make scrambled eggs

(2) Topic change: Either the participant or the CP introduce a new, slightly unrelated topic and the discussion continues, for example, *I don't like scrambled eggs, I prefer boiled eggs or poached eggs. My friend has a new gadget to poach eggs… What is in the present? How do you know that person?*

[32] The menu could be substituted for participants who did not like or eat scrambled eggs. Substitutions were necessary only for one PWA (3A) in the setting with the familiar conversation partner.

The middle 02:00 minutes of the conversation from the start of the video to the defined endpoint were extracted and analysed. In seven cases, the defined endpoint of the conversations was before the 02:00 mark. This was only the case for either of the two procedural conversations. When this happened, longer samples from the other procedural conversation with the same conversation partner were taken, to make up the missing time. This led to 04:00 minutes per conversation type and 08:00 minutes per conversation partner. In total 16:00 minutes of conversation per participant were analysed. Only for 10C, the procedural conversations with the familiar conversation partner did not add up to 04:00 minutes. The data for these conversations (i.e., raw numbers of gestures and WFD) were excluded from the statistical analyses (see 5.4.5).

For the two narrative topics, PWA/NHP were given the instructions while the conversation partner was present. In case of the instructions for the two procedural topics, the conversation partner was asked to leave the room for a few minutes. This was done to blind the conversation partner to the procedures that the participant was supposed to describe and gave the opportunity for the researcher to give additional instructions in case of comprehension impairment.

5.3.5.3 Conversation partners.

All participants completed two conversation sessions with the same topics[33] (see Table 5.16) and in the same order. As indicated in Figure 5.1, there was a least a one-week gap between the two conversation sessions to avoid practise effects.

5.4 Analyses

The following sections give an overview of how conversations were coded and data were analysed. 5.4.1 introduces the coding procedure, 5.4.2 and 5.4.3 provide details on how the language and gesture were analysed. Finally, 5.4.4 refers back to the research question, giving information how each was addressed and which analyses were run (see Chapter 4 for hypotheses).

[33] Participants could choose to tell about a different memory and a different busy weekend at the second conversation session.

5.4.1 Coding procedure.

The videos of the conversations were coded using the gesture and sign language analysis program ELAN (Wittenburg, Brugman, Russel, Klassmann, & Sloetjes, 2006). Coding was conducted using different tiers below the video (see Figure 5.4):

(a) Speech occurring with gesture
(b) Iconic
(c) Metaphoric
(d) Deictic
(e) Beat
(f) Pantomime
(g) Emblem
(h) Air writing & Numbers
(i) Other
(b)–(i): Type of gesture
(j) WFD
(k) WFD +/-gesture
(l) WFD +/-resolved
(m) Facilitative
(n) Communicative
(o) Augmentative
(p) Compensatory
(m)–(p): Function of semantically rich gesture

Figure 5.4. ***Tiers for coding process in ELAN.***

To a certain extent, the order of the tiers also indicated the order of the coding process. First of all, gesturing was identified (see 5.4.3.1) and co-occurring speech was transcribed on tier (a) (see 5.4.2). Gestures were categorised according to McNeill (2000) on tiers (b) to (i) (see 5.4.3.1). WFD were identified in tier (j). Tier (k) marked whether or not the WFD was accompanied by gesture and tier (l) indicated whether or not it was resolved (see 5.4.2). Finally, the function of the semantically rich gestures was identified on tiers (m) to (p) (see 5.4.3.2). The coding procedure is described in more detail in Appendix H: Gesture coding procedure.

5.4.2 Language coding process.

Speech co-occurring with gesture was transcribed using ordinary orthographic conventions and, if necessary, broad phonemic transcription. Following Lanyon and Rose (2009), instances of WFD were identified. Murray and Clark's (2006) indicators of word retrieval difficulty[34] have been used in earlier studies investigating gesture production in aphasia (e.g., Cocks, Dipper, et al., 2013; Pritchard et al., 2013) and were applied in the current study. The list of indicators for a WFD (see below) was adapted for the current study by adding the last point (i.e., filling words) and providing examples.

- Pause of at least 500ms
- Circumlocution of a target word, for example, *the thing you use to stir things up* instead of *spoon*
- Producing onomatopoeia in the place of a target verb, for example, *brumm* instead of *driving*
- Semantic errors, for example, *fork* instead of *spoon*[35]
- Phonological paraphasias, for example, *tork* instead of *fork*
- Neologisms, that is, words in which less than 50% of target phonology is present (Marshall, 2006)
- Metalinguistic comments, for example, *I don't know*
- Repetitions included a word or phrase immediately repeated (not if repetition served emphasis), for example, *you take that that that that thing*
- Filling words, for example, *uh* and *um*

After having identified the WFD, they were checked for the co-occurrence with a semantically rich gesture (see 5.4.3.2) and for resolution. A WFD was classified as being 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.

Identifying and classifying WFD (for the co-occurrence of semantically rich gesture and for resolution) was necessary in order to answer RQ 3 which is about the function that gestures play during WFD. More details about the analysis can be found in 5.4.5.3.

5.4.3 Gesture coding process.

Gestures were analysed through a system of observations focused on arms and hands. All instances of gesturing during the conversations were coded and counted (see

[34] There is a dispute about whether these indicators could also occur due to disfluencies other than lexical retrieval. An alternative interpretation, for example, is cognitive processing. This and other interpretations are discussed in Chapter 7.
[35] Semantic errors can only be identified 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.

5.4.3.1). With this quantification of gestures, the overall number of gestures PWA and NHP used in conversation could be explored (RQ 1; see 5.4.5.1) and broken down into different categories (RQ 2; 5.4.5.2). The analysis of the functions of semantically laden gestures (see 5.4.3.2) enabled RQ 4 (see 5.4.5.4) to be answered.

5.4.3.1 Identifying and categorising gestures.

All incidents of gesturing were categorised as (1) iconic, (2) metaphoric, (3) deictic, (4) beat, (5) pantomime, and (6) emblem gestures along Kendon's continuum (McNeill, 1992, 2000). For example, a gesture was coded as an iconic gesture if it depicted an object or an action, such as shaping the outline of a box or making a whisking movement when scrambling eggs. Metaphoric gestures were similar to iconic gestures but depicted more abstract concepts, such as implying that something is switched on when referring to *idea* (see footnote 3). Clear pointing gestures, usually executed with the index finger were coded as a deictic gesture. Beat gestures had no clear handshape and only underlined the rhythm of the speech or the stress. Gestures that depicted an entire scene and were produced without speech were coded as pantomime gestures, such as pretending to drive a car and checking the back mirror. Finally, a gesture that carried a certain meaning, such as thumbs up for *good* was coded as an emblem gesture. For more detail about the different categories of gestures and Kendon's continuum see section 2.1.2. The continuum is displayed in Figure 5.5:

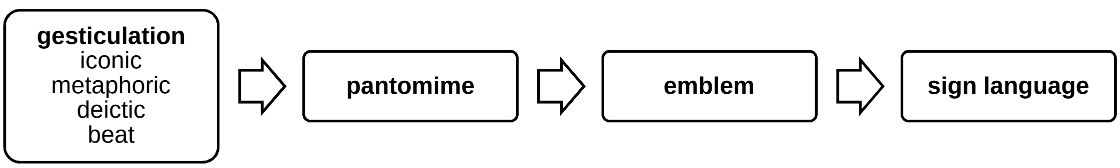

Figure 5.5. ***Kendon's continuum according to McNeill (1992, 2000) in detail.***

Since sign language is a complex language system, it was not included into this study. Two gesture types featured in the data which are not part of Kendon's continuum. These were air writing letters and number gestures (usually signalled by holding up the required number of fingers). These were categorised as (7) air writing & numbers. This type of gesture was identified in earlier studies and mainly used by PWA (Cicone et al., 1979; Sekine & Rose, 2013; Sekine et al., 2013). They are different to the other spontaneously produced gestures as they are not as free as gesticulations, for example, but also not culturally agreed on as emblems. In some respects, air writing gestures are akin to the fingerspelling alphabet of sign languages, in that they call upon orthographic representations. Of course, there are also important differences, principally in the form of the gestures. Air writing mimics orthographic forms, while fingerspelling uses distinct signs to represent letters. PWA use air writing gestures very strategically by applying preserved numeric and orthographic knowledge and represent it in gesture. Because of their intact language, this type of gesture is rarely used by NHP. All other that did not fit into any of the six categories were categorised as (8) other gestures. The modified gesture continuum is displayed in Figure 5.6:

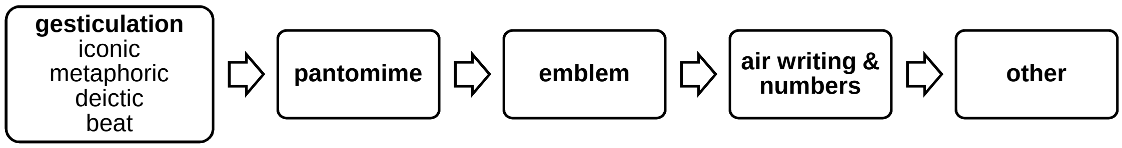

Figure 5.6. ***Kendon's continuum, modified for the current study.***

5.4.3.2 Categorising semantically rich gestures.

In order to explore the effect of semantics on gesturing, the eight categories of gesture outlined above were reconfigured for further analysis. In this reconfiguration, semantically rich gestures ((1) iconic, (2) metaphoric, (5) pantomime, and (6) emblem gestures) which are gestures that convey information about the co-occurring word and/or concept (i.e., with and without co-occurring speech), were contrasted with semantically empty gestures ((3) deictic[36], (4) beat, and (7) other gestures). This reconfiguration allowed for investigation of the different gestures participants used in conversation (RQ 2, see 5.4.5.2 and RQ 4, see 5.4.5.2).

Additionally, the semantically rich gestures were sub-divided into four different groups according to their function in speech: (1) facilitative[37], (2) communicative, (3) augmentative, or (4) compensatory (see Table 5.17). This allowed for investigation of whether participants were using gesture mainly to facilitate, supplement or to replace speech (RQ 4, see 5.4.5.4).

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[36] Deictic gestures may play an important role in conversation. With referring to specific objects and places, they are often linked to semantic content. Other than semantically rich gestures that depict content themselves, deictic gestures, however, only refer to the object, so do not carry any semantic information about the word or concept.

[37] Semantically rich gestures that occurred in resolved WFD were classified as 'facilitative' gestures. This classification is purely based on a potentially facilitative role of gesture in lexical retrieval and a hypothetical term. It may therefore be problematic as one cannot conclude that a gesture in this context indeed facilitated lexical retrieval. Therefore, 'facilitative' in the context of this study simply refers to semantically rich gestures produced in resolved WFD. The author is aware of the meaning of this term in context of previous gesture research (e.g., Krauss et al. (2000) and their Lexical Facilitation Model).

Table 5.17. ***Functions of semantically rich gestures.***

Category	Explanation
Facilitative	The gesture was produced during a WFD that was resolved by the speaker.
Communicative	The gesture was produced during a WFD that was not resolved by the speaker.
Augmentative	The gesture accompanied speech and did not occur during a WFD.
Compensatory	The gesture replaced speech (i.e., there was no co-occurring speech) and did not occur during a WFD.

Note. WFD = word-finding difficulty/ies.

5.4.4 Inter-rater agreement.

All 324 2-minute-conversations were coded and analysed by the principal investigator, an English-speaking SLT with experience with aphasia. 10% of all 2-minute-conversations were coded by a second judge, a native English speaker, 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. Overall inter-rater agreement for the identification of gestures and WFD is reported in Table 5.18. If there was a difference in coding, the version of the first coder was used for the further analysis.

Table 5.18. ***Inter-rater reliability levels 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.

The reliability for the identification of WFD was lower for both PWA (78.60%) and NHP (87.24%) than the one for the identification of gestures for PWA (92.39%) and NHP (98.49%). In both cases, the agreement between judges was better for NHP than for PWA.

In case of the types of gestures and WFD, the reliability was tested using Cohen's κ. For the type of gestures (i.e., iconic, metaphoric, deictic, beat, emblem, pantomime, air writing & number, and other gestures), judges reached substantial agreement for PWA, $\kappa = .637$, $p < .001$, and moderate agreement for NHP, $\kappa = .585$, $p < .001$. In case of the pantomime gestures, the first coder identified three pantomime gestures in the conversation samples of the PWA, while the second coder identified five. Similarly, the first coder did not identify any pantomime gestures in the conversation samples of the NHP, whereas the second coder identified three. Because of the low number of gestures identified in this category by either coder, reliability appears to be very low.

For the type of the WFD (±gesture and ±resolved), concordance was substantial for both PWA, $\kappa = .730$, $p < .001$, and NHP, $\kappa = .706$, $p < .001$. Detailed results for the different type of gestures and WFD are reported in Table 5.19 and Table 5.20:

Table 5.19. ***Inter-rater reliability levels for the different types of gesture.***

	Reliability level for PWA in %	Reliability level for NHP in %	Total reliability level in %
Iconic	94.72	80.32	88.00
Metaphoric	98.71	97.77	98.20
Deictic	91.84	92.11	90.05
Beat	90.28	55.41	75.85
Pantomime	60.00	0.00	37.50
Emblem	100	100	100
Air writing % Numbers	68.09	100	68.75
Other	92.39	77.08	87.14

Note. PWA = participant/s with aphasia, NHP = neurologically healthy participant/s.

Table 5.20. ***Inter-rater reliability levels for the different types of WFD.***

	Reliability level for PWA in %	Reliability level for NHP in %	Total reliability level in %
WFD +gesture	81.59	84.87	82.13
WFD -gesture	72.45	89.12	81.98
WFD +resolved	77.10	88.00	82.69
WFD -resolved	79.76	66.67	77.45

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

5.4.5 Data analysis.

Quantitative analysis compared the use of different types of gestures using McNeill's dimensions (2000) across the two groups (PWA/NHP), the two conversation partners (FCP/UFCP), and the two conversation types (narrative/procedural). Different analyses were conducted to answer the five RQs. Each of these analyses will be explained in more detail in the sections below. For hypothesised outcomes, please see Chapter 4.

5.4.5.1 RQ 1: Overall number of gestures.

To what extent do PWA and NHP employ gestures in conversation? What influence does the conversation partner (i.e., familiar vs. unfamiliar conversation partner) have on the use of gesture? Do different conversation topics (i.e., narrative vs. procedural) elicit a different number of gestures?

RQ 1 addressed the overall number of gestures that participants (PWA vs. NHP) used during conversation and whether this was affected by the different conversation partner (FCP vs. UFCP) and conversation topic (narrative vs. procedural). To answer these questions, one independent sample t-test (analysis 1.1) and two 2x2 mixed methods ANOVA (analyses 1.2 and 1.3) were conducted. Below, details of each analysis are given.

5.4.5.1.1 Analysis 1.1.

The first analysis compared PWA and NHP on the basis of the overall number of gestures. An independent samples *t*-test was conducted (see Table 5.21).

Table 5.21. ***Overall number of gestures – Analysis 1.1.***

Overall number of gestures	
PWA	NHP

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; independent samples *t*-test.

5.4.5.1.2 Analysis 1.2.

In the second analysis, PWA and NHP (between-subjects factor) were compared on basis of the overall number of gestures with the two different conversation partners (FCP vs. UFCP; within-subjects factor) with a repeated-measures two-way analysis of variance (ANOVA), as Table 5.22 indicates below:

Table 5.22. ***Overall number of gestures – Analysis 1.2.***

Overall number of gestures			
PWA		NHP	
FCP	UFCP	FCP	UFCP

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; FCP = familiar conversation partner/s; UFCP = unfamiliar conversation partner/s; 2x2 repeated-measures 2-way ANOVA.

5.4.5.1.3 Analysis 1.3.

Table 5.23 displays the third analysis which compared PWA and NHP (between-subjects factor) on basis of the overall number of gestures in the two different conversation topics (narrative vs. procedural; within-subjects factor) with a repeated-measures two-way ANOVA:

Table 5.23. ***Overall number of gestures – Analysis 1.3.***

Overall number of gestures			
PWA		NHP	
narrative	procedural	narrative	procedural

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; 2x2 repeated-measures 2-way ANOVA.

5.4.5.2 RQ 2: Different types of gestures.

To what extent do PWA and NHP use different types of gestures (i.e., semantically rich gestures that convey information about the co-occurring word and/or concept (iconic, metaphoric, pantomime, emblem, and air writing & number gestures) vs. semantically empty gestures (deictic, beat, and other gestures)) in conversation? Does the conversation topic (i.e., narrative vs. procedural) have an influence on the use of different gesture types?

RQ 2 focused on the distribution of the use of semantically rich gestures and semantically empty gestures during conversation. The different groups (PWA vs. NHP) were contrasted and the influence of the conversation topic (narrative vs. procedural) was investigated. A descriptive analysis (analysis 2.1) and a 2x2 repeated-measures 2-way ANOVA (analysis 2.2) were conducted to answer these questions. Details of the analyses are given in the following subsections.

5.4.5.2.1 Analysis 2.1.

To avoid multiple analyses, the different behaviour of PWA and NHP in terms of the production of different types of gestures was explored descriptively only (see Table 5.24).

Table 5.24. ***Different types of gestures – Analysis* 2.1.**

Overall number of gestures			
PWA		NHP	
semantically rich gestures	semantically empty gestures	semantically rich gestures	semantically empty gestures

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; descriptive analysis.

A descriptive breakdown of the different types of gestures (i.e. iconic, metaphoric, deictic, beat, emblem, pantomime, air writing & number, and other gestures) was conducted as well.

5.4.5.2.2 Analysis 2.2.

The second analysis was the main analysis to answer RQ 2. Here, PWA and NHP (between-subjects factor) were compared based on the percentage of semantically rich gestures (in relation to the overall number of gestures in each conversation topic) in the different conversation topics (narrative vs. procedural; within-subjects factor). Therefore, a 2x2 repeated-measures 2-way ANOVA was conducted (see Table 5.25):

Table 5.25. ***Different types of gestures – Analysis 2.2.***

Semantically rich gestures in %			
PWA		NHP	
narrative	procedural	narrative	Procedural

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; 2x2 repeated-measures 2-way ANOVA.

5.4.5.3 RQ 3: Word-finding difficulties.

Do gestures help to resolve word-finding difficulties?

WFD were the focus of RQ 3. Participants were compared on their overall number of WFD (descriptively only; analysis 3.1). A correlation analysis was run to find out about the relationship between the overall production of gestures and the overall number of WFD (analysis 3.2). PWA and NHP were compared on the number of WFD, whether they were accompanied by a gesture and whether the WFD could be resolved only descriptively (analysis 3.3). Subsequent Wilcoxon signed-rank tests were administered on the different types of WFD (analysis 3.4). A subsequent 2x2 Pearson’s chi square test was conducted for PWA only to find out about the interaction between gesture production and resolution in WFD (analysis 3.5). Details are given in the following subsections.

5.4.5.3.1 Analysis 3.1.

Descriptive statistics were used to compare PWA and NHP on their overall number of WFD (see Table 5.26).

Table 5.26. ***Word-finding difficulties – Analysis 3.1.***

Overall number of WFD	
PWA	NHP

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; descriptive analysis.

5.4.5.3.2 Analysis 3.2.

A correlation analysis was administered to investigate the relationship between the overall number of gestures and the overall number of WFD experienced by the participants. The analysis is depicted in Table 5.27:

Table 5.27. ***Word-finding difficulties – Analysis 3.2.***

PWA		NHP	
	Overall number of WFD		Overall number of WFD
Overall number of gestures		Overall number of gestures	

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participants; WFD = word-finding difficulty/ies; Pearson's *r*.

5.4.5.3.3 Analysis 3.3.

The distribution of the different types of WFD[38] (+gesture/+resolved, +gesture/-resolved, -gesture/+resolved, and -gesture/-resolved) for PWA and NHP was investigated descriptively only to avoid multiple comparisons. An overview is given in Table 5.28:

Table 5.28. ***Word-finding difficulties – Analysis 3.3.***

Overall number of WFD							
PWA				NHP			
+gesture/ +resolved in %	+gesture/ -resolved in %	-gesture/ +resolved in %	-gesture/ -resolved in %	+gesture/ +resolved in %	+gesture/ -resolved in %	-gesture/ +resolved in %	-gesture/ -resolved in %

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; descriptive analysis.

5.4.5.3.4 Analysis 3.4.

A subsequent analysis investigated the differences between the four types of WFD. Therefore, six Wilcoxon signed-rank tests (with Bonferroni correction) were administered for each group. These aimed to determine the differences between the different types of WFD. An overview is given in Table 5.29 (for PWA) and Table 5.30 (for NHP) below:

[38] The percentage scores express the proportion of the types of WFD in relation to the overall number of WFD.

Table 5.29. ***Word-finding difficulties – Analysis 3.4a.***

Overall number of WFD					
PWA					
+gesture/ +resolved vs. +gesture/ -resolved	+gesture/ +resolved vs. -gesture/ +resolved	+gesture/ +resolved vs. -gesture/ -resolved	+gesture/ -resolved vs. -gesture/ +resolved	+gesture/ -resolved vs. -gesture/ -resolved	-gesture/ +resolved vs. -gesture/ -resolved

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

Table 5.30. ***Word-finding difficulties – Analysis 3.4b.***

Overall number of WFD					
NHP					
+gesture/ +resolved vs. +gesture/ -resolved	+gesture/ +resolved vs. -gesture/ +resolved	+gesture/ +resolved vs. -gesture/ -resolved	+gesture/ -resolved vs. -gesture/ +resolved	+gesture/ -resolved vs. -gesture/ -resolved	-gesture/ +resolved vs. -gesture/ -resolved

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

5.4.5.3.5 Analysis 3.5.

The relationship between gesture production and the resolution of WFD experienced by PWA and NHP was investigated by a 2x2 Pearson’s *chi square* test. This compared the four types of WFD (±gesture and ±resolved; see Table 5.31 and
Table 5.32).

Table 5.31. ***Word-finding difficulties – Analysis 3.5a.***

PWA		
	+resolved	-resolved
+gesture		
-gesture		

Note. PWA = participant/s with aphasia; 2x2 Pearson’s *chi square* test.

Table 5.32. ***Word-finding difficulties – Analysis 3.5b.***

NHP		
	+resolved	-resolved
+gesture		
-gesture		

Note. NHP = neurologically healthy participant/s; 2x2 Pearson’s *chi square* test.

5.4.5.4 RQ 4: Functions of semantically rich gestures.

What different functions can semantically rich gestures play in conversation? Are there different patterns in PWA and NHP?

RQ 4 focused on the functions semantically rich gestures took in conversation. Assuming that there was no difference in the functions gestures took in the different conditions (conversation partners and conversation types) participants were only compared based on the distribution of the four functions (facilitative, communicative, augmentative, and compensatory). To answer this question, descriptive analysis and Wilcoxon signed-rank tests were administered. This is described in the following paragraphs.

5.4.5.4.1 Analysis 4.1.

The main difference between the two groups was analysed descriptively only to avoid multiple comparisons. Table 5.33 provides an overview of the variables:

Table 5.33. *Semantically rich gestures – Analysis 4.1.*

Overall number of semantically rich gestures							
PWA				NHP			
Facilitative in %	Communicative in %	Augmentative in %	Compensatory in %	Facilitative in %	Communicative in %	Augmentative in %	Compensatory in %

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; descriptive analysis.

5.4.5.4.2 Analysis 4.2.

To find out more about the significant differences between the functions of semantically rich gestures, six Wilcoxon signed-rank tests (with Bonferroni correction) for each group were conducted (see Table 5.34 for PWA and Table 5.35 for NHP).

Table 5.34: *Semantically rich gestures – Analysis 4.2a.*

Overall number of semantically rich gestures					
PWA					
facilitative vs. communicative	facilitative vs. augmentative	facilitative vs. compensatory	communicative vs. augmentative	communicative vs. compensatory	augmentative vs. compensatory

Note. PWA = participant/s with aphasia; Wilcoxon signed-rank tests.

Table 5.35: *Semantically rich gestures – Analysis 4.2b.*

Overall number of semantically rich gestures					
NHP					
facilitative vs. communicative	facilitative vs. augmentative	facilitative vs. compensatory	communicative vs. augmentative	communicative vs. compensatory	augmentative vs. compensatory

Note. NHP = neurologically healthy participant/s; Wilcoxon signed-rank tests.

5.4.5.5 RQ 5: Participant factors.

What participant factors (i.e., severity of aphasia, fluency of speech, lexical production skills, verbal semantic skills, non-verbal semantic skills, cognitive skills, and motor skills) *have an influence on overall gesture production and the production of semantically rich gestures?*

RQ 5 aimed to determine whether there was a relationship between the performance on language, cognition, and motor assessments and gesture use. Several correlation analyses for PWA and NHP were run to answer this question. Details are given below.

5.4.5.5.1 Participants with aphasia.

Each composite test score (severity of aphasia, fluency of speech, lexical production skills, verbal and non-verbal semantic skills, cognition, and motor skills) was correlated with the overall number of gestures produced. The two semantic composite scores (verbal and non-verbal) were also correlated with the percentage of the semantically rich gestures. Table 5.36 below gives more details:

Table 5.36. *Participant factors PWA – Analysis 5.1a.*

	Severity	Fluency	Lexical production	Verbal semantics	Non-verbal semantics	Cognition	Motor
Gestures overall							
Semantically rich gestures	[redacted]					[redacted]	

Note. PWA = participant/s with aphasia; Person's *r* and Spearman's *rho*.

Additionally, the composite cognition score was correlated with the percentage of WFD +gesture/+resolved and WFD +gesture /-resolved (see Table 5.37). This examined whether the cognitive skills were associated with the production of gesture during WFD. If so, this might be indicative of a modality switching strategy.

Table 5.37. *Participant factors PWA – Analysis 5.1b.*

	WFD +gesture/ +resolved in %	WFD +gesture/-resolved in %
Cognition		

Note. WFD = word-finding difficulty/ies.

5.4.5.5.2 Neurologically healthy participants.

The results of the two assessments (cognition and motor skills) of NHP were correlated with the overall number of gestures (see Table 5.38).

Table 5.38. ***Participant factors NHP – Analysis 5.2.***

	Cognition	Motor skills
Gestures overall		

Note. NHP = neurologically healthy participant/s.

Chapter 6 Results

This chapter starts with an exploration of the data to look for outliers (6.1) before the global characteristics of the dataset are described and results of the statistical analyses are given (6.2). Subsections 6.3 to 6.7 show the results against the five research questions. A summary of the overall findings of this study is given in 6.8.

6.1 Outlier analysis

The datasets of PWA and NHP were analysed for outliers. Individual data points were defined as outliers if they differed from the group mean by at least two standard deviations. As summarised in Table 6.1, eight of the PWA produced outlying scores. Two (16A and 13A) were outliers on five and six variables respectively. However, none of the participants was an outlier on more than 25% of all variables. Also, there was no indication that scores were invalid. The lower scores of 13A and 16A on the assessment variables reflected the severity of their language impairment. Therefore, all data were retained for statistical analyses.

Table 6.1. ***Outliers.***

Variable	ID	Group	Score	Group *M*	*SD*	Difference in *SD*
WAB-R AQ (%)	16A	PWA	31.60	68.01	16.946	> 2
	13A	PWA	36.70	68.01	16.946	> 2
	14A	PWA	37.20	68.07	16.946	> 2
WAB-R Fluency	13A	PWA	2.00	4.80	2.093	> 2
	16A	PWA	2.00	4.80	2.093	> 2
	2A	PWA	9.00	4.80	2.093	> 2
	6A	PWA	9.00	4.80	2.093	> 2
	7A	PWA	9.00	4.80	2.093	> 2
Motor skills (%)	14A	PWA	26.20	80.37	15.140	> 2
Gestures UFCP	13A	PWA	65.00	194.00	51.946	> 2
Procedural gestures overall	13A	PWA	58.00	197.32	48.333	> 2
Sem. rich gestures overall	13A	PWA	67.00	205.42	71.246	> 2
Sem. rich gestures overall (%)	10A	PWA	29.64	57.14	11.302	> 2
	15A	PWA	32.81	57.14	11.302	> 2
Sem. empty gestures overall	10A	PWA	311.00	149.89	54.158	> 2
Sem. rich gestures procedural (%)	10A	PWA	31.70	62.60	15.130	> 2
WFD +gesture/-resolved (%)	16A	PWA	47.06	17.59	11.053	> 2
	14C	NHP	5.79	1.41	1.621	> 2
WFD -gesture/-resolved (%)	13A	PWA	37.68	12.09	8.606	> 2
Facilitative (%)	16A	PWA	13.86	50.23	12.489	> 2
Communicative gestures (%)	2C	NHP	7.04	1.28	1.574	> 2
Compensatory gestures (%)	16A	PWA	36.14	3.38	7.797	> 2

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; FCP = familiar conversation partner/s; UFCP = unfamiliar conversation partner/s; *M* = mean; *SD* = standard deviation; WAB-R = Western Aphasia Battery – Revised; AQ = aphasia quotient; WFD = word-finding difficulties.

6.2 Global characteristics of the data

Before any statistical analyses were carried out, the datasets of PWA and NHP were checked for normal distribution. Normal distribution indicated by a skewness score of between -1 and +1 and if the Shapiro-Wilk test, which is used to test normality on smaller sample sizes (< 50), was not significant ($p > 0.05$). Table 6.2 summarises the data that were not normally distributed.

Data that were not normally distributed were analysed descriptively or with non-parametric tests. In some cases, ANOVA tests were employed. This was because the skewness was only marginally outside the range for normal distribution and because ANOVA is robust and not sensitive to moderate deviations from normality (e.g., Glass, Peckham, & Sanders, 1972; Harwell, Rubinstein, Hayes, & Olds, 1992; Lix, Keselman,

& Keselman, 1996). The distribution of the data will be further described in the following result subsections.

Table 6.2. *Statistical analyses.*

Topic (analysis)	Test(s)	Variable(s)	Distribution
RQ 1: Overall number of gestures			
Overall use of gesture (analysis 1.1)	*t*-test	PWA vs. NHP; gestures overall	normally distributed
Influence of the conversation partner (analysis 1.2)	2x2 ANOVA	PWA vs. NHP; gestures FCP vs. gestures UFCP	normally distributed
Influence of the conversation topic (analysis 1.3)	2x2 ANOVA	PWA vs. NHP; narrative gestures overall vs. procedural gestures overall	procedural gestures overall (PWA) are not normally distributed
RQ 2: Different types of gestures			
Different types of gestures (analysis 2.1)	descriptive analysis 2x2 ANOVA	PWA vs. NHP; semantically rich gestures overall vs. semantically empty gestures overall	semantically empty gestures overall (PWA) are not normally distributed
Influence of the conversation topic on the use of semantically rich gestures (analysis 2.2)		PWA vs. NHP; semantically rich gestures narrative (%) vs. semantically rich gestures procedural (%)	semantically rich gestures procedural (PWA and NHP) are not normally distributed
RQ 3: Word-finding difficulties			
Word-finding difficulties (analysis 3.1)	Descriptive analysis	PWA vs. NHP; WFD overall	normally distributed
Correlations (analysis 3.2)	Pearson's *r* descriptive analysis	PWA & NHP; relationship between overall number of WFD & overall number of gestures	normally distributed
Word-finding difficulties (analyses 3.3-3.5)	Wilcoxon signed-rank tests	PWA vs. NHP; +gesture/+resolved vs. +gesture/ -resolved vs. -gesture/+resolved vs. -gesture/-resolved	+gesture/-resolved (PWA and NHP) and -gesture/-resolved (PWA) are not normally distributed
	2x2 Pearson's *chi square*	comparisons between all types of WFD +gesture/+resolved, -gesture/+resolved, +gesture/ -resolved, -gesture/-resolved	

Table 4.2. *Statistical analyses* (*continued*).

Topic (analysis)	Test(s)	Variable(s)	Distribution
RQ 4: Functions of semantically rich gestures			
Functions of semantically rich gestures (analyses 4.1-4.2)	descriptive analysis	PWA vs. NHP; facilitative (%) vs. communicative (%) vs. augmentative (%) vs. compensatory (%)	facilitative (%) (PWA), communicative (%) (NHP), and compensatory (%) (PWA) are not normally distributed
	Wilcoxon signed-rank tests	comparisons between all functions	
RQ 5: Participant factors			
Correlation matrix PWA (analysis 5.1a)	Spearman's *rho* & Pearson's *r*	WAB-R AQ & WAB-R fluency & lexical production & verbal semantics & non-verbal semantics & cognition & motor & gestures overall & semantically rich gestures overall (%) (only for verbal and non-verbal semantic skills)	WAB-R AQ, WAB-R fluency, lexical production, cognition, motor skills, and semantically rich gestures overall (%) are not normally distributed
Correlation matrix PWA (analysis 5.2b)	Spearman's *rho*	cognition & +gesture/+resolved (%) & +gesture/ -resolved (%)	cognition and +gesture/-resolved (%) are not normally distributed
Correlation matrix NHP (analysis 5.3)	Spearman's *rho* & Pearson's *r*	cognition & motor & gesture overall	cognition is not normally distributed

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; FCP = familiar conversation partner/s; UFCP = unfamiliar conversation partner/s; WFD = word-finding **difficulty/ies**; WAB-R = Western Aphasia Battery – Revised; AQ = aphasia quotient.

6.3 RQ 1: Overall number of gestures

To what extent do PWA and NHP employ gestures in conversation? What influence does the conversation partner (i.e., familiar vs. unfamiliar conversation partner) have on the use of gesture? Do different conversation topics (i.e., narrative vs. procedural) elicit a different number of gestures?

6.3.1 Overall number of gestures.

For both participant groups, the data for the overall number of gestures were normally distributed, W (19) = .931, p = .183 for PWA and W (20) = .955, p = .445 for NHP. An independent sample t-test was conducted to compare the number of gestures produced by PWA and NHP. As expected, both participant groups, PWA and NHP, employed gestures during the conversations but contrary to expectations, there was no significant difference in the overall number of gestures between PWA and NHP, t (37) = -1.060, p = .296. See Table 6.3 for means, standard deviations, and standard errors:

Table 6.3. *Overall use of gesture.*

	M	*SD*	*SE*
PWA	355.32	92.519	21.225
NHP	384.10	76.674	17.145

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

6.3.2 Influence of the conversation partner.

The data for the number of gestures produced with FCP and UFCP were both normally distributed for PWA and NHP, W (19) = .971, p = .802 for PWA (FCP), W (20) = .963, p= .596 for NHP (FCP), W (20) = .956, p = .471 for PWA (UFCP), and W (21) = .961, p = .531 for NHP (UFCP). Therefore, the influence of the conversation partner on the use of gesture was analysed by means of a 2x2 repeated measures 2-way ANOVA with one between-factor (PWA vs. NHP) and one within-factor (FCP vs. UFPC). There was a main effect with a large effect size of the conversation partner on the number of gestures produced in conversation, F (1, 37) = 24.358, p < .001 (η_p^2 = .397), with both PWA and NHP producing more gestures in the conversations with the unfamiliar conversation partner. There was no main effect of group, F (1, 37) = 1.124, p = .296 (η_p^2 = .029) and no interaction between conversation partner and participant group, F (1, 37) = 0.979,

p = .329 (η_p^2 = .026). Both non-significant results revealed small effect sizes. The results are depicted in Figure 6.1:

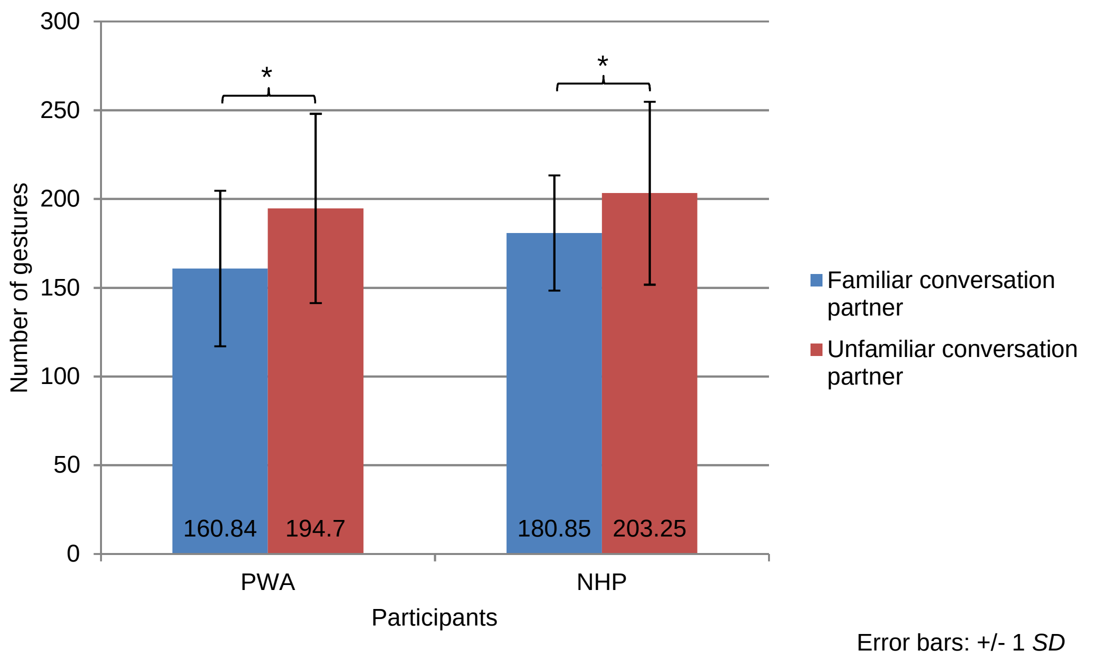

Figure 6.1. ***Influence of the conversation partner on gesture production for PWA and NHP, including error bars of +/-1 SD. Significant differences are marked with *.***

6.3.3 Influence of the conversation topic.

The data for the number of gestures produced in narrative and procedural conversations overall were normally distributed for both participant groups, W (19) = .973, p = .836 for PWA (narrative), W (21) = .973, p = .836 for NHP (narrative), W (19) = .884, p = .025 for PWA (procedural), and W (20) = .979, p = .927 for NHP (procedural). These data were entered into a second 2x2 repeated measures 2-way ANOVA with one between-factor (PWA vs. NHP) and one within-factor (narrative vs. procedural) to investigate the influence of the conversation topic on gesture production. There was a significant main effect of the conversation topic for both groups, F (1, 37) = 44.807, p < .001 (η_p^2 = .548) with a large effect size. Procedural topics elicited significantly more gestures than narrative topics. There were no main effect of group F (1, 37) = 1.132, p = .294 (η_p^2 = .030) and no interaction between topic and participant group, F (1, 37) = 3.401, p = .073 (η_p^2 = .084). The non-significant main effect (group) had a small effect size, while the effect size of the interaction was medium. The results are illustrated in Figure 6.2:

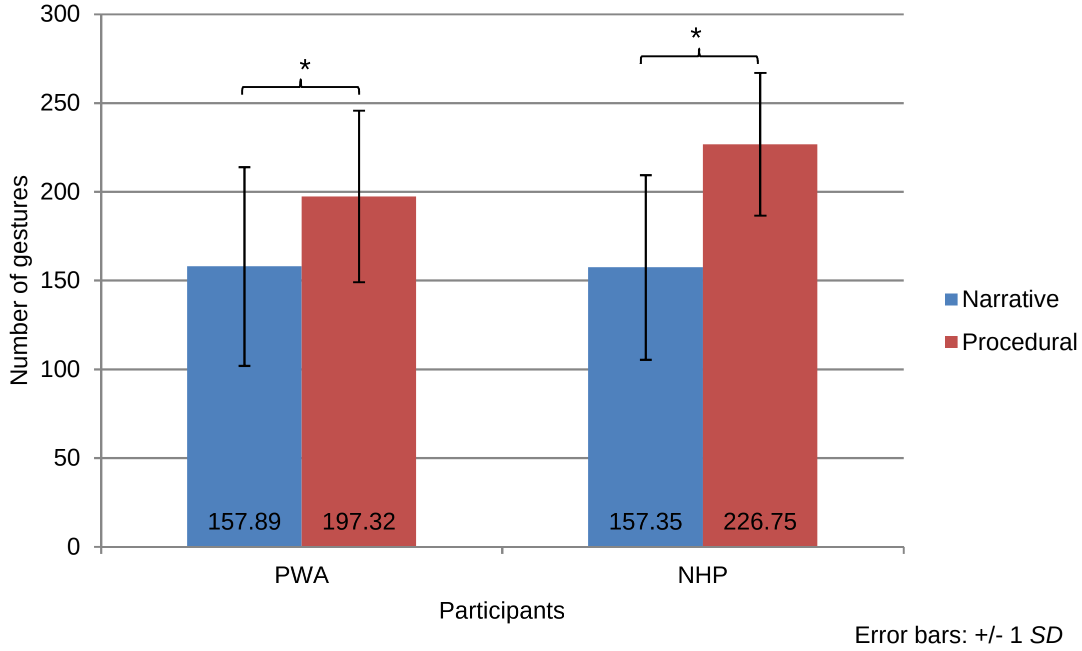

Figure 6.2. ***Influence of the conversation topic on gesture production for PWA and NHP, including error bars of +/-1 SD. Significant differences are marked with *.***

6.4 RQ 2: Different types of gestures

To what extent do PWA and NHP use different types of gestures (i.e., semantically rich gestures that convey information about the co-occurring word and/or concept (iconic, metaphoric, pantomime, emblem, and air writing & number gestures) vs. semantically empty gestures (deictic, beat, and other gestures)) in conversation? Does the conversation topic (i.e., narrative vs. procedural) have an influence on the use of different gesture types?

6.4.1 Different types of gesture.

While the data for the overall number of semantically rich gestures were normally distributed, W (19) = .946, p = .332 for PWA and W (20) = .967, p = .688 for NHP, the overall number of semantically empty gestures was only normally distributed for NHP, W (19) = .892, p = .036 for PWA and W (20) = .943, p = .271 for NHP. Descriptive statistics revealed that both PWA and NHP used more semantically rich gestures (i.e., iconic, metaphoric, pantomime, emblem, air writing, and number gestures) than semantically empty gestures (i.e., deictic, beat, and other gestures). Figure 6.3 shows the different use of semantically rich and semantically empty gestures for both PWA and

NHP. Both groups reveal a similar pattern, in that they produced more semantically rich than semantically empty gestures overall:

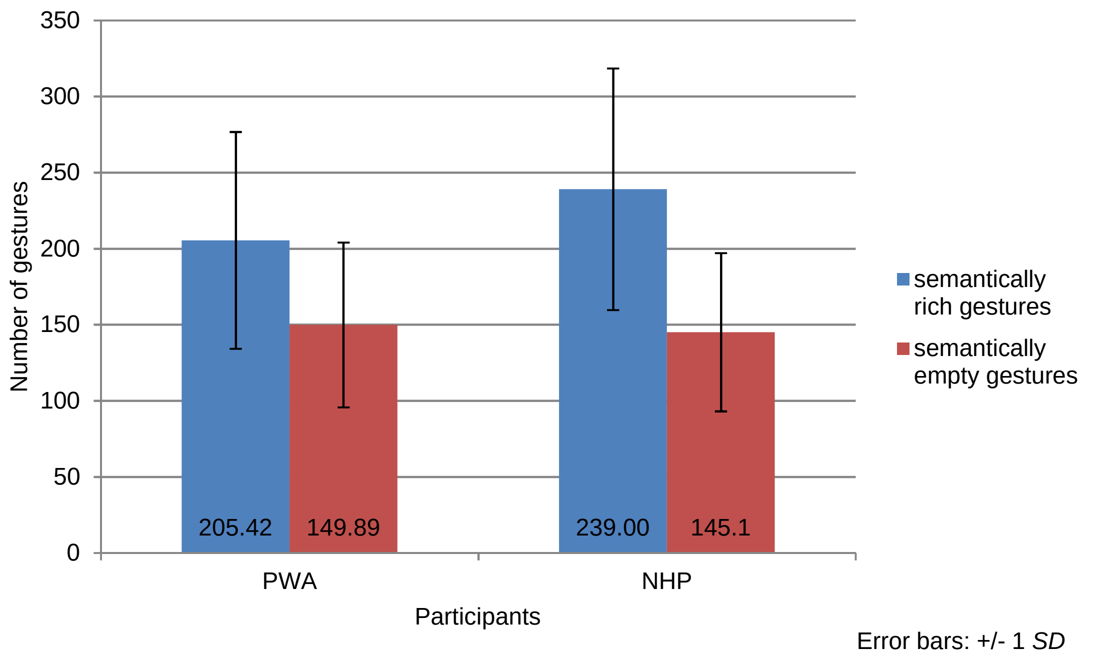

Figure 6.3. ***Use of semantically rich and semantically empty gestures for PWA and NHP.***

A finer breakdown for gesture type is given in Table 6.4. There were marginal differences between PWA and NHP on each type, but no statistical tests were conducted for comparison. All participants produced a similar percentage of iconic and emblem gestures. While PWA 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 classified (i.e., other) than NHP.

Table 6.4. ***Different types of gestures.***

	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.

6.4.2 Influence of the conversation topic.

For PWA and NHP, only the data for semantically rich gestures produced in narrative conversation (in %) were normally distributed, *W* (20) = .931, *p* = .159 for PWA, *W* (21) = .393, *p* = .209 for NHP. Data for semantically rich gestures produced in procedural conversation (in %) were not normally distributed for either PWA or NHP, *W* (20) = .901, *p* = .042 for PWA and *W* (21) = .897, *p* = .030 for NHP. As both variables were only minimally skewed and studies have shown that an ANOVA is robust in this circumstance, a 2x2 repeated measures 2-way ANOVA was conducted to explore the influence of the conversation topic on the production of semantically rich gestures. The between-factor was group (PWA vs. NHP) and the within-factor was topic (narrative vs. procedural). There was a main effect of topic, showing that procedural conversation topics elicited more semantically rich gestures than narrative conversation topics, and the effect size was large, *F* (1, 39) = 58.273, *p* < .001 (η_p^2 = .599). There was no main effect of group, *F* (1, 39) = 1.185, *p* = .283 (η_p^2 = .030) and no interaction of topic and group, *F* (1, 39) = 0.207, *p* = .652 (η_p^2 = .009). Here, the effect sizes of the main effect of group and of the interaction were small. The percentages of semantically rich gestures that were produced in procedural and narrative conversation topics are displayed in Figure 6.4:

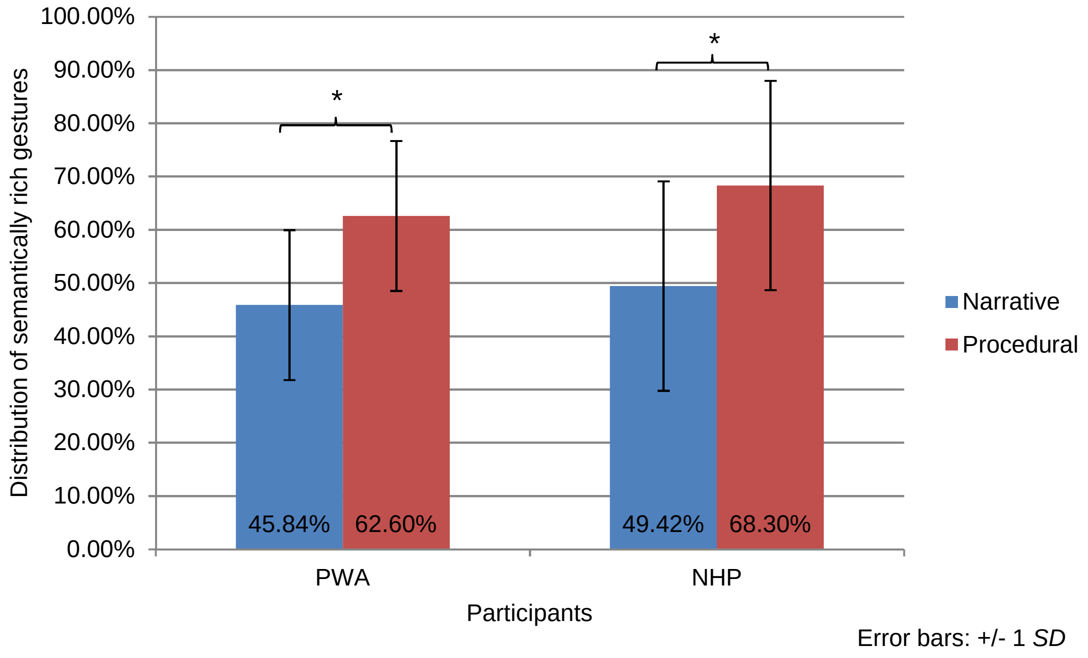

Figure 6.4. ***Influence of the conversation topic on the use of semantically rich gestures (in %).***

6.5 RQ 3: Word-finding difficulties

Do gestures help to resolve word-finding difficulties?

6.5.1 General analysis.

Descriptive statistics revealed that both PWA and NHP experienced a number of WFD. In fact, NHP experienced more WFD (M = 117.80, SD = 23.171) than PWA (M = 107.84, SD = 30.183).

Nine of the 11 variables used to analyse the influence of gesture production in WFD were normally distributed: W (19) = .931, p = .183 for PWA (overall number of gestures) and W (20) = .955, p = .445 for NHP (overall number of gestures); W (20) = .976, p = .881 for PWA (WFD overall) and W (21) = .977, p = .897 for NHP (WFD overall); W (20) = .946, p = .312 for PWA (+gesture/+resolved) and W (21) = .932, p = .149 for NHP (+gesture/ +resolved); W (20) = .980, p = .937 for PWA (-gesture/+resolved) and W (21) = .931, p = .141 for NHP (-gesture/+resolved); and finally W (21) = .968, p = .691 for NHP (-gesture/-resolved). The remaining three variables were not normally distributed: W (20) = .843, p = .004 for PWA (-gesture/-resolved), W (20) = .867, p = .010 for PWA (+gesture/-resolved), and W (21) = .828, p = .002 for NHP (+gesture/-resolved).

As the data for most variables were normally distributed, parametric analyses were employed.

6.5.2 Correlation analyses.

The relationship between the overall number of gestures and the overall number of WFD was investigated for both PWA and NHP. Since all relevant variables for these analyses were normally distributed (see Shapiro-Wilk normality tests in above), parametric correlations analyses (Pearson's *r*) were conducted.

There was a significant relationship for PWA between the overall number of gestures and the overall number of WFD, r (17) = .474, p = .040. This indicated that PWA who experienced more WFD also produced more gestures overall, pointing to a potential role for gesture in WFD (see Figure 6.5).

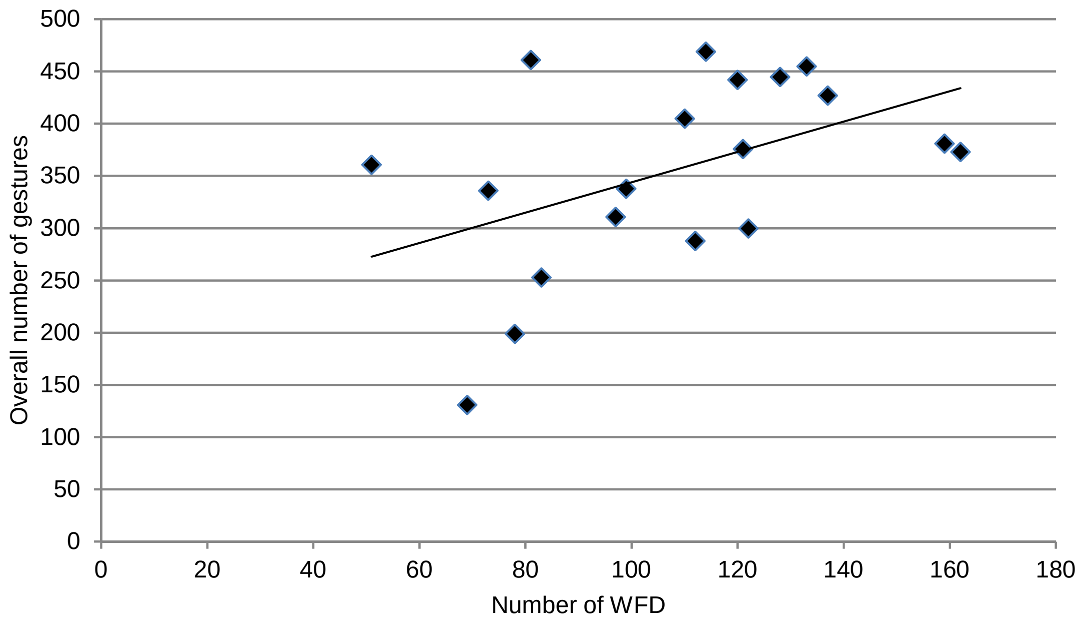

Figure 6.5. ***Correlation between the number of gestures and the overall number of WFD for PWA.***

For the NHP, there was no significant relationship between the overall number of gestures and the overall number of WFD, r (18) = .076, p = .751.

When comparing the correlation analysis for each group, it is apparent that the values r_{pwa} and r_{nhp} are different; additionally, one of the values indicates a significant correlation (r_{pwa}). Nevertheless, the question remains whether the difference between these two values is large enough to assume that these are not just estimates of the same population (Edwards, 1976). Therefore, a test of significance of the difference between these two values r_{pwa} and r_{nhp} was conducted. In this test, the correlation coefficients were transformed into z-values and inserted into a given formula (Edwards, 1976; p. 89f.). Results revealed a non-significant difference between the two correlation coefficients, $z = 1.626$, $p = 0.104$.

6.5.3 Distribution of the different types of WFD.

The following analyses examined the relationship between the production of gestures[39] and the resolution or non-resolution of WFD. Four categories of WFD were identified: (1) +gesture/+resolved, (2) +gesture/-resolved, (3) -gesture/+resolved, and (4) -gesture/-resolved. To find out about the influence of gesture production on the resolution of WFD, these are the main questions:

- Are resolved WFD typically accompanied by gestures? If this is the case, there should be more WFD of the +gesture/+resolved type compared to the -gesture/+resolved type.
- Are unresolved WFD less likely to be accompanied by gestures? If this is the case, there should be more WFD of the -gesture/-resolved type compared to the +gesture/-resolved type.

Table 6.5 reports the number of WFD in each category. To avoid multiple comparisons, the distribution of the different types of WFD for PWA and NHP were only explored descriptively. Only the differences between the types of WFD within the two participant groups were analysed using statistical analyses (see 6.5.3.1 and 6.5.3.2). Both PWA and NHP produced a high number of WFD +gesture/+resolved. While NHP produced a high number of WFD -gesture/+resolved as well, this type was less common for PWA. Instead, PWA produced many WFD +gesture/-resolved and WFD -gesture/-resolved. The findings indicate that NHP almost always resolved their WFD, independent of co-occurring gestures. For PWA, however, more WFD were resolved if they were accompanied by a gesture than if they were not.

[39] One has to acknowledge that using percentage scores may lead to a smoothing effect of data. For example, someone who produced ten WFD with four +gesture/+resolved, one +gesture/-resolved, two -gesture/+resolved, and three -gesture/-resolved would be given the same score as someone who produced 100 WFD with 40 +gesture/+resolved, ten +gesture/-resolved, 20 -gesture/+resolved, and 30 -gesture/-resolved since they did not differ in the distribution.

Table 6.5. ***Distribution of different types of WFD (in %).***

	PWA		NHP	
	M	*SD*	*M*	*SD*
+gesture/+resolved	47.02	14.129	53.31	16.251
+gesture/-resolved	17.59	11.053	1.41	1.621
-gesture/+resolved	23.30	10.299	40.92	15.624
-gesture/-resolved	12.09	8.606	3.34	1.402

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; WFD = word-finding difficulty/ies; *M* = mean; *SD* = standard deviation.

In the following sections, data for the two participant groups will be described in detail, including statistical tests to explore the differences between the four types of WFD (6.5.3.1 and 6.5.3.2). The major findings will be summarised in 6.5.4.

6.5.3.1 Participants with aphasia.

Figure 6.6 gives an overview of the distribution of the different types of WFD (in %) for PWA:

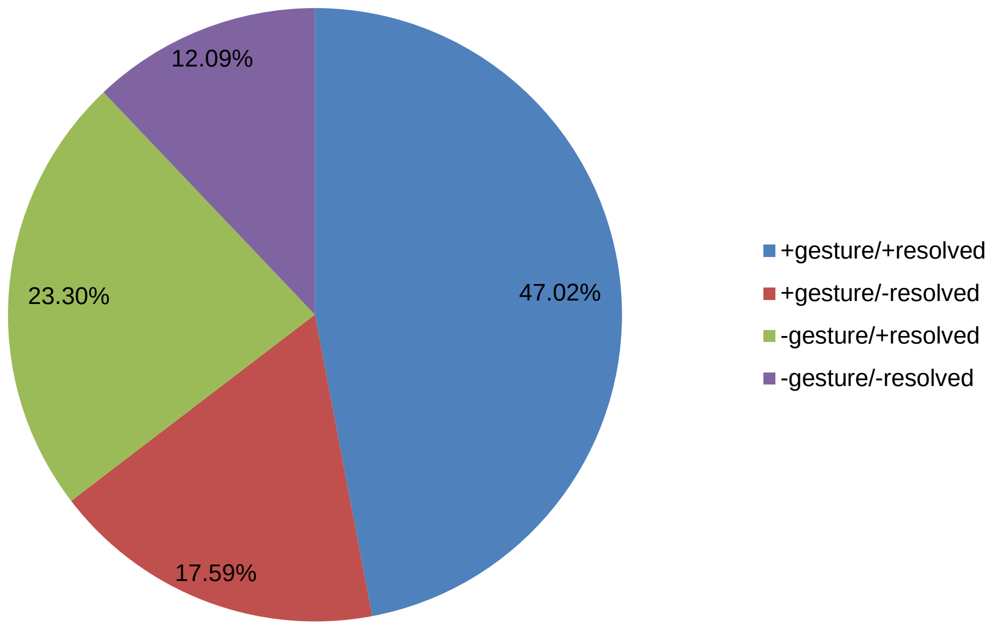

Figure 6.6. ***Distribution of different types of WFD (in %) for PWA.***

PWA were able to resolve 70.32% of WFD (+gesture/+resolved and -gesture/+resolved). Of those resolved WFD (the blue and the green sections of Figure 6.6), most were accompanied by gestures (+gesture/+resolved; the blue section of Figure 6.6). Nevertheless, PWA also produced many unresolved WFD (+gesture/-resolved and -gesture/-resolved; the purple and red sections of Figure 6.6). Numerically, more of these unresolved WFD were also accompanied by gestures (+gesture/-resolved; the red section of Figure 6.6). Subsequent Wilcoxon signed-rank tests (with Bonferroni correction) were conducted to explore the significant differences between the different types of WFD (see Table 6.6).

Table 6.6. ***Difference matrix for word-finding difficulties of PWA.***

	+gesture/+resolved	+gesture/-resolved	-gesture/+resolved	-gesture/-resolved
+gesture/ +resolved				
+gesture/ -resolved	$W = 10$, $z = -3.547$, $p < .001$**			
-gesture/ +resolved	$W = 10$, $z = -3.547$, $p < .001$**	$W = 71$, $z = -1.269$, $p = .204$		
-gesture/ -resolved	$W = 5$, $z = -3.733$, $p < .001$**	$W = 56$, $z = -1.829$, $p = .067$	$W = 23$, $z = -3.061$, $p = .002$*	

Note. PWA = participant/s with aphasia; ** = significant at $p < .001$; * = significant at $p < .05$.

These analyses revealed that the gestural difference between the resolved WFD (+gesture/+resolved vs. -gesture/+resolved) was significant with PWA producing more gestures in resolved WFD than in unresolved WFD. This indicated a possible effect of gesture production on the resolution of WFD. The gestural difference between unresolved WFD (+gesture/-resolved vs. -gesture/-resolved) was not significant.

Subsequently, a 2x2 Pearson's Chi Square analysis was conducted for PWA (Pring, 2005), to examine the relationship between the production of gestures in WFD and their resolution[40]. Results revealed a significant relationship between these two factors, X^2 (1) = 12.356, $p < .01$, indicating that WFD that occurred with gestures were more likely to be resolved than WFD that occurred without gesture production. See Table 6.7 for raw scores entered into the analysis:

Table 6.7. ***Raw scores of the different types of WFD for PWA used for Chi Square analysis.***

PWA	WFD +resolved	WFD -resolved
WFD +gesture	1054	330
WFD -gesture	495	222

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

[40] The data entered into this analysis was the overall number of instances for each type of WFD. The other analyses in this section used percentage data calculated for all cases. The scores reported in Table 6.5 are the mean scores of these individual percentages.

6.5.3.2 Neurologically healthy participants.

The distribution of the different types of WFD (in %) for NHP is displayed in Figure 6.7:

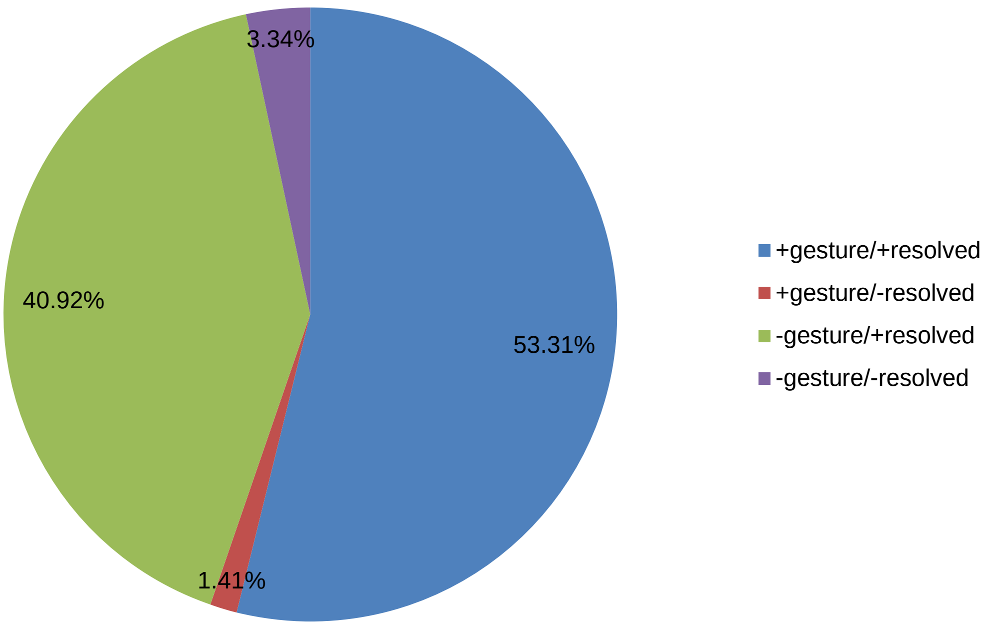

Figure 6.7. ***Distribution of different types of WFD (in %) for NHP.***

As expected, NHP were able to resolve more WFD than PWA (+gesture/+resolved and -gesture/+resolved). Numerically, there is only a small difference between resolved WFD with gesture and those without, although the largest group (the blue section of Figure 6.7) is resolved WFD with a gesture (+gesture/+resolved). Unlike PWA, NHP only produced a small number of unresolved WFD (+gesture/-resolved vs. -gesture/-resolved). Here, the number of unresolved WFD that were accompanied by gestures was lower than the ones without gesture. This pointed to a possible relationship between gesture production and resolution. To find out more about the differences between the different types of WFD, subsequent Wilcoxon signed-rank tests (with Bonferroni correction) were conducted (Table 6.8).

Table 6.8. ***Difference matrix for WFD of NHP.***

	+gesture/+resolved	+gesture/-resolved	-gesture/+resolved	-gesture/-resolved
+gesture/ +resolved				
+gesture/ -resolved	*W* = 0, *z* = -4.015, *p* < .001**			
-gesture/ +resolved	*W* = 65, *z* = -1.755, *p* = .079	*W* = 0, *z* = -4.015, *p* < .001**		
-gesture/ -resolved	*W* = 0, *z* = -4.015, *p* < .001**	*W* = 14, *z* = -3.398, *p* = .001**	*W* = 0, *z* = -4.015, *p* < .001**	

Note. NHP = neurologically healthy participant/s; ** = significant at *p* < .001; * = significant at *p* < .05.

Unlike PWA, there was no significant gestural difference between the groups of resolved WFD (+gesture/+resolved and -gesture/+resolved) for NHP, despite the numerical difference. This suggested that there was only a trend for gesture production playing an important role for the resolution of WFD. The gestural difference between the two unresolved WFD types (+gesture/-resolved vs. -gesture/-resolved) was significant, such that more unresolved WFD were not accompanied by gesture than those that were. This supported the (non-significant) trend of gestures helping to resolve WFD. If there was a gesture, the WFD was less likely to be unresolved (i.e., +gesture/-resolved < -gesture/-resolved).

To explore the relationship between the production of gestures in WFD and their resolution for NHP, 2x2 Pearson's Chi Square analysis was also conducted. Similar to PWA, results revealed a significant relationship between these two factors for NHP, X^2 (1) = 40.657, $p < .01$. According to that, it was more likely for WFD to be resolved if they occurred with a gesture than without. This finding was surprising as the Wilcoxon signed rank tests (see Table 6.8) did not reveal a significant difference between resolved WFD with and without gesture production. Therefore, these results and subsequent implications have to be treated with care. Table 6.9 depicts the raw scores used to conduct the analysis:

Table 6.9. ***Raw scores of the different types of WFD for NHP used for Chi Square analysis.***

NHP	WFD +resolved	WFD -resolved
WFD +gesture	1313	35
WFD -gesture	910	84

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

6.5.4 Summary.

Both PWA and NHP produced more resolved WFD than unresolved. While there were significantly more gestures in resolved WFD than no gestures for PWA, this was only a trend for NHP. Nevertheless, NHP produced significantly fewer gestures in unresolved WFD. This revealed the importance of gesture production during WFD, indicating that gestures may have a facilitative function (see below). This was not the case for PWA as they produced marginally more unresolved WFD with gestures than without. Nevertheless, both chi square analyses revealed a significant relationship between the production of gestures in WFD and their resolution for PWA and NHP.

6.6 RQ 4: Functions of semantically rich gestures

What different functions can semantically rich gestures play in conversation? Are there different patterns in PWA and NHP?

6.6.1 General analysis.

Four potential gesture functions were identified and examined. These were: (1) facilitative, (2) communicative, (3) augmentative, and (4) compensatory (see 5.4.3.2 for definitions). Unlike the different types of WFD that included the overall number of gestures, these four functions represent only the subsection of semantically rich gestures. Therefore, the category of facilitative gestures corresponds to the +gesture/+resolved WFD category but they are not identical. This is the same for the category of communicative gestures and the +gesture/-resolved WFD category.

Of the eight variables (four functions of gestures x two participant groups), five were normally distributed, W (21) = .960, p = .513 for NHP (facilitative), W (20) = .974, p = .837 for PWA (communicative), W (20) = .969, p = .727 for PWA (augmentative), W (21) = .947, p = .295 for NHP (augmentative), and W (21) = .365, p = .114 for NHP (compensatory), while three were not, W (20) = .852, p = .006 for PWA (facilitative), W (21) = .725, p < .001 for NHP (communicative), and W (20) = .365, p < .001 for PWA (compensatory). As the p-values of the normality tests for the latter variables were highly significant, the variables were explored descriptively or via non-parametric tests.

Table 6.10 provides an overview of means and standard deviations for the different functional categories. Both PWA and NHP produced a high number of facilitative gestures. This was in line with the above analyses of the role of gesture in WFD (see

6.5). While NHP also produced also a high number of augmentative gestures, this was not the case for PWA. Instead, PWA produced many communicative gestures. For both groups, there were only few compensatory gestures.

Table 6.10. ***Distribution of the different functions of semantically rich gestures (in %).***

	PWA		NHP	
	M	*SD*	*M*	*SD*
facilitative	50.23	12.488	47.40	11.963
communicative	27.25	13.072	1.28	1.574
augmentative	19.14	10.173	50.59	12.511
compensatory	3.38	7.797	0.73	0.536

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

The results of PWA and NHP will be described in more detail, including statistical tests to explore the differences between the different functions of semantically rich gestures (6.6.2 and 6.6.3). 6.6.4 will summarise the major findings.

6.6.2 Participants with aphasia.

An overview of the distribution of the different functions of semantically rich gestures (in %) is given in Figure 6.8:

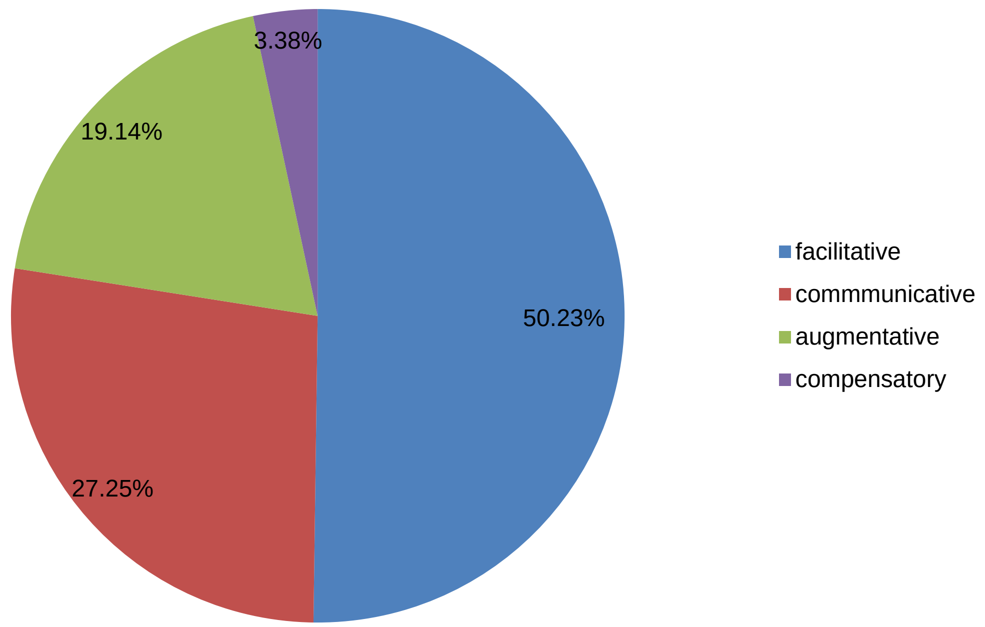

Figure 6.8. ***Distribution of the different functions of semantically rich gestures (in %) for PWA.***

More than 75% of all semantically rich gestures were produced during WFD (facilitative and communicative) with the majority leading to the resolution of WFD. This confirmed the finding of the previous research question, relating gesture production to the resolution of WFD. Only a small number of gestures was produced outside of WFD with more gestures accompanying speech than replacing it (augmentative > compensatory).

To explore the differences between the different functions, subsequent Wilcoxon signed-rank tests (with Bonferroni correction) were conducted for PWA. See Table 6.11 for the analyses and their results:

Table 6.11. ***Difference matrix for functions of semantically rich gestures of PWA.***

	Facilitative	Communicative	Augmentative	Compensatory
Facilitative				
Communicative	$W = 21$, $z = -3.136$, $p = .002$*			
Augmentative	$W = 0$, $z = -3.920$, $p < .001$**	$W = 67$, $z = -1.419$, $p = .156$		
Compensatory	W = 1, z = -3.883, $p < .001$**	$W = 0$, $z = -3.920$, $p < .001$**	$W = 18$, $z = -3.248$, $p = .001$*	

Note. PWA = participant/s with aphasia; ** = significant at $p < .001$; * = significant at $p < .05$.

There were highly significant differences between almost all four roles of semantically rich gestures. Only the difference between the communicative and the augmentative gestures was not significant. This indicated that semantically rich gestures could take different roles and that the production of those gestures played an important role in WFD in general (facilitative and communicative) and in their resolution in particular (facilitative). Only a small number of gestures were produced to replace speech (compensatory).

6.6.3 Neurologically healthy participants.

Figure 6.9 provides an overview of the distribution of the different functions of semantically rich gestures for NHP:

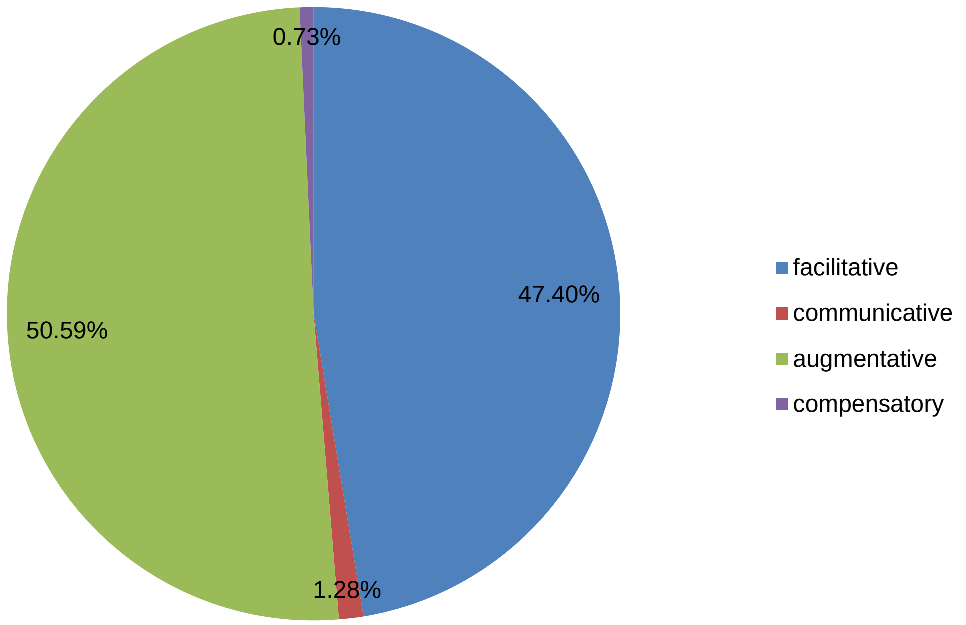

Figure 6.9. ***Distribution of the different functions of semantically rich gestures (in %) for NHP.***

NHP produced only about 50% of all gestures during WFD (facilitative and communicative) with almost all being resolved (facilitative). The other half of gestures was produced outside of WFD (augmentative and compensatory). Similar to the PWA, only a small number of gestures were used to replace speech.

Subsequent Wilcoxon signed-rank tests (with Bonferroni correction) were conducted to explore the differences between the different functions (see Table 6.12):

Table 6.12. ***Difference matrix for functions of semantically rich gestures of NHP.***

	Facilitative	Communicative	Augmentative	Compensatory
Facilitative				
Communicative	$W = 0$, $z = -1.015$, $p < .001$**			
Augmentative	$W = 100$, $z = -0.539$, $p = .590$	$W = 0$, $z = -4.015$, $p < .001$**		
Compensatory	$W = 0$, $z = -4.015$, $p < .001$**	$W = 48$, $z = -1.349$, $p = .177$	$W = 0$, $z = -4015$, $p < .001$**	

Note. NHP = neurologically healthy participant/s; ** = significant at $p < .001$; * = significant at $p < .05$.

Only the differences between facilitative and augmentative gestures and the difference between communicative and compensatory gestures were not significant. The significant difference between facilitative and communicative gestures underlined the important role gesture production plays during WFD. The significant difference between augmentative and compensatory gestures reflects the fact that while NHP often gesture alongside fluent speech, they rarely gesture to replace it. As expected, NHP mainly used gestures to either facilitate WFD (facilitative) or supplement speech (augmentative).

6.6.4 Summary.

For both PWA and NHP, about 50% of all semantically rich gestures played a facilitative function. The major difference between the two groups can be found in the number of communicative gestures, which are semantically gestures produce during a WFD that was not resolved by the speaker. While NHP produced only a small number of communicative gestures, this type played an important role for PWA. This difference was the other way round in the production of augmentative gestures, which are semantically rich gestures produced alongside fluent speech. Here, NHP produced a large number of these gestures, while augmentative gestures did not play such an important role for PWA. Both groups produced only a small number of compensatory gestures to replace speech.

6.7 RQ 5: Participant factors

What participant factors (i.e., severity of aphasia, fluency of speech, lexical production skills, verbal semantic skills, non-verbal semantic skills, cognitive skills, and motor skills) have an influence on overall gesture production and the production of semantically rich gestures?

Participants completed a number of language, cognition, and motor assessments (see 5.3.1 for details). Language assessments were only administered with PWA and explored severity of aphasia (WAB-R AQ), fluency of speech (WAB-R score), lexical production skills (OANB list A, objects and actions), verbal semantic skills (PALPA #47 & #49, synonym judgement tasks of verbs & adjectives, VAST verb comprehension). and non-verbal semantic skills (PPTT & KDT). Tests of non-verbal cognitive skills (part of CLQT) and motor skills (BCoS-Praxis) were completed by both PWA and NHP. To find out more about the influence of participant factors, the assessment scores of all participants were correlated with the overall number of gestures. Additionally, verbal and non-verbal semantic skills were correlated with the overall number of semantically rich gestures (%) to find out about the influence of semantic skills on the production of this subtype of gestures.

Some of these variables showed normal distribution – W (20) = .907, p = .055 for PWA (verbal semantic skills), W (20) = .919, p = .095 for PWA (non-verbal semantic skills), W (21) = .937, p = .191 for NHP (motor skills), W (19) = .931, p = .183 for PWA (gestures overall), and W (20) = .955, p = .445 for NHP (gestures overall) – while the majority did not – W (20) = .895, p = .033 for PWA (WAB-R AQ), W (20) = .826, p = .002 for PWA (WAB-R fluency), W (20) = .835, p = .003 for PWA (lexical production skills), W (20) = .889, p = .026 for PWA (cognition), W (21) = .886, p = .019 for NHP (cognition), W (20) = .743, p < .001 for PWA (motor skills), and W (19) = .900, p = .049 for PWA (semantically rich gestures overall (%)).

To gain an overview of inter-correlations between participant factors and gesture production, two correlation matrices were created, one for PWA and one for NHP. The results will be described in the following subsections.

6.7.1 Participants with aphasia.

6.7.1.1 Correlation table.

Based on the results of the Shapiro-Wilk normality tests (see above), the normally distribute variables were entered into parametric correlation analyses (Pearson's *r*; indicated by *r*). The variables not showing normal distribution were analysed with the non-parametric correlation equivalent (Spearman's *rho*; indicated by r_s). Results are given in Table 6.13:

Table 6.13. ***Correlation analyses for participant factors and gesture production of PWA.***

	Severity	Fluency	Lexical production	Verbal semantics	Non-verbal semantics	Cognition	Motor
Gestures overall	$r_s(17) = .410$, $p = .081$	$r_s(17) = .487$, $p = .035$*	$r_s(17) = .584$, $p = .009$*	$r(17) = .396$, $p = .094$	$r(17) = .381$, $p = .107$	$r_s(17) = .582$, $p = .009$*	$r_s(17) = .369$, $p = .120$
Semantically rich gestures	[redacted]			$r_s(17) = .230$, $p = .344$	$r_s(17) = .362$, $p = .128$	[redacted]	

Note. PWA = participant/s with aphasia; ** = significant at $p < .001$; * = significant at $p < .05$.

A number of significant relationships ($p < .05$) were revealed in this correlation matrix; some of them were highly significant ($p < .01$). All significant relationships were positive, that is to say, the higher a score was, the higher was the other score. The variable being involved in most relationships were the lexical production skills. This indicated that the ability of naming appears to play a role in other variables (e.g., verbal and non-verbal semantic skills and the overall number of gestures produced). But also verbal semantic skills highly correlated with other participant skills. However, there was no relationship to either the overall production of gestures or the production of semantically rich gestures. This was also the case of non-verbal semantic skills.

6.7.1.2 Significant correlations for PWA.

The matrix in Table 6.13 revealed three significant relationships between participant scores of PWA and the overall number of gestures. These will be described in more detail in the following.

6.7.1.2.1 Fluency.

The correlation analysis revealed a significant relationship between the fluency of speech and the overall number of gestures, $r_s(17) = .487$, $p = .035$. Participants with more fluent speech also produced more gestures during conversation overall (see Figure 6.10).

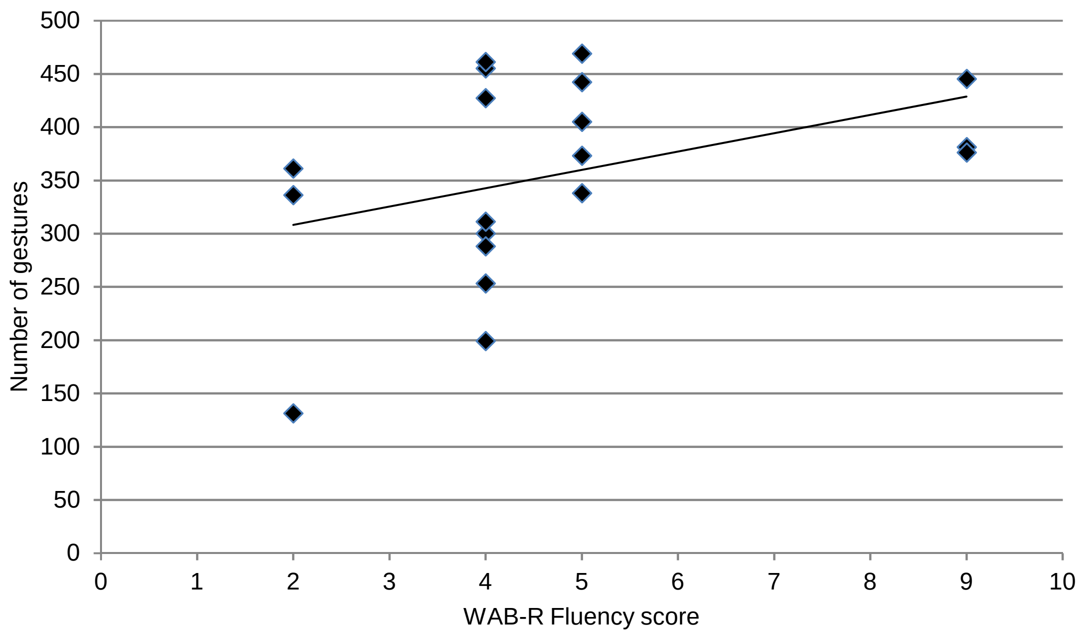

Figure 6.10. ***Correlation between the overall number of gestures and the WAB-R fluency for PWA.***

6.7.1.2.2 Lexical production skills.

There was a highly significant relationship between lexical production skills and the overall number of gestures produced in conversation, r_s (17) = .584, p = .009. PWA with better lexical production skills produced significantly more gestures overall than those with poorer lexical production skills (see Figure 6.11).

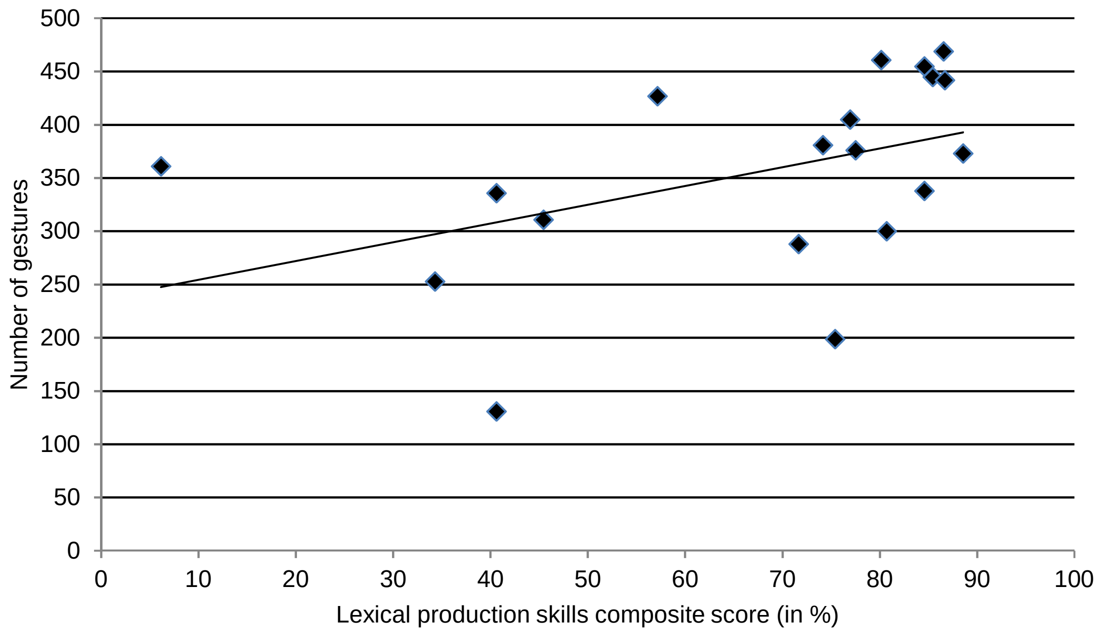

Figure 6.11. *Correlation between the overall use of gesture and lexical production skills (in %) for PWA.*

6.7.1.2.3 Cognitive skills.

For PWA, the relationship between non-verbal cognitive skills and overall gesture production was significant, r_s (17) = .582, p = .009. PWA with better non-verbal cognitive skills produced more gestures overall than PWA with poorer non-verbal cognitive skills (see Figure 6.12).

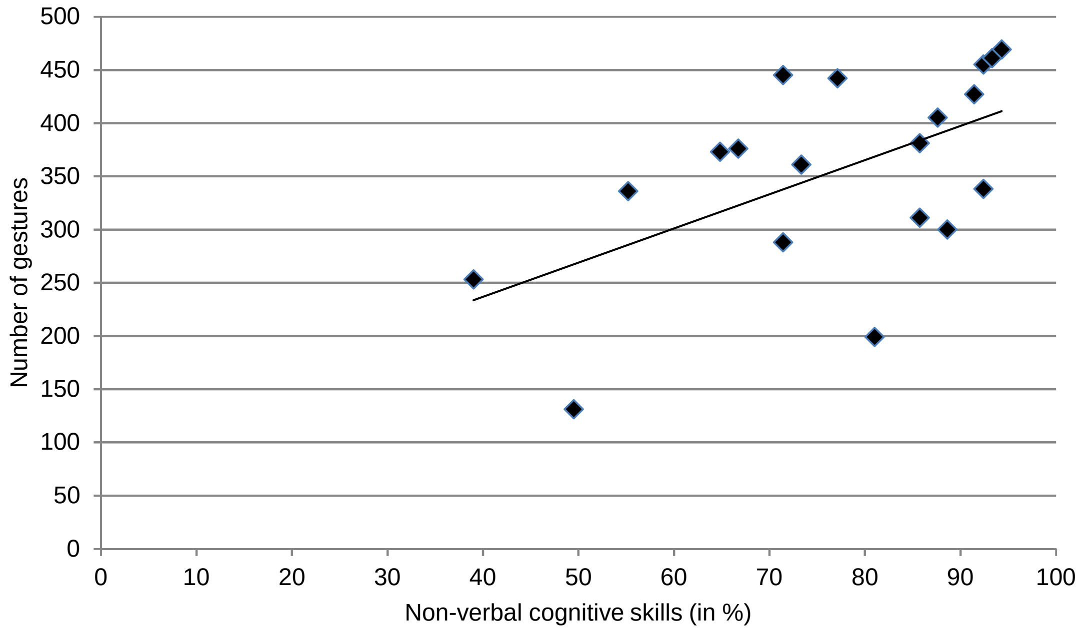

Figure 6.12. ***Correlation between the overall use of gesture and non-verbal cognitive skills (in %) for PWA.***

6.7.1.3 Cognitive skills and gesture production in WFD.

The correlation matrix of the participant factors revealed a significant relationship between non-verbal cognitive skills and the overall production of gestures. To investigate the influence of cognition on the use of gesture in the resolution of WFD, subsequent correlation analyses between non-verbal cognitive skills, the WFD +gesture/+resolved and WFD +gesture/-resolved were conducted.

Only +gesture/+resolved was normally distributed, W (20) = .946, p = .312, while the other variables were not, W (20) = .889, p = .026 (cognition) and W (20) = .867, p = .010 (+gesture/-resolved). Therefore, all variables were entered into non-parametric correlation analyses (Spearman's *rho*; see Table 6.14 for the results).

Table 6.14. ***Correlation matrix for cognition and WFD +gesture for PWA.***

	Cognition	+gesture/+resolved (%)	+gesture/-resolved (%)
Cognition			
+gesture/+resolved (%)	r_s(18)=.598, p=.005*		
+gesture/-resolved (%)	r_s(18)=.023, p=.925	r_s(18)=-.385, p=.094	

Note. PWA = participant/s with aphasia; WFD = word-finding difficulty/ies ** = significant at p < .001; * = significant at p < .05.

This correlation matrix revealed one highly significant relationship ($p < .01$) between cognition and WFD +gesture/+resolved, r_s (18) = .598, $p = .005$. Participants with better non-verbal cognitive skills produced a significantly higher proportion of resolved WFD that were accompanied by gesture than those with poorer non-verbal cognitive skills (see Figure 6.13).

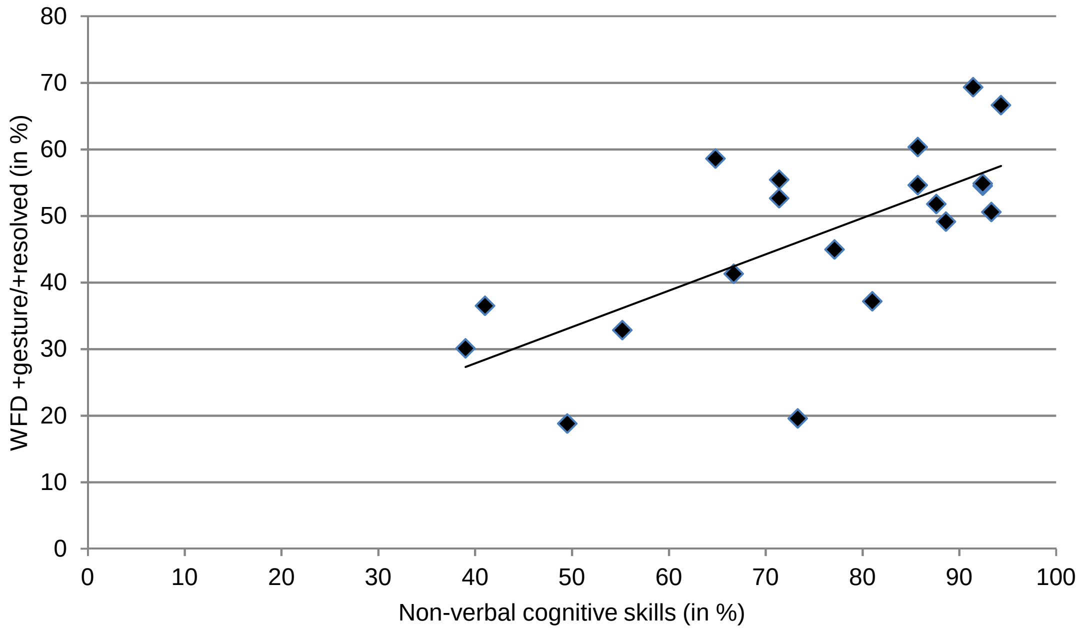

Figure 6.13. ***Correlation between WFD +gesture/+resolved (in %) and non-verbal cognitive skills (in %) for PWA.***

6.7.2 Neurologically healthy participants.

Another correlation matrix was created for the participant factors and the overall number of gestures for NHP. Normally distributed variables were analysed with the parametric correlation Pearson's r while not-normally distributed variables were entered into a non-parametric Spearman's rho correlation analysis. Table 6.15 gives an overview of the results:

Table 6.15. ***Correlation analyses for participant factors and gesture production of NHP.***

	Cognition	Motor
Gestures overall	$r_s(18)=.282$, $p=.228$	$r(18)=.259$, $p=.269$

Note. NHP = neurologically healthy participant/s; ** = significant at $p < .001$; * = significant at $p < .05$.

Neither the cognitive nor the motor skills of NHP correlated with the overall production of gestures.

6.8 Post-hoc analyses

The findings reported to far stimulated further questions which were addressed by additional post-hoc analyses. These are outlined in this section according to the corresponding research question.

6.8.1 RQ 1: Overall number of gestures.

6.8.1.1 Influence of speech fluency on the overall number of gestures.

The significant correlation between fluency and gesture production invited a further post-hoc analysis, comparing participants with fluent and non-fluent aphasia (as defined by the WAB) and NHP. Results are reported in Table 6.16. There was a significant difference between participants with fluent and non-fluent aphasia in terms of the overall production of gestures (t (17) = 2.121, p = .049). Those with fluent aphasia produced more gestures than NHP while those with non-fluent aphasia produced fewer gestures than NHP.

Table 6.16. ***Overall use of gesture, comparing fluent and non-fluent aphasia.***

	M	*SD*
PWA	355.32	92.519
Fluent	403.63	44.689
Non-fluent	320.18	103.850
NHP	384.10	76.674

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

6.8.1.2 Difference between gestures produced during WFD and gestures produced outside WFD.

PWA and NHP produced a similar number of gestures overall. Furthermore, both groups experienced a similar number of WFD. One explanation for the similar number of gestures overall may be the high number of WFD experienced by the NHP. It is of interest to find out more about the difference between the number of gestures produced during WFD and those produced alongside more fluent speech. Therefore, descriptive post-hoc analyses were conducted. The majority of the variables were normally distributed, W (19) = .958, p = .530 for PWA (gestures during WFD), W (20) = .920, p = .097 for NHP (gestures during WFD), and W (19) = .941, p = .277 for PWA (gestures outside WFD), while one was not, W (20) = .898, p = .038 for NHP (gestures outside WFD).

Table 6.17. ***Difference between gestures produced during WFD and gestures produced outside WFD.***

	Gestures during WFD		Gestures outside WFD	
	M	*SD*	*M*	*SD*
PWA	71.58	25.446	36.36	14.628
NHP	67.15	24.618	50.65	19.645

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; WFD = word-finding difficulty/ies; *M* = mean; *SD* = standard deviation.

Results depicted in Table 6.17 revealed that all participants produced more gestures during WFD than outside of WFD. While there are only marginal differences between the two groups in the number of gestures produced during WFD, NHP produced more gestures outside of WFD than PWA.

6.8.1.3 Influence of the conversation partner on the overall number of WFD.

Similar to the overall number of gestures produced during conversation, there was no difference between PWA and NHP in terms of gesture production with the different conversation partners either: Both participant groups produced significantly more gestures in the conversations with the UFCP than in those with the FCP. One explanation for the increase in the number of gestures when talking to someone unfamiliar may be an increased number of word-finding difficulties. Descriptive post-hoc analyses revealed marginal differences in the number of WFD arising in each of the different conversation-partner-conditions. This was true for all participants, but the effects differed. NHP experienced marginally more WFD in the conversations with the UFCP whereas PWA showed the opposite effect and experienced marginally more WFD when talking to the FCP. Details are given in Table 6.18 below:

Table 6.18. ***Overall number of WFD, comparing conversations with FCP and UFCP.***

	WFD FCP		WFD UFCP	
	M	*SD*	*M*	*SD*
PWA	54.95	15.522	52.85	15.567
NHP	57.62	14.016	60.14	11.141

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; WFD = word-finding difficulty/ies; FCP = familiar conversation partner/s; UFCP = unfamiliar conversation partner/s; *M* = mean; *SD* = standard deviation.

Neither of these differences in the number of WFD was significant. This suggests that it was not the number of WFD having an influence on the increased gesture production in the conversation with the UFCP.

6.8.1.4 Influence of the conversation topic on the overall number of WFD.

All participants produced significantly more gestures in the conversations with a procedural topic than in the narrative conversations. There was no difference between PWA and NHP. A potential explanation for the increased number of gestures in procedural conversations may be an increased number of WFD, therefore descriptive post-hoc analyses were conducted. Results showed that PWA experienced almost the same number of WFD in narrative and in procedural conversations. For NHP, a marginal difference was found, with more WFD occurring in procedural conversations (see Table 6.19).

Table 6.19. ***Overall number of WFD, comparing procedural and narrative conversation topics.***

	WFD narrative		WFD procedural	
	M	*SD*	*M*	*SD*
PWA	54.11	15.888	53.74	15.954
NHP	57.43	11.927	60.60	13.667

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; WFD = word-finding difficulty/ies; *M* = mean; *SD* = standard deviation.

Similar to the influence of the conversation partner (see 6.8.1.3), these results suggest that the increased gesture production in procedural conversation topics could not be explained by an increased number of WFD.

6.8.2 RQ 2: Different types of gestures.

6.8.2.1 Influence of the conversation topic on the production of semantically rich and semantically empty gestures.

Descriptive analyses on the distribution of semantically rich and semantically empty gestures over the different type of conversation were conducted. All participants produced more semantically rich gestures in procedural than in narrative conversations. For the distribution of semantically empty gestures, there was the opposite effect for PWA, with more semantically empty gestures in narrative than in procedural conversations. NHP, however, produced a similar amount of semantically empty gestures in all conversation topics (see Table 6.20).

Table 6.20. *Distribution of semantically rich and semantically empty gestures, including conversation topic.*

	PWA		NHP	
	M	*SD*	*M*	*SD*
Semantically rich gestures	205.42	71.246	239.00	79.385
Narrative	76.53	37.200	80.29	48.583
Procedural	128.89	45.206	155.50	41.706
Semantically empty gestures	149.89	54.158	145.10	52.042
Narrative	81.37	31.115	71.90	28.402
Procedural	68.53	28.125	71.25	29.873

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

6.8.2.2 Relationship between semantically rich gestures and the overall number of WFD.

All participants produced significantly more semantically rich than semantically empty gestures. Again, there was no difference between PWA and NHP. One explanation for the increased use of semantically rich gestures, especially in aphasia, may be linked to the number of WFD that potentially could be resolved. Therefore, a post-hoc analysis was conducted. Indeed, there was a significant relationship between the overall number of WFD and the number of semantically rich gestures for PWA, r (17) = .536, p = .018. This suggests that in aphasia, semantically rich gestures may play an important role during WFD (see Figure 6.14).

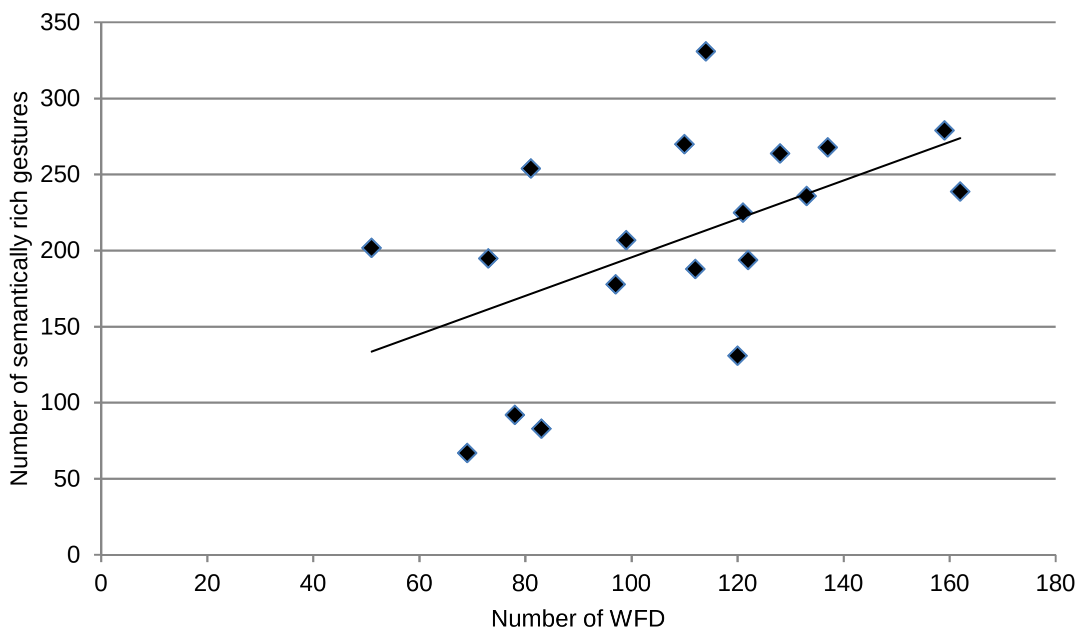

Figure 6.14. *Correlation between the number of semantically rich gestures and the overall number of WFD for PWA.*

6.8.2.3 Relationship between semantically rich gestures and the number of resolved WFD.

Exploring further the finding that semantically rich gestures played an important role in WFD, the influence of semantically rich gestures on the successful resolution of WFD was examined using another post-hoc analyses. Results revealed that there was a significant relationship between the overall number of semantically rich gestures and the number of resolved WFD for PWA, r (17) = .498, p = .030. This supports the assumption that semantically rich gestures played an important role in the resolution of WFD in aphasia as well (see Figure 6.15).

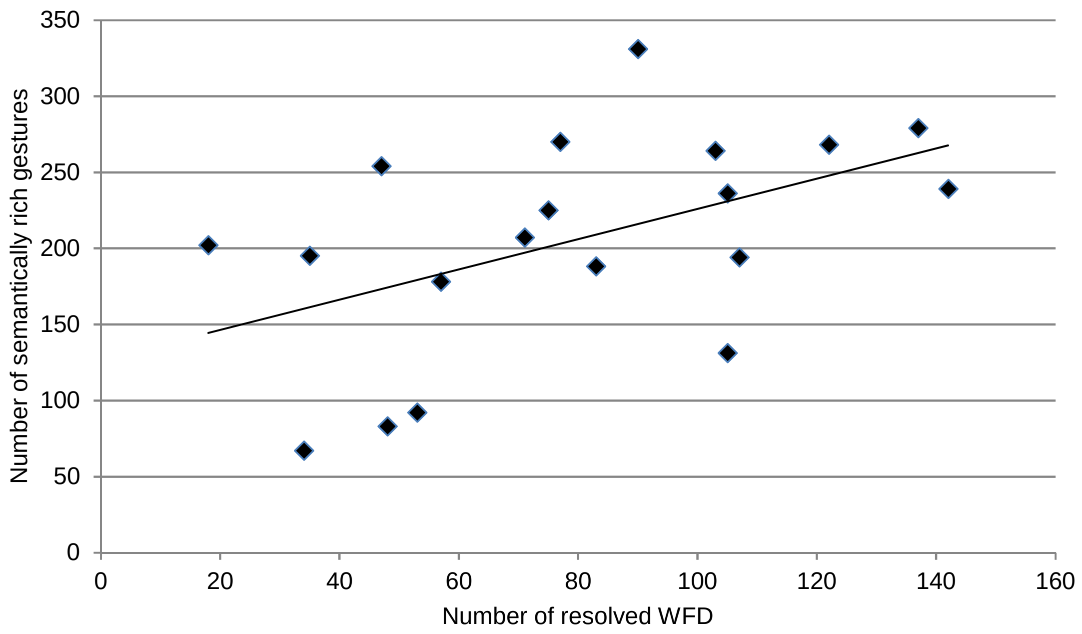

Figure 6.15. ***Correlation between the number of semantically rich gestures and the number of resolved WFD for PWA.***

6.8.2.4 Relationship between beat gestures and speech fluency.

Results revealed that PWA produced about half the number of the beat gestures that NHP did. With beat gestures being rhythmically linked to the fluency of speech, it is of interest to find out about a link between the number of beat gestures and the fluency of speech. Post-hoc analyses revealed a significant relationship between speech fluency and the number of beat gestures, r_s (17) = .494, p = .032 in aphasia, suggesting that participants with fluent aphasia produced more beat gestures than those with non-fluent aphasia (see Figure 6.16).

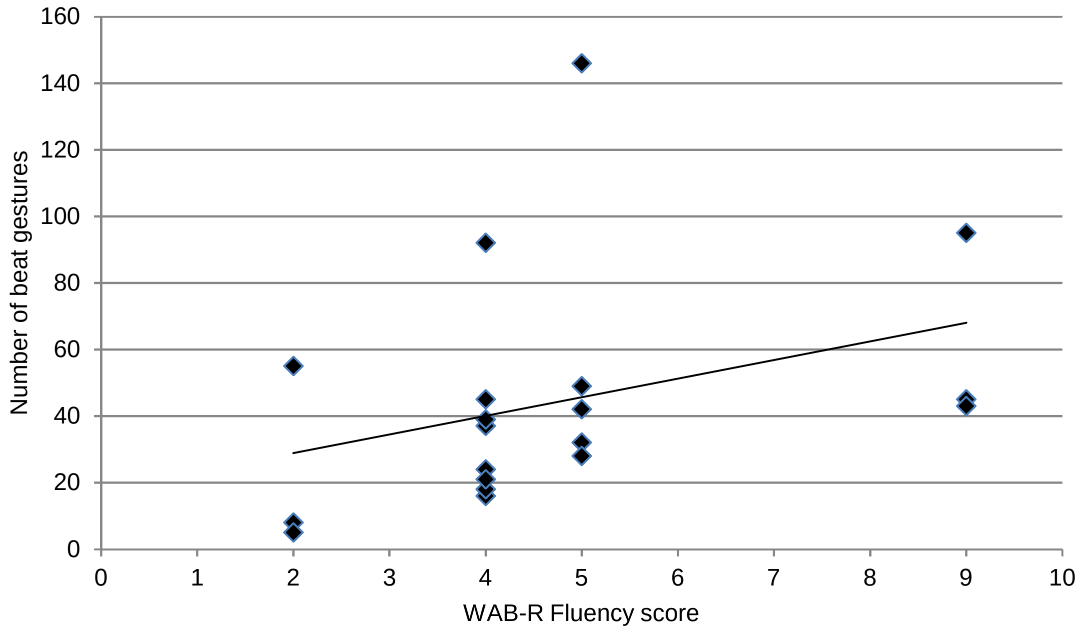

Figure 6.16. ***Correlation between the number of beat gestures and the WAB-R fluency for PWA.***

6.8.2.5 Relationship between other gestures and motor skills.

PWA produced a substantial amount of *other* gestures, that is, gestures that could not be clearly categorised or were incomplete (i.e., the stroke, that is the core part of the gesture, was missing; see footnote 20). A potential explanation for these many unclassifiable gestures may be linked to the motor skills of PWA as earlier studies revealed a link between gesture quality and motor skills. Post-hoc analyses, however, did not show a relationship between the number of *other* gestures and motor skills for PWA, r_s (17) = -.105, p = .669.

6.8.3 RQ 3: Word-finding difficulties.

6.8.3.1 Relationship between age and the overall number of WFD.

NHP produced marginally more WFD than PWA, suggesting that WFD are a common part of speech production. One explanation for the high number of WFD in the healthy group may be down to their age. As both participant groups represent a large age span, it was of interest to find out more about this relationship. However, post-hoc analyses revealed no relationship between age and the number of WFD for either participant group, r (17) = .062, p = .802 for PWA and r (18) = -.285, p = .223 for NHP.

6.8.4 RQ 4: Functions of semantically rich gestures.

6.8.4.1 Relationship between aphasia severity and the overall number of compensatory gestures.

Surprisingly, PWA only produced a small percentage of compensatory gestures. 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 analyses investigated the relationship between aphasia severity (WAB-R AQ) and the both the proportion of compensatory gestures and the overall number of compensatory gestures. Results revealed no significant link between aphasia severity and compensatory gesture production (%: r_s (17) = -.007, p = .977; #: r_s (17) = .241, p = .320). This indicates that aphasia severity did not have an influence on the production of compensatory gestures.

6.8.5 RQ 5: Participant factors.

6.8.5.1 Relationship between lexical production skills and the overall number of WFD.

A possible explanation for the relationship between the lexical production skills and the overall number of gestures may be due to an increased number of WFD. Therefore, a post-hoc analysis was conducted. For PWA, there was a significant relationship between the lexical production skills and the overall number of WFD experienced in the conversations, r_s (17) = .605, p = .006. This finding indicates that participants with better lexical production skills also experienced more WFD (see Figure 6.17).

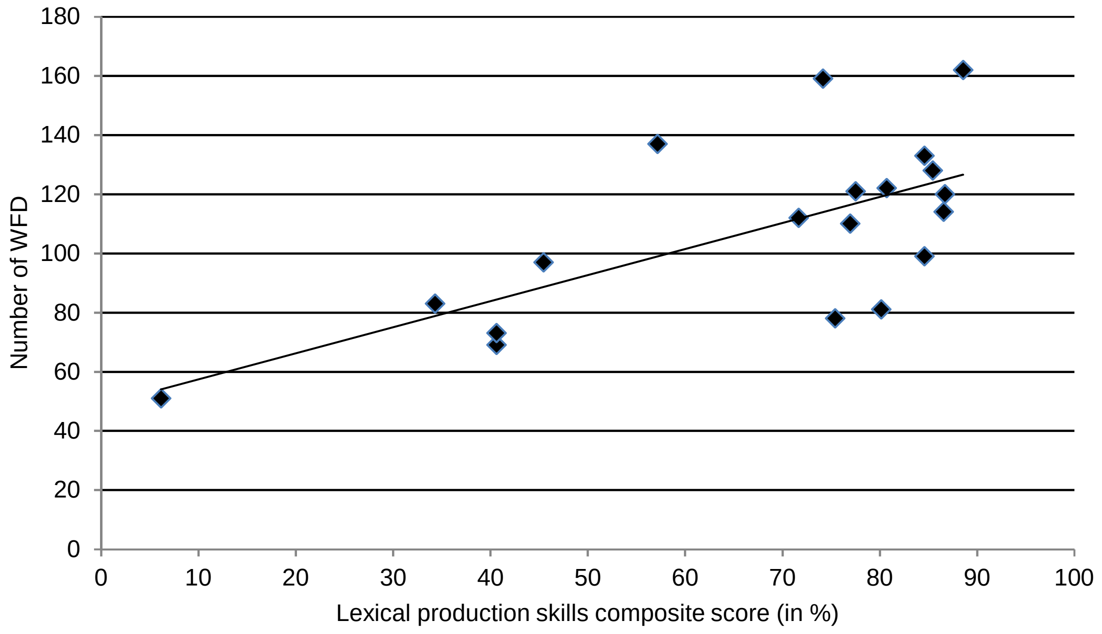

Figure 6.17. ***Correlation between the lexical production skills (in %) and the overall number of WFD for PWA.***

6.8.5.2 Relationship between lexical production skills and the number of resolved WFD.

The previous finding revealed a significant link between the lexical production skills and the overall number of WFD. To find out more about the success of resolving WFD and the potential influence of the lexical production skills, a further post-hoc analysis was conducted. Results revealed a significant relationship between the lexical production skills and the number of resolved WFD in PWA, r_s (17) = .625, p = .004 (see Figure 6.18).

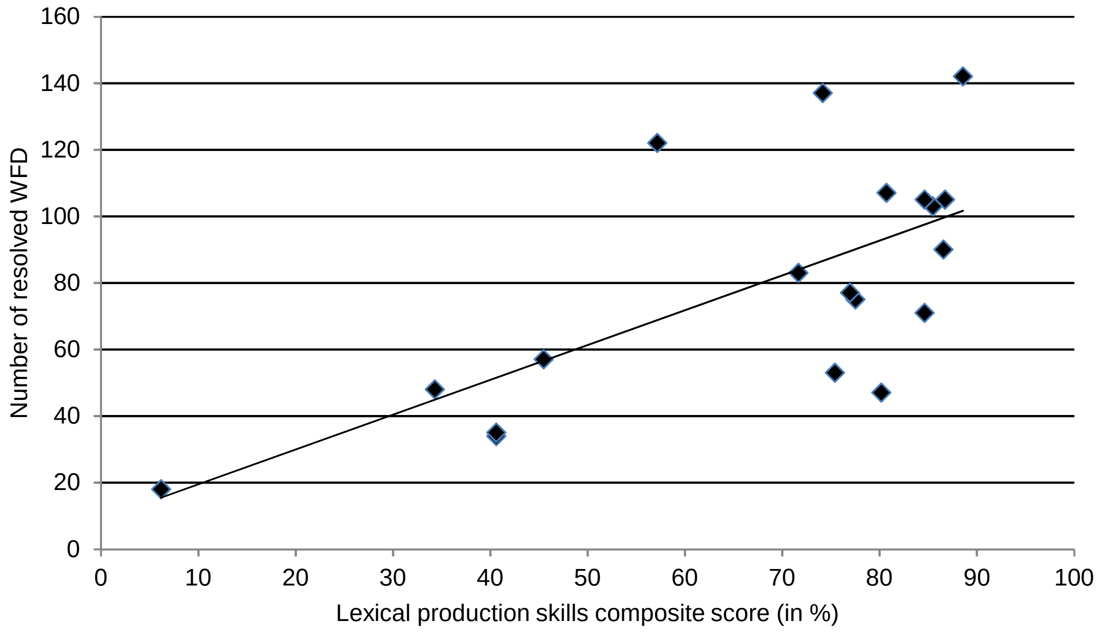

Figure 6.18. ***Correlation between the lexical production skills (in %) and the number of resolved WFD for PWA.***

6.9 Summary

This chapter outlined and analysed the results against the research questions. PWA and NHP showed many similarities (that were supported by statistical analyses): (1) They produced a similar number of gestures overall (RQ 1; no significant difference between the two groups), (2) for both groups, the conversations with the unfamiliar conversation partner elicited significantly more gestures than the ones with a familiar conversation partner (RQ 1), (3) for both groups, procedural topics led to significantly more gestures than narrative topics (RQ 1), (4) overall, participants from both groups produced more semantically rich gestures than semantically empty gestures (RQ 2), and (5) semantically rich gestures occurred significantly more often in procedural than in narrative conversation topics (RQ 2).

Differences between the two groups became visible when WFD and the different functions of semantically rich gestures were analysed. While both groups experienced many WFD overall (with NHP experiencing marginally even more WFD than PWA), only PWA displayed a relationship between the overall number of WFD and the overall number gestures, indicating that gestures may play an important role in WFD. Subsequent analyses (for both PWA and NHP) revealed a relationship between the production of gestures in WFD and the resolution of those difficulties, suggesting that gesture production might play a role in lexical retrieval. However, PWA also had a number of WFD that were not resolved, yet accompanied by gestures. Indeed, for them, more unresolved WFD were accompanied by gesture than not. NHP were able to resolve most WFD – either with the production of a gesture or not. They barely produced any unresolved WFD. If they did, these WFD were usually not accompanied by gesture.

Turning to the function of the semantically rich gestures, both groups employed a high number of facilitative gestures, repeating the finding that gestures often accompanied resolved WFD. For NHP, almost all other gestures accompanied speech outside WFD (i.e., the gestures were augmentative) while this was only true for a small number of semantically rich gestures for PWA. As expected, NHP produced only a small amount of communicative and compensatory gestures, while communicative gestures played an important role for the PWA. This repeated the finding that PWA produced a high number of unresolved WFD that were accompanied by gestures.

The correlation matrix for NHP did not reveal any relationship between any assessments and the overall number of gestures. For PWA, fluency, lexical production skills and cognitive skills had an influence on the overall production of gestures. There was no relationship between verbal and non-verbal semantic skills and the overall number of semantically rich gestures. In an additional correlation matrix, investigating the relationship between cognition and the different types of WFD (+gesture/+resolved and +gesture/-resolved), there was significant link between the cognitive skills and the proportion of the WFD +gesture/+resolved.

The results of this study will be discussed in detail in Chapter 7 and considered against the findings of previous studies.

Chapter 7 Discussion

The aim of this study was to explore gesture production in the conversation of people with aphasia and neurologically healthy speakers. In a novel addition to existing research gesture production was analysed against the variables of conversation partner (i.e., familiar vs. unfamiliar) and conversation topic (i.e., narrative vs. procedural). A further aim was to explore the function of gesture in relation to speech and particularly whether gesture may facilitate lexical retrieval or compensate for the language disorder. Although previous studies have found evidence for gesture supporting and replacing speech in aphasia, there is limited evidence about the facilitative role of gesture in lexical retrieval. WFD were coded according to their co-occurrence with gesture and their resolution. Four potential functions of semantically rich gestures were defined, based on their co-occurrence with WFD and/or fluent speech production (i.e., facilitative, communicative, augmentative, and compensatory). Finally, potential influences of participant factors on the production of gesture were investigated, such as aphasia severity and fluency of speech.

The following subsections revisit the research questions and review the results against the findings of previous research (see 7.1). In 7.2, contributions made by the study are discussed, including the clinical implications. The limitations of the study and issues for future research are summarised in 7.3. Finally, 7.4 provides a summary of the entire study.

7.1 Revisiting the research questions

7.1.1 RQ 1: Overall number of gestures.

Results showed that on average, PWA and NHP produced a similar number of gestures, although post-hoc analyses revealed that participants with non-fluent aphasia produced fewer gestures per time than NHP and participants with fluent aphasia produced more. All participants (PWA and NHP) were influenced by conversation partner and topic, such that they gestured more with UFCP and when talking about procedures.

7.1.1.1 Overall number of gestures.

The finding that PWA and NHP produced a similar number of gestures overall is surprising and not in line with the common finding that PWA generally produce more gestures than NHP in order to facilitate, supplement, and/or replace speech. Nevertheless, the evidence base suggested that the number of gestures over time was fewer for participants with non-fluent aphasia than NHP and participants with fluent aphasia, who gestured most often (i.e., PWA_{nf} < NHP < PWA_{f}) (e.g., Carlomagno & Cristilli, 2006; Carlomagno et al., 2005; Cicone et al., 1979; Cocks, Dipper, et al., 2013; R. J. Duffy et al., 1984; Hadar, Wenkert-Olenik, et al., 1998; M. Herrmann et al., 1988; Kong et al., 2015; Le May et al., 1988; Lott, 1999; Macauley & Handley, 2005; Pritchard et al., 2013; Sekine & Rose, 2013; Sekine et al., 2013). An exception was the study by Glosser et al. (1986) who investigated different conversation situations in PWA and NHP and found no fundamental differences between the two participant groups in terms of gesture quantity. According to the authors, aphasia did not affect the number of gestures produced in conversation but did affect gesture quality: NHP produced more complex gestures and used them differently from PWA, indicating that the language impairment had an influence on both gesture quality and function.

The finding that PWA and NHP produced a similar number of gestures overall could be due to several reasons: (1) the method of eliciting spontaneous speech, (2) the participant characteristics of PWA, (3) the method of counting gestures, and (4) the number of WFD experienced by NHP. These four issues will be reviewed in turn.

The contrastive findings between the current and previous studies may be due to different speech elicitation techniques. In this study, participants were required to relate a procedural explanation or a narrative to their partner, in a conversation format. This contrasts with studies that employed pure monologues (e.g., Borod et al., 1989; Carlomagno & Cristilli, 2006; Carlomagno et al., 2005; Cocks et al., 2011; Cocks, Dipper, et al., 2013; R. J. Duffy et al., 1984; Hadar, Wenkert-Olenik, et al., 1998; Lott, 1999; Pritchard et al., 2013) or interviews that were scaffolded by the examiner, for example, by leading the conversation through asking questions (e.g., Cicone et al., 1979; M. Herrmann et al., 1988; Le May et al., 1988; Macauley & Handley, 2005). Studies with healthy speakers have shown that gesture increases when the speaker is placed under increased processing load (e.g., Chawla & Krauss, 1994; de Ruiter, 1995, 1998; Kita, 2000; Morsella & Krauss, 2004; Slobin, 1996; Wesp, Hesse, Keutmann, & Wheaton, 2001). This is shown, for example, when the speaker has to impart a complex array to another person (e.g., Hostetter, Alibali, & Kita, 2007; Kita & Davies, 2009; Melinger & Kita, 2007). The speaking task employed in this study was quite demanding, which may have inflated gesture production. However, both groups were subject to these demands making this an unlikely explanation for the eliminated difference between PWA and NHP.

The similar performance of PWA to NHP in terms of the overall number of gestures produced during conversations may be down to the characteristics of the participants.

To show a difference in gesture production between PWA and NHP, it may be the case that PWA have to fall below a certain threshold, for example, in terms of aphasia severity or lexical production skills. Correlation analyses indeed revealed a relationship between lexical production skills and the overall number of gestures (see 6.7.1.2 and 7.1.5.1). Here, PWA who had better word-finding skills and therefore performed more like NHP, produced more gestures. However, a similar correlation was not found for overall aphasia severity (see 6.7.1.1). It seems that either severity did not have an influence on gesture production or the sample did not include enough participants with severe aphasia (n = 3) for this to show an effect. Participant characteristics could therefore provide a partial explanation for the similar performance of PWA and NHP.

Another explanation for the similar performance of PWA and NHP in terms of the overall number of gestures, may be the methodology applied to calculate the gesture-speech ratio. In effect, there are two methods of doing this: (1) gesture-per-word ratio and (2) gesture-per-time ratio. The majority of studies applied both measurements and came to the conclusion that PWA produced more gestures both over time and per word than NHP (e.g., Cocks, Dipper, et al., 2013; M. Herrmann et al., 1988; Kong et al., 2015; Lott, 1999; Macauley & Handley, 2005; Pritchard et al., 2013; Sekine & Rose, 2013; Sekine et al., 2013). When comparing different types of aphasia in terms of speech fluency (e.g., fluent vs. non-fluent aphasia), the outcomes depended on the applied measurement though: While participants with fluent aphasia produced more gestures per time, participants with non-fluent aphasia produced more gestures per word (e.g., Carlomagno & Cristilli, 2006; Cicone et al., 1979; R. J. Duffy et al., 1984; Le May et al., 1988; Sekine et al., 2013). These studies indicate that participants with fluent aphasia would be expected to produce more gestures per time than NHP, who in turn would be expected to produce more gestures than participants with non-fluent aphasia (i.e., PWA_f > NHP > PWA_{nf}). In the current study, only the second measurement was applied, that is, participants were compared in terms of the overall number of gestures produced in 16 minutes (see 5.3.5.2). Descriptive post-hoc analyses revealed that participants with fluent aphasia did indeed produce more gestures per time and participants with non-fluent produced fewer gestures per time than NHP (see 6.8.1.1). With a similar number of fluent and non-fluent participants with aphasia having taken part in the current study, it may well be the case that the more gestures per minute produced by the PWA_f and the fewer gestures per minute produced by the PWA_{nf} levelled each other out and led the PWA to produce at a similar level as NHP. This fluency factor and its influence on the production of gestures will be discussed in 7.1.5.1.1 below.

Finally, the similar number of gestures produced by PWA and NHP overall could be explained by the high number of WFD experienced by the NHP in the current study. In many previous studies WFD were identified as one of the reasons for an increased gesture production rate in aphasia (e.g., Carlomagno et al., 2005; Cocks et al., 2011; Cocks, Dipper, et al., 2013; Hadar, 1991; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994; Lanyon & Rose, 2009; Pritchard et al., 2013). Cocks, Dipper, et al. (2013), for example, found a significant difference between PWA and NHP in the overall number of iconic gestures, but when those gesture produced during WFD were removed from the analysis, this difference was no longer significant (see 4.3). In the current study, the participant groups experienced a similar number of WFD with NHP experiencing marginally more WFD than PWA (see 6.5 and 7.1.3). Descriptive post-hoc analyses revealed that all participants produced more gestures during WFD than outside of WFD. Furthermore, PWA and NHP produced a similar number of gestures during WFD, suggesting that the comparable number of WFD across participant groups is likely to have contributed to their similar gesture scores.

Aside from the lack of between-group difference, the high number gestures produced by all participants is striking: PWA produced 355.32 and NHP 384.10 gestures overall, which equates to approximately 22 gestures per minute for PWA and approximately 24 gestures per minute for NHP. It is difficult to set these numbers against the evidence base as many studies either do not report raw scores but percentages and distributions instead (e.g., M. Herrmann et al., 1988; Kong et al., 2015) or do not report on the length of the speech sample (e.g., Macauley & Handley, 2005; Sekine & Rose, 2013). One of the few studies that reported on the number of gestures per minute was the one by Lott (1999). She observed approximately seven gestures per minute in PWA and approximately five gestures per minute in NHP. This reveals a huge difference between the current study and earlier studies.

There are four potential explanations for this high number of gestures overall: (1) the method of eliciting spontaneous speech, (2) individual variation, (3) the difficulty of objectively coding gestures, and (4) the number of WFD experienced by NHP. To avoid repetition, only individual variation and the difficulty of gesture coding will be discussed in the following paragraphs.

Individual variation, such as an outlier dragging up the mean, could explain the high number of gestures produced overall. This explanation is challenged by the outlier analyses (see 6.1) which revealed no outlier in the data set of the overall number of gestures produced for either group. PWA ranged between the production of approximately eight and 29 gestures per minute, NHP between approximately 15 and 31 gestures per minute. Interestingly, none of these numbers matches with the numbers that were reported in the study by Lott (1999), suggesting fundamental differences between the participants investigated by the author and those who took part in the current study. Indeed, the current study did not include participants with Wernicke's aphasia while they were part of the study of Lott (1999). It is questionable though whether this difference in the type of the aphasia could have such an impact on the number of gestures produced per minute; also given the fact that there was a difference in the number of gestures produced by NHP between the current study and the study by Lott (1999). Therefore, individual variation is unlikely to explain the high number of gestures.

Instead, one may explain this finding with the gesture coding process applied. Despite guidelines, the process of coding gestures is a rather subjective one as it not only depends on coding guidelines. Coding errors may have inflated the number of gestures. However, this account is challenged by the results of the reliability checking. 10% of the data were double coded by a second, independent judge. There was 92.9% agreement on the number and types of gestures present in the PWA sample and 98.49% for the NHP sample. These levels of reliability reached by the two coders suggests that the gesture coding system was reliable. Based on this, it is unlikely for the gesture coding process to explain the high number of gestures. However, comparing the average number of gestures produced by the participants in the current study and the participants in the study by Lott (1999), one may wonder whether different gesture coding criteria were applied. For example, it may have been the case that the current study included more behaviours as gesture or applied different gesture boundaries than Lott (1999). Consequently, a movement that was coded as one gesture by Lott (1999) might have been coded as two or three gestures in the current study. As gesture coding highly depends on the definitions of what is a gesture, this account is very likely to explain the rather high number of gestures identified in the current study.

7.1.1.2 Influence of the conversation partner.

The finding that all participants, PWA and NHP, produced significantly more gestures in the conversations with the UFCP than in the conversations with the FCP was novel. To date, no other study has investigated the influence of different conversation partners on gesture production. However, there have been several studies that explored the influence of different conversation partners on language production in neurologically healthy speech (e.g., Bortfeld et al., 2001; Boyle et al., 1994; Clark & Carlson, 1981; Clark & Marshall, 1981; Clark & Schaefer, 1987; Fleming & Darley, 1991; T. Herrmann, 1983; Hornstein, 1985; Kent et al., 1981; Li et al., 1995). These indicate that the familiarity of the conversation partner typically relates to the formality of language used. Language analysis as conducted by Boyle et al. (1994) and T. Herrmann (1983), for example, found that conversations with a FCP elicited abbreviated, informal, and implicit language. Speakers could rely on shared knowledge and experiences. They could use expressions that outsiders would not understand. Conversations with UFCP, in contrast, led to more concrete, detailed, formal, and explicit language. As there was no previously established common ground between the two speakers, abbreviations, for example, could lead to misunderstandings. According to Labov (1972), the formality of language is characterised by lexical items that are relatively context-independent (e.g., full nouns instead of pronouns) and by redundancy (i.e., expressing something more than once if it helps to add clarity). Extrapolating from these findings one can hypothesise that the participants in the current study may have used more formal and detailed language when conversing with the unfamiliar partner and that this in turn stimulated the production of more gestures.

Why might formal language be associated with a high rate of gesture production? One explanation may relate to WFD. More concrete, direct, formal and explicit language elicited by UFCP may exert pressure on the speaker and so lead to more WFD. As WFD were associated with gesture production, this might, in turn explain the conversation partner effect on gesturing. However, descriptive post-hoc analyses did not support this argument for either participant group. PWA and NHP showed no effect of conversation partner on the experience of WFD. Therefore, WFD are very unlikely to explain the increased number of gestures in the conversations with UFCP for all participants.

A second explanation argues that the complexity of speech is associated with gesture production. For example, studies have compared the description of pictures that differed in complexity with the finding that the more complex a picture was, the more gestures the speakers produced (e.g., Hostetter et al., 2007; Kita & Davies, 2009; Melinger & Kita, 2007). One could transfer this finding onto the conditions posed by different conversation partners and hypothesise that the conversations with the UFCP were more demanding than those with the FCP. However, unlike the above studies, the demands were not conceptual but rather pragmatic in nature, as the conversation topics were the same when talking to the FCP and UFCP. Here, another study is of interest. Holler and Beattie (2003) investigated the pragmatic role of gestures in ambiguous situations. They asked nine participants to retell picture stories. The stories included homonyms, that is, ambiguous words, such as *glasses* or *toast*, and control words. The study found that participants gestured more in situations with ambiguous words, probably to disambiguate them. In summary, it seems that increased gesture production is stimulated when speech is complex or when meaning has to be disambiguated for the sake of the listener. Such conditions may apply when conversations are conducted with unfamiliar conversation partners, mainly because of the lack of shared reference.

The influence of the conversation partner may relate to different conversation behaviours they adopted. Although this was not explored systematically, differences between individuals were observed. It is possible that such differences were influenced by partner familiarity, with knock on effects for gesture. This would have to be established in future research (see 7.3 for more details).

7.1.1.3 Influence of the conversation topic.

A second novel finding was that procedural conversations elicited significantly more gestures than narrative topics, both for PWA and NHP. Conversation topic has not been explored previously in relation to gesture production in aphasia. However, there is evidence that topic affects the type of language used (e.g., Ulatowska et al., 1990; Ulatowska & Bond, 1983; Ulatowska, Doyel, et al., 1983; Ulatowska, Freedman-Stern, et al., 1983; Ulatowska, Macaluso-Haynes, et al., 1981; Ulatowska, North, et al., 1981). For example, the core vocabulary used by speakers varies depending on the conversation topic (e.g., Ulatowska et al., 1990; Ulatowska, North, et al., 1981).

As with the influence of the conversation partner on gesturing, the influence of the conversation topic may be down to either (1) the number of WFD induced or (2) the nature of procedural language and the close relationship between speech production and gesturing. These will be reviewed in turn below.

The restricted and very precise vocabulary needed to describe processes may put speakers under pressure and may therefore lead to more WFD in those conversations. However, descriptive post-hoc analyses revealed no significant differences between the number of WFD in narrative and procedural conversations. Similar to the influence of the conversation partner (see 7.1.1.2), these results suggest that the increased gesture production in procedural conversation topics could not be explained by an increased number of WFD.

Alternatively, the nature of the language elicited by procedural conversations and the close relationship between speech production and gesturing may explain the effect of topic on gesture. Procedural topics require very precise, concrete language. In comparison to language elicited by narrative topics, procedural language is also very detailed and action-focussed as the speaker needs to explain what to do in step by step fashion. Furthermore, it is important that the conversation partner understands the different steps necessary to get to the end result. All of these requirements of procedural topics would encourage gesture production, especially the production of semantically rich gestures, such as iconic and pantomime gestures. More details about the type of language elicited by procedural topics are discussed in the light of different types of gestures in 7.1.2.

7.1.1.4 Summary.

To summarise, there was no difference between PWA and NHP on their high number of gestures overall. This may in part be explained by the characteristics of the PWA who performed similarly to the NHP. The second part of this explanation may be the methodology applied to calculate the gesture-speech ratio as not gestures per word but gestures per time were analysed giving NHP the opportunity to produce more gestures due to their unimpaired language. This leads to the third part of the explanation, the similar number of WFD in all participants. The gesture production of all participants was influenced by the familiarity of the conversation partner and the conversation topic. Both of these influences could be explained by the type of language elicited. The more concrete, direct, formal and explicit language used for the unfamiliar conversation partner and the specific and very precise vocabulary used to describe processes may lead to more gestures.

7.1.2 RQ 2: Different types of gestures.

On average, all participants performed similarly and produced significantly more semantically rich than semantically empty gestures in their conversations overall. In part, this was related to topic, in that all participants produced significantly more semantically rich gestures in procedural than in narrative conversations. Post-hoc analyses revealed some differences in the type of gesture between PWA and NHP with PWA producing more speech-replacing gestures, such as pantomime and air writing & number gestures.

7.1.2.1 Semantically rich versus semantically empty gestures.

All participants produced significantly more semantically rich than semantically empty gestures and, as with the overall number of gestures, there was no difference between the PWA and NHP on this factor.

The production of semantically rich gestures may have been further influenced by (1) the conversation topic and (2) the incidence of WFD. These issues will be reviewed in turn below.

As argued above, procedural discourse differs from narrative discourse in that it contains more action and object-focussed language. Such language seems to simulate gesture (e.g., Pritchard et al., 2015). Furthermore, the accompanying gestures are likely to depict the discourse content, so will fall into the semantically rich categories. In line with this view, both PWA and NHP produced more semantically rich gestures in the procedural conversations than in the narrative conversations. Furthermore, this finding sheds light on the general finding that gesture production is higher in procedural than in narrative discourse. It is clear that this difference is due entirely to the greater production of semantically rich gestures.

The preponderance of semantically rich gestures may also be linked to the high number of WFD in all participants (see 7.1.3). It may be the case that semantically rich gestures are particularly likely to occur when there is a WFD. Post-hoc analyses revealed significant relationships between the overall number of WFD and the number of semantically rich gestures for PWA (see 6.8.2.1) as well as the number of resolved WFD and the number of semantically rich gestures (see 6.8.2.3). This suggests that in aphasia, semantically rich gestures may play an important role during WFD and during their resolution. In their study, Lanyon and Rose (2009) found that PWA generally used more gestures during a WFD than during fluent speech. Analysing the different types of gestures that occurred during WFD, they were mainly iconic, pantomime, or emblem gestures (i.e., semantically rich gestures). This is in line with the findings of the current study. It has to be acknowledged that the significant relationship between WFD and semantically rich gestures does not make any predictions about the facilitative function of gestures. This issue will be discussed in detail in 7.1.3 and 7.1.4. Nevertheless, to find out more about the role of semantically rich gestures in the resolution of WFD, further research needs to be conducted, for example, with a gesture cueing paradigm. This issue will be picked up in 7.3.

The predominance of semantically rich gestures in all participants may be related to their communicative value, that is, these gestures help to supplement and/or replace speech. In this light, the similar performance of all participants goes against the evidence base. According to previous studies, PWA were expected to produce more semantically rich gestures than NHP due to their language impairment and based on the communicative value of semantically rich gestures (e.g., Ahlsén & Schwarz, 2013; Carlomagno et al., 2005; Cicone et al., 1979; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Lanyon & Rose, 2009; van Nispen et al., 2014). Different explanations for this finding may be similar to those discussed above in relation to the overall number of gestures produced. In addition, the high use of semantically rich gestures by PWA may be explained by their relatively unimpaired semantic skills: On the verbal semantic tests, all PWA scored between 71.34% and 97.08% (*M* = 86.69%, *SD* = 8.419) and on the non-verbal semantic tests, they scored between 75.05% and 98.10% (*M* = 88.58%, *SD* = 7.032). The assessments used to calculate these two composite scores (see 5.3.1.3) varied in their cut-off scores. Nevertheless, about half of all PWA scored ≥90% on both composite scores, indicating good verbal and non-verbal semantic knowledge. Based on this performance, it may be hypothesised that for most participants the production of semantically rich gestures was not suppressed by impaired semantic skills. This issue and the link between gesture production and semantic skills will be discussed in 7.1.5.2 in more detail.

It was perhaps surprising that, given their good semantic skills, PWA did not produce more semantically rich gestures than NHP to facilitate, supplement, and/or replace speech. Evidence for an increased use of gestures carrying semantic information in aphasia was found in previous studies (e.g., Ahlsén & Schwarz, 2013; Carlomagno et al., 2005; Cicone et al., 1979; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Lanyon & Rose, 2009; Sekine & Rose, 2013; van Nispen et al., 2014). According to the researchers, the finding that PWA produced more semantically rich gestures than NHP suggests that PWA used those gestures differently than NHP, mainly to facilitate lexical retrieval and to compensate for the language disorder. Investigating these functions was also part of the current study and the results will be discussed in 7.1.4. An explanation for the finding that PWA and NHP produced a similar number of semantically rich gestures may also be down to the number of WFD and whether or not they could be resolved. This will be discussed in 7.1.3.

7.1.2.2 Distribution of gesture subtypes

Comparing gesture subtypes as produced by PWA and NHP revealed a number of (marginal) differences. While PWA produced more speech-replacing gestures (i.e., pantomime and emblem gestures), NHP produced more metaphoric gestures. Both groups produced a similar number of iconic gestures. Many PWA used air writing & number gestures to cue themselves during lexical retrieval or to give the conversation partner a hint about the currently inaccessible word. Furthermore, PWA produced more deictic and other gestures, while there were more beat gestures in the conversations of NHP. The different gesture subtypes will be discussed in the following subsections.

7.1.2.2.1 Iconic, metaphoric, pantomime, and emblem gestures.

The finding that PWA produced more speech-replacing gestures than NHP, such as pantomime and emblem gestures, is in line with the literature suggesting that PWA produce gestures to compensate for the language impairment (e.g., Beeke et al., 2001; M. Herrmann et al., 1988; Lanyon & Rose, 2009; Sekine & Rose, 2013). Nevertheless, comparing different functions of semantically rich gestures (i.e., facilitative, communicative, augmentative, and compensatory gestures), the current study only found a small group of compensatory gestures for all participants. This and co-occurring findings will be discussed in more detail in 7.1.4.

Iconic and metaphoric gestures were the dominant gesture subtypes for all participants. While iconic gestures were distributed similarly over PWA and NHP, NHP produced slightly more metaphoric gestures. The latter is likely to be linked to the type of language produced and the difference between iconic and metaphoric gestures. According to McNeill (1992, 2000), iconic gestures reflect the meaning of speech pictographically while metaphoric gestures depict an abstract concept (see 2.1.2). These definitions suggest that while iconic gestures may be linked to more concrete, imageable language, metaphoric gestures may occur alongside more abstract speech. Many studies investigated the effect of concreteness and/or imageability in aphasia, for example, in repetition tasks (Martin & Saffran, 1996), word reading (Newton & Barry, 1997), word recognition (Crutch & Warrington, 2005), reading comprehension (Barry & Gerhand, 2003), and naming performance (Nickels & Howard, 1995). While there are some exceptions (e.g., Marshall, Pring, Chiat, & Robson, 1996; Papagno & Cacciari, 2010), findings show that PWA often show a concreteness effect, that is, they performed better on words with higher concreteness and/or higher imageability (e.g., Kiran, Sandberg, & Abbott, 2009). The finding that NHP produced slightly more metaphoric gestures than PWA is in line with this research; that is, NHP are more likely to produce the abstract language that stimulates these gestures. It was surprising though that PWA and NHP produced a similar number of iconic gestures overall. Previous studies found a preponderance of iconic gestures in PWA compared to NHP (e.g., Carlomagno et al., 2005) to facilitate, supplement, and/or replace speech.

The high number of iconic gestures produced by NHP may relate to the high number of gestures produced overall (see 6.3.1). It is important to note that this relationship was not significant though. The comparable production of iconic gestures across PWA and NHP may be explained by the rather good language skills of PWA, which reduced group differences. The latter issue will be discussed in more detail in 7.1.5.1.2.

7.1.2.2.2 Air writing & number gestures.

Air writing and number gestures were another gesture type that was mainly used by PWA. It has been argued that they play an important role in aphasia, especially in self-cueing (e.g., Howard & Harding, 1998). In this study, writing down the first letter of the target word (during a WFD) also gave the conversation partner a clue about the word the PWA was trying to access. Depending on whether the WFD could be resolved, the gesture function was classified differently (i.e., facilitative or communicative). 7.1.4 will discuss these functions.

7.1.2.2.3 Deictic gestures.

Another difference arose in the use of deictic gestures, with PWA producing more of these gestures than NHP. This high use of deictic gestures in aphasia was in line with the findings of Le May et al. (1988), although the authors did not account for this finding. In a recent single case study, Klippi (2015) investigated the use of pointing gestures in aphasia in a conversation. Results revealed numerous instances of pointing gestures in different conversational contexts. The author therefore concluded that PWA may use deictic gestures to communicate in an interaction. Such gestures may “compensate for language and even allow PWA to avoid the trouble sources of verbal output, such as word finding difficulties” (p. 352). Some of these pointing gestures explored in the current study may have been stimulated by the specific research conditions. The majority of the conversations with the PWA in this study took place at the participants’ homes, either in their kitchen or their living room. In the context of the second procedural topic *How to make scrambled eggs*, some PWA started pointing at objects and tools they would use when they could not access the word. In some situations, especially in conversations with family members or friends, originally semantically empty gestures, such as deictics, may have acquired distinctive meanings. Within this (small) community these gestures are conventionalised and are now semantically rich gestures. An example from this study comes from 2PUF who used an upward pointing gesture with his index finger when referring to Scotland. As he spent many years working and living in Scotland, he uses this concept often during conversation. Through frequent use of this gesture as a reference for Scotland, the gesture has acquired this meaning and can now be used without speech with his regular conversation partners.

7.1.2.2.4 Beat gestures.

In the study by Le May et al. (1988), PWA produced more beat gestures[41] than NHP. The reverse was found in the current study. The decreased use of beat gestures in PWA may stem from the function of beat gestures themselves. According to McNeill (1992,

[41] Le May et al. (1988) referred to beat gestures as ‘batons’.

2000), beat gestures are rhythmical gestures during which the "hand moves along with the rhythmical pulsation of speech" (McNeill, 1992, p. 15). Unlike semantically rich and deictic gestures, they do not refer to an action or an object, but carry prosodic function. They are used to underline and stress what is said verbally. Based on their characteristics, beat gestures are expected to occur in mainly fluent speech. Non-fluent speech, especially that of participants with Broca's aphasia, however, is often characterised by absent prosodic features as the results of the study by Danly and Shapiro (1982) showed. Based on these findings, it is interesting that Le May et al. (1988) found an increased use of beat gestures in participants with non-fluent aphasia. In the current study, nine PWA had fluent and 11 had non-fluent speech. Post-hoc analyses indeed revealed a significant relationship between speech fluency and the number of beat gestures (see 6.8.2.3). It seems likely, therefore, that the difference in beat gestures between PWA and NHP was largely due to speech fluency.

7.1.2.2.5 Other gestures.

Finally, PWA produced more *other* gestures than NHP. These were gestures that could not be clearly categorised or that were not complete, that is, gestures that were abandoned mid-gesture. In either case, gestures could not be categorised according to their meaning and/or function and were counted as *other*. This was more often the case when coding the gestures of PWA than of NHP. It may therefore be related to the underlying language disorder.

There are two main explanations for this high number of *other* gestures in aphasia: (1) impaired gesture production in aphasia and (2) WFD. These will be reviewed in turn below.

Many studies that investigated gesture production in aphasia in comparison to neurologically healthy speech came to the conclusion that there were differences in the quality of gestures produced (e.g., Cocks et al., 2011; Cocks, Dipper, et al., 2013; Glosser et al., 1986; Mol et al., 2013). In their study, Mol et al. (2013) analysed the iconic gestures produced by PWA and NHP. Results revealed that PWA produced less complex gestures than NHP and their iconic gestures contained less information. The high number of incomplete gestures produced by PWA in the current study may be further evidence of poor quality gesture production. Informativeness and comprehensibility were not measured. However, it is likely that gestures missing a stroke would achieve low scores on such measures. Interestingly there was no relationship between participants' motor skills and their overall gesture production. This will be discussed in 7.1.5.2.2 in more detail. Motor skills were also not predictive of the frequency of uninterpretable gestures as post-hoc analyses revealed (see 6.8.2.5).

An alternative explanation for the high number of other gestures in PWA may be down to the high number of WFD. Informal observations made during data collection suggested that some of the incomplete gestures occurred alongside unresolved WFD; i.e. the PWA started to gesture, stopped pre-stroke and abandoned both the gesture and the word retrieval attempt. It is possible that these instances reflected not just a failure to access the word form, but also a failure to access meaning, and hence an inability to generate a complete gesture. However, this argument remains speculative and is not supported by any data in the study. Further research might shed more light on the origin of incomplete gestures in aphasia.

7.1.2.3 Summary.

Both PWA and NHP groups produced significantly more semantically rich than semantically empty gestures overall. Again, the production of different types of gestures was influenced by the conversation topic with procedural conversations eliciting significantly more semantically rich gestures than narrative conversations. This effect may have been due to the more object and action-focussed language elicited by procedural conversation topics.

The type of language elicited by procedural conversation topics may not be the only explanation for the high number of semantically rich gestures (especially in PWA). The occurrence of WFD may also play an important role. Indeed, there was a significant relationship between the overall number of WFD and the number of semantically rich gestures for PWA indicating a likely role for semantically rich gestures during WFD in aphasia.

Comparing the different gesture subtypes conflated in semantically rich and semantically empty gestures revealed a number of differences between PWA and NHP; some of which were only marginal. The most striking one was that PWA produced twice as many speech-replacing gestures, such as emblem, pantomime, and air writing & number gestures than NHP. Additionally, the high number of iconic and metaphoric gestures produced by NHP was not expected based on the literature (e.g., Carlomagno et al., 2005).

7.1.3 RQ 3: Word-finding difficulties.

Results revealed an equally high number of WFD experienced by all participants. Due to their healthy language, NHP were able to resolve almost all WFD, both with and without gesture production. PWA, however, showed a number of unresolved WFD as well, even though the majority of all WFD could be resolved. About two thirds of the resolved WFD occurred with a gesture, suggesting gestures play a role during the resolution.

The finding that PWA and NHP experienced an equally large number of WFD in the current study is against the findings of existing literature. Those studies reported only very few experiences of WFD by NHP, on average only about once a week (e.g., Brown, 1991; Burke et al., 1991). WFD in aphasia, however, are regarded as a typical symptom of impaired language (see 2.3.2.1). It is therefore surprising that the NHP experienced as many WFD as the PWA in the current study. The explanation may lie in (1) the age of the participants, (2) in the criteria used to identify WFD in this study, and (3) speech processing. These issues will be discussed in turn.

One explanation for the high number of WFD in NHP may be down to the age span of participants. Earlier studies have found a link between aging and word retrieval failure (e.g., Bortfeld et al., 2001; Burke et al., 1991; Rastle & Burke, 1996). In their study, for example, Shewan and Henderson (1988) compared participants of different age classes on their efficiency in communication. They found that the messages of participants under 50 years contained more content per time unit than the messages of those over 50 years. However, this explanation was challenged by the finding that age did not correlate with the number of WFD in the current study (see 6.8.3.1).

Alternatively, the explanation may be down to the criteria used to identify WFD. The current study used the criteria by Murray and Clark (2006) to identify WFD (see 5.4.2). These criteria allowed WFD of very short duration to be included. It was likely that the WFD of the PWA were of much longer duration than those of the NHP. Observations confirmed that WFD of the NHP were typically more fleeting or rapidly resolved, while those of the PWA were prolonged. It may also relate to the sampling method as the same length of conversations was analysed for PWA and NHP (i.e., 2 minutes per conversation leading to 16 minutes in total; see 5.3.5.2). Therefore, NHP produced much more language in the given time so had more opportunities for word retrieval to fail. Had the denominator been the number of words produced, presumably PWA would have produced proportionally more WFD than NHP.

Furthermore, the applied criteria to identify WFD also included filler words, such as *uh* and *um*, as an indicator for WFD. However, these filler words may indicate a speech disfluency, which could be a product of (1) planning a new utterance, (2) describing something difficult (i.e., either new to the discourse/ conversation or unfamiliar to the speaker/conversation partner), or (3) distraction (Arnold, Hudson Kam, & Tanenhaus, 2007). Furthermore, disfluencies result “from the tension between the time needed to plan upcoming speech and from the need to avoid long delays or silences, which may signal that the speaker is no longer participating in the conversation” (Arnold & Tanenhaus, 2011, p. 202)[42]. Corley and Stewart (2008) added to this, that participants inserted filler words when they were uncertain or had to make a decision. One could argue that this was especially the case in the procedural conversations due to incomplete knowledge about how something is done (e.g., not all participants had made scrambled eggs before) or being unable to word a (rather complex) process. Despite their potentially different origin, these disfluencies were also coded as WFD in the current study and may be one of the reasons for an increased number of WFD, especially in NHP.

Finally, there may be processes that have an influence on fluency even in neurologically healthy speech. According to Broen and Siegel (1972) and Oviatt (1995), the number of disfluencies also depends on the type of the spontaneous speech sample, as they observed significantly more disfluencies in conversations than in monologues. Explanations for this difference may arise from speakers’ different behaviour in these two situations. Some conversation partners may have caused disfluencies, for example, by asking questions or making interjections. Disfluencies are a type of WFD, indicated by hesitations/pauses, filler words (e.g., *uh*, *um*), repetitions or repairs (e.g., Arnold & Tanenhaus, 2011; Fox Tree & Clark, 1997).

The relationship between gesture production and the resolution of WFD, may hint towards a facilitative function of gesture. Indeed, all participants produced more gestures during WFD than outside of WFD. Gestures may also support the fluency of speech, if not caused by purely lexical failure. If disfluencies can also be resolved by the production of gestures, this underlines the important role of gesture production during spontaneous speech, in participants with impaired and unimpaired language. To find out more about the role of gesture production in disfluencies other than typical WFD, especially in neurologically healthy speech, more research has to be conducted. One way may be to investigate gesture production in different conversation settings applying finer criteria for categorising disfluencies, for example, based on their indicators (i.e., pause, filler word, circumlocution). 7.3 will discuss this issue in more detail.

[42] according to Clark (1996) and Clark and Wasow (1998)

Many studies have identified WFD as an explanation for an increased gesture production in aphasia (e.g., Ahlsén & Schwarz, 2013; Hadar, 1991; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994; Lanyon & Rose, 2009) (see 2.4.3). The finding that resolution of WFD was far more common for NHP than PWA, is as expected due to their unimpaired language. Observations confirmed that WFD of the NHP were typically more fleeting or rapidly resolved, while those of the PWA were prolonged. Nevertheless, for both groups, the data indicated an association between WFD resolution and gesture production which suggests that gestures played an important role during the resolution of WFD.

A number of authors have argued for a relationship between the WFD of PWA and their use of gesture and have suggested that gestures are used to facilitate access to blocked words (e.g., Cocks, Dipper, et al., 2013; Le May et al., 1988; Pritchard et al., 2013). A correlation analysis revealed a significant relationship between the overall number of gestures produced during the conversations and the overall number of WFD for PWA. Participants who experienced more WFD also produced more gestures in general. This effect was not found in the data of the NHP. Nevertheless, by comparing the two correlation coefficients, no significant difference between the two z-scores (i.e., PWA vs. NHP) could be found. This may be due to the small sample size and the significant relationship between the overall number of gestures and the overall number of WFD for PWA needs to be treated with care. Although this relationship was not evident for the NHP, the difference between the groups was not upheld by further analysis.

Results showed most WFD experienced by PWA that were accompanied by gesture were resolved. Furthermore, a significantly smaller number of WFD without gesture were resolved as subsequent Wilcoxon signed-rank tests revealed. Overall, significantly more gestures were produced in resolved than in unresolved WFD. A subsequent chi-square analysis revealed a significant link between gesture production and the resolution of WFD. These findings are all in favour of a facilitative function of gesture and they are in line with previous research studies highlighting the role of gesture production in aphasia, especially during WFD (e.g., Ahlsén, 2005; Ahlsén & Schwarz, 2013; Behrmann & Penn, 1984; Cocks et al., 2011; Cocks, Dipper, et al., 2013; Glosser et al., 1986; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994; Helasvuo, 2004; Kong et al., 2015; Lanyon & Rose, 2009; Le May et al., 1988; Pedelty, 1987; Pritchard et al., 2013). The majority of earlier studies explored the difference between gesture production in resolved and unresolved WFD to make assumptions of the role of gesture in resolution (e.g., Cocks et al., 2011; Cocks, Dipper, et al., 2013; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar &

Yadlin-Gedassy, 1994; Lanyon & Rose, 2009; Pritchard et al., 2013). The authors proposed that if gesture production played an important role in lexical retrieval, participants would produce significantly more gestures during resolved WFD than during unresolved WFD. Some indeed found this pattern (e.g., Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994; Lanyon & Rose, 2009). However, others did not (e.g., Cocks et al., 2011; Cocks, Dipper, et al., 2013; Pritchard et al., 2013).

More support for the importance of gesture production during WFD comes from gesture therapy studies. The majority of the studies investigating the therapeutic effect of gesture production on the resolution of WFD came to the conclusion that gesture cues, especially in combination with other types of facilitation led to positive outcomes in lexical retrieval (see Rose, Raymer, et al., 2013 for a review).

The association between WFD resolution and gesture production is further supported by the finding that PWA produced significantly more resolved WFD accompanied by gesture than resolved WFD without a gesture. This indicates an important role of gesture production in the resolution of WFD when language is impaired. Nevertheless, the finding that PWA did not produce significantly fewer unresolved WFD accompanied by a gesture than unresolved WFD without a gesture may point towards the fact that there may be aspects of impaired language resulting in WFD that even the production of gesture cannot fix.

There are two potential explanations for the important role of gesture production during WFD in the current study: (1) Gesture production plays an important role in lexical retrieval and (2) semantic knowledge has an influence on gesture production in WFD. In the following paragraphs, these two issues will be reviewed in turn.

The important role of gesture production in lexical retrieval has already been argued by Krauss et al. (2000) and articulated in the Lexical Facilitation Model. According to this model, gestures are primarily produced to facilitate lexical retrieval with gestures being produced just before their lexical affiliate. The Sketch Model by de Ruiter (2000) does not seek to explain the facilitative function of gesture. Yet, there are three feedback mechanisms allowed in the Sketch Model: (1) within the conceptualiser, (2) post-phonological encoding using the speech comprehension system (comparable to inner speech but more abstract), and (3) after articulation when the speaker can hear him/herself speaking (or hear him/herself starting to make a slip of the tongue). Based on these three feedback mechanisms, Lanyon and Rose (2009) argue that the Sketch

Model can account for both lexical access facilitation and gesture used as compensation for a lexical access problem. Following up on this, de Ruiter and de Beer (2013) additionally claim that gestures are sometimes produced instead of speech, without necessarily being connected to a lexical entry. Unlike the Lexical Facilitation Model, this facilitation process is largely semantic. Because of the feedback loops, the speaker knows about an error early and triggers semantic information to be boosted which may lead to a gesture. The production of a gesture subsequently may lead to the target word. Based on these two models, gesture production plays an important role in lexical retrieval and can directly be linked to the relationship between gesture production and the resolution of WFD found in this study, both for PWA and NHP. Nevertheless, more research is needed to shed light on the role of gesture production during WFD. 7.3 will discuss this issue in more detail.

The association between the production of gesture and the resolution of WFD may be due to another factor. Speakers may have different degrees of access to blocked words. In some cases, there may be partial activation of the word, although insufficient to trigger its production. This partial activation, particularly of semantic knowledge, may allow for a gesture to be produced. In other instances, retrieval failure may be more profound. Here, there is very little knowledge of the blocked word and therefore insufficient to stimulate a gesture. Resolution of the former WFD is more likely than the latter. However, the gestures could be incidental to that resolution. This might simply reflect the differing degrees of access. Further research may be able to find out more about these different types of WFD and information needed in order for gesture to facilitate lexical retrieval.

Unsurprisingly, given their intact language, the majority of WFD experienced by the NHP were resolved, with only 4.48% being unresolved. This group revealed an association between gesture production and WFD resolution, so more WFD were resolved when they were accompanied by a gesture than when not. This is in line with previous research findings. For example, Krauss et al. (1996) came to the conclusion that gestures also played an important role in neurologically healthy speech, especially during WFD. The majority of studies investigating the role of gesturing during WFD applied a rather restricting technique: They compared speech production when participants were allowed to gesture to speech production when participants had to suppress their gesturing, for example, by sitting on their hands (e.g., Beattie & Coughlan, 1999; Frick-Horbury & Guttentag, 1998; Graham & Heywood, 1975; Morsella & Krauss, 2004; Rauscher et al., 1996; Rimé, 1982; Rimé et al., 1984). The majority of these studies reported more fluent speech when participants were allowed to gesture. Also, Frick-Horbury and Guttentag (1998) found that participants resolved more WFD when being allowed to gesture.

Researchers therefore concluded that gestures played an important role in speech production and helped to also resolve WFD. This issue will be picked up later in 7.1.4.

To summarise, PWA and NHP experienced an equally large number of WFD, only partly in line with the existing literature. There are several explanations for the high number of WFD by NHP, ranging from participant to methodological factors. The resolution of WFD was far more common for NHP than PWA, as would be expected. Nevertheless, for both groups, the data indicated that resolution may be related to gesture production, hence gesture may serve a potentially facilitative function.

7.1.4 RQ 4: Functions of semantically rich gestures.

Results showed that all participants produced semantically rich gestures with different functions. While NHP almost exclusively produced gestures during resolved WFD and alongside fluent speech, PWA produced gestures during resolved and unresolved WFD, alongside fluent speech and without speech. The majority of gestures produced by PWA were those during resolved WFD, that is, gestures with a potentially facilitative role. PWA furthermore differed from NHP in the large percentage of gestures during unresolved WFD.

7.1.4.1 Different functions of semantically rich gestures.

Percentage scores suggested that both PWA and NHP produced gestures that served different functions. The proportions of specific gesture functions were distributed differently but in line with the results of RQ 3 (see 7.1.3). The main findings can be summarised as follows: (1) About 50% of all semantically rich gestures of either group were coded as facilitative (i.e., they were produced during a WFD that could be resolved by the speaker), (2) compensatory gestures, (i.e., gestures that occurred without speech and not during a WFD) were not common in either group, even though PWA produced more compensatory gestures than NHP, (3) PWA produced many communicative gestures (i.e., gestures that were produced during a WFD that could not be resolved by the speaker) whereas NHP produced almost none of these, and (4) NHP produced even more augmentative gestures than facilitative gestures (i.e., gestures that occurred alongside speech and not during a WFD) while PWA produced only a minor proportion of these gestures. These finding that all participants, especially those with aphasia produced gestures serving different functions is in line with the existing literature (e.g., Ahlsén, 2005; Feyereisen, 1983; Helasvuo, 2004; Kong et al., 2015; Lanyon & Rose, 2009; Le May et al., 1988; Macauley & Handley, 2005; Pedelty, 1987). The majority of these studies came to the conclusion that augmentative, that is, speech-accompanying gestures were the gestures mostly identified in their participants while the WFD resolving gestures, that is, facilitative gestures were the most debated ones as they could not be identified in key studies investigating the facilitative effect of gestures (e.g., Cocks et al., 2011; Cocks, Pritchard, Cornish, Johnson, & Cruice, 2013; Dipper et al., 2015; Pritchard et al., 2013).

Wilcoxon signed-rank tests were used to investigate within-group comparisons of gesture functions and revealed that PWA produced significantly more facilitative gestures than communicative, augmentative, and compensatory gestures. This finding is in line with the finding of RQ 3 (see 7.1.3) that PWA produced significantly more WFD +gesture/+resolved than any of the other types of WFD. For NHP, however, only the differences between facilitative gestures and communicative and compensatory gestures were significant, while the difference between facilitative and augmentative gestures was not.

This analysis, which was confined to the semantically rich gestures produced similar conclusions to the analysis of all gestures conducted for RQ3. That is, a very large number of semantically rich gestures for both groups were coded as *facilitative*, since they accompanied resolved WFD. Once again the findings are pointing to a potential role of gesture in the resolution of WFD. It also suggests that this role is performed by semantically rich rather than semantically empty gestures.

7.1.4.2 Communicative gestures.

One reason for labelling the group of semantically rich gestures that occurred during unresolved WFD as communicative was the fact that these gestures still may carry communicative value and give important information to the conversation partner. The communicative gestures of PWA may have performed two roles: The participant either (1) gestured for him/herself to facilitate lexical retrieval but failed or (2) produced these gestures for the benefit of the conversation partner by adding information to his/her impaired speech and asking the conversation partner for help. The second reason is in line with conversation being a collaborative/co-constructed action between the speaker and the conversation partner in aphasia (e.g., Armstrong, Ferguson, & Mortensen, 2011; Auer & Bauer, 2011; Beeke et al., 2013; Bloch & Beeke, 2008; Goodwin, 1995, 2003; Oelschlaeger & Damico, 2003).

Both proposals are consistent with theories of repair, which stress that this can be accompanied by the speaker (self-initiated) or partner (other-initiated) (e.g., Auer & Bauer, 2011). Depending on the severity of the aphasia, PWA may be able to complete such a repair process themselves or need the assistance of the conversation partner. In this context, communicative gestures may have been produced originally as an attempt to self-repair, that is, as attempted facilitative gestures. If this did not lead to successful lexical retrieval, the PWA needed the support of the conversation partner to finish the repair process (i.e., other-repair), making the gesture communicative. These communicative gestures may have also provided information to the conversation partner from the very beginning without the intention to self-repair.

Communicative gestures may vary in their degree of communicativeness, an issue which was not investigated in the current study. Therefore, future research may explore the degree to which gestures communicate to the conversation partner and transmit information.

7.1.4.3 Compensatory gestures.

The low proportion of compensatory gestures in aphasia was surprising. Based on numerous studies that identified this function of gesture production in aphasia (see 2.4.4.2 and 3.4.1), a higher proportion of gestures replacing speech was expected.

Two factors could have had an influence on the low proportion of compensatory gestures produced by PWA in this study: (1) the severity of the aphasia or the (2) coding scheme of WFD. These factors will be reviewed in turn in the following subsections.

In terms of the severity of the aphasia, it may have been the case that the level of language impairment did not require participants to produce compensatory gestures. This would predict a relationship between the overall number of compensatory gestures and aphasia severity. Post-hoc analyses, however, explored this and did not find such an effect. One has to acknowledge though this was not a large scale study and only three participants were diagnosed with severe aphasia (WAB-R AQ < 50.9; see 5.3.1.1.1). Instead of producing compensatory gestures to communicate, all PWA mainly relied on speech production and produced gestures alongside speech and/or during WFD. This is in line with the second hypothesis: the coding scheme of WFD. Gestures were coded as compensatory only if they occurred without speech and outside of a WFD (see 5.4.3.2). Therefore, gestures occurring within WFD but without speech may have served a compensatory function but were coded as either facilitative or communicative, depending on whether the participant could resolve the WFD on their own. This may have been the case in previous studies as well. However, in most of those, no such specific coding scheme was applied, excluding speech-replacing gestures that occurred during WFD.

It seemed that the PWA in this study always tried to communicate by speech first and rarely attempted to communicate by gesture alone. This is supported by the low number of speech-replacing gestures, such as pantomimes and emblems[43] (see 2.1.2). It is also in line with the general communicative behaviour of humans. Neurologically healthy communication includes both verbal and non-verbal elements, but with the primary focus on speech (e.g., Burns, 1991; Cassell, 2000; Davidson et al., 2003). Using a gesture as a compensatory method of communication, requires a fundamental shift in this well-established ‘habit’. It may be that this shift needs to be supported in therapies that are attempting to teach the use of compensatory gesture. This issue will be picked up in 7.2.2.

7.1.4.4 Summary.

PWA and NHP produced different functions of semantically rich gestures in conversation. The main difference between the two groups was in the distribution of these gesture functions. NHP mainly produced facilitative and augmentative gestures. Only a very small proportion of their semantically rich gestures were categorised as communicative and compensatory. This finding was not surprising given their intact language processing. PWA produced high proportions of facilitative and augmentative gestures as well. However, communicative gestures occurred often too. It was hypothesised that these may have been failed attempts to facilitate word production, or they may have performed a cueing function for the conversation partner. Interestingly, compensatory gestures constituted only a small proportion of semantically rich gestures, although this proportion was twice as large for PWA compared to NHP. This points towards the fact, that even with a language impairment, PWA mainly focussed on the production of speech rather than relying on other communicative methods, such as gestures.

7.1.5 RQ 5: Participant factors.

Background tests were used to explore factors that might relate to gesture production. A range of factors were tested with PWA, including lexical production, semantic, cognitive and motor skills, while NHP were only tested on cognition and motor skills. As expected, results revealed that in case of the NHP, neither cognitive skills nor motor skills had an influence on their gesture production. For PWA, however, three significant links between participant factors and the production of gestures could be established: (1) fluency, (2) lexical production skills, and (3) cognitive skills (see 7.1.5.1), while the other participant factors did not reveal a relationship with the production of gestures (see 7.1.5.2).

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[43] On average, PWA produced 0.75 pantomime and 0.6 emblem gesture each.

7.1.5.1 Significant factors.

7.1.5.1.1 Fluency.

The finding that participants who scored higher on the WAB-R fluency measurement produced significantly more gestures than participants who scored lower goes in line with previous studies that established a strong link between fluency of speech and the overall number of gestures (e.g., Carlomagno & Cristilli, 2006; Le May et al., 1988; Lott, 1999; Sekine & Rose, 2013; Sekine et al., 2013) (see 2.4.1.2.2). According to Sekine et al. (2013), the relationship between gesture production and fluency of speech output was stronger than the relationship between gesture production and the type of the aphasia (see 2.3.1). The research study conducted by Carlomagno and Cristilli (2006) was the only exception to this finding. The results of their study did not reveal a significant difference in gesture production between participants with fluent and non-fluent aphasia. Nevertheless, the authors found that if PWA were compared based on their gesture production per word, the relationship was inverse, that is, participants with non-fluent speech production produced significantly more gestures than participants with fluent speech production. This was in line with the previous study by Pedelty (1987) who compared PWA on both measurements. Since this study did not calculate a gesture production score per word but per time frame only (i.e., 16 minutes overall), this comparison was not possible.

The relationship between speech fluency and gesture production may originate with one category of gesture, namely beats. This is true for both neurologically healthy and impaired speech. Studies investigating the production of different types of gestures in participants with fluent and non-fluent aphasia, came to the conclusion that participants with fluent aphasia produced a similar number of beat gestures as NHP (e.g., Carlomagno & Cristilli, 2006; Le May et al., 1988; Lott, 1999; Sekine & Rose, 2013; Sekine et al., 2013). Post-hoc analyses in this study revealed a significant relationship between speech fluency and the number of beat gestures (see 6.8.2.3). It seemed, therefore, that beats were at least contributing to the correlation between fluency of speech and gesture production.

Furthermore, participants with fluent speech output probably said more in their conversations than participants with non-fluent speech. Therefore, they had more opportunities to produce gestures, either alongside successful speech (augmentative gestures) or during WFD (facilitative and communicative gestures).

A rather similar proposal is that the relationship between speech fluency and the overall number of gestures may be related to better lexical production skills. Results revealed an inter-correlation between the fluency assessment of the WAB-R and the composite score assessing lexical production skills (see 6.7.1.1). This issue will be discussed in 7.1.5.1.2 below.

7.1.5.1.2 Lexical production skills.

The finding that participants with better preserved lexical production skills (i.e., word retrieval) also produced significantly more gestures than those with poorer lexical production skills was rather unexpected as previous studies reported the opposite; participants with better preserved lexical production skills were found to produce fewer gestures (e.g., Carlomagno et al., 2005; Cocks et al., 2011; Cocks, Dipper, et al., 2013; Hadar, 1991; Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994; Lanyon & Rose, 2009; Pritchard et al., 2013). It was therefore anticipated that participants with poorer lexical production skills would produce more gestures to compensate for speech or to facilitate lexical retrieval. Instead, participants with higher scores in lexical retrieval produced more gestures overall. Lexical production scores correlated with a number of measures, such as aphasia severity, speech fluency and semantic skills. These confounds make interpretation difficult. What becomes clear from this picture is, however, that participants who performed better on lexical production also performed better on the other assessments and produced significantly more gestures, that is, their language skills were closest to the language skills of the NHP.

One potential explanation for this link between lexical production skills and the overall number of gestures could be similar to the link between fluency of speech and the overall number of gestures (see 7.1.5.1.1): Participants with good lexical access probably said more in their conversations and therefore had more opportunities to deploy gesture and to experience more WFD. Indeed, PWA with good lexical access experienced more WFD than PWA with poorer skills (see 6.8.5.1). This may well have been the mediating factor for the increased number of gestures by PWA with good lexical skills. This is also supported by the finding that all participants produced more gestures during WFD than outside of WFD (see 6.5.3). These findings relate to the low number of compensatory, that is, speech-replacing gestures. Had more gestures of this type been employed, the relationship with lexical production skills might have been less strong (or even inverse).

7.1.5.1.3 Cognitive skills.

Cognition was another factor that had an influence on gesture production: Participants with better cognitive skills produced significantly more gestures overall than participants with poorer cognitive skills. The cognitive tasks in the present study included symbol cancellation, symbol trails, design memory, mazes, and design generation. These tasks assessed both executive function and working memory. There is evidence from the literature that both capacities are deployed during gesturing.

Studies by Glosser and Goodglass (1990), Purdy (1992, 2002), Purdy et al. (1994), Purdy and Koch (2006), and Yoshihata et al. (1998), for example, have established a link between gesture production and executive functions. This suggests that executive function may play an important role in implementing gesture production during communication. It may, for example, enable the person to switch between communication modalities (e.g., from speech to gesture and the other way round), particularly in instances of communication failure.

Other studies investigated the relationship between working memory and gesture production (e.g., Barquero & Logie, 1999; Pearson et al., 1999) and have come to the conclusion that especially pantomime gestures are affected by working memory. One explanation for this may be that participants with poor working memory may not be able to ‘hold’ a complex piece of information long enough in order to decide what is conveyed verbally and what is gestured. Furthermore, in gesture processing, it is the role of the working memory to integrate spatial and propositional information into situational and encyclopaedic knowledge (see 2.1.4 and 7.2.1.1).

This argument that cognitive skills may be required to switch modalities in the face of word-finding failure was investigated with a follow-up post-hoc analysis. This explored the relationship between cognitive skills and the production of gesture in instances of WFD. Results showed a relationship between cognition and the number of +gesture/+resolved WFD (see 6.7.1.3). While only suggestive, the findings may indicate that good cognition enabled the person to monitor word-finding failure and initiate the gesture strategy.

7.1.5.2 Non-significant factors.

Next to these three factors that revealed a significant relationship with the production of gestures (i.e., fluency, lexical production skills, and non-verbal cognitive skills), other factors did not, such as aphasia severity, semantic skills (verbal & non-verbal), and motor skills.

7.1.5.2.1 Aphasia severity.

Results of the current study revealed no significant relationship between the overall production of gestures and the severity of aphasia. This is in line with the majority of previous studies investigating this link (e.g., Behrmann & Penn, 1984; Borod et al., 1989;

Hogrefe et al., 2012; Hogrefe et al., 2013; Macauley & Handley, 2005; Pedelty, 1987; Rose & Douglas, 2003). There are a few exceptions to this finding (e.g., Borod et al., 1989; Glosser et al., 1986; Kong et al., 2015; Mol et al., 2013). Nevertheless, in the study conducted by Borod et al. (1989), this relationship was no longer evident when participants with global aphasia were excluded from the analysis. Instead of a link between aphasia severity and gesture production, many researchers have come to the conclusion that other features of aphasia have an influence on the production of gestures. They have argued that the type of the aphasia, especially based on the fluency of the speech output, was the best predictor of gesture production (e.g., Behrmann & Penn, 1984; Carlomagno et al., 2005; Cicone et al., 1979; Cocks, Dipper, et al., 2013; R. J. Duffy et al., 1984; Le May et al., 1988; Lott, 1999; Mol et al., 2013; Pedelty, 1987; Sekine & Rose, 2013; Sekine et al., 2013) (see 2.4.1.2.2 and 6.7.1.2.1).

A potential explanation for why the severity of aphasia is not a predictor for gesture production may be due to the complexity of the severity measure, which is calculated according to a specific algorithm by means of an aphasia battery, such as the AAT in German (Huber et al., 1983) and the WAB-R (Kertesz, 2007) and the BDAE (Goodglass et al., 2001) in English. Having severe aphasia does not indicate anything about the specific language impairment. In fact, every aphasia is different regarding the specific impairment distribution across language areas tested to calculate the score. Often, participants are tested on their naming abilities, language comprehension, and repetition of words/objects and sentences/situations. Usually, their spontaneous speech is rated as well on factors such as fluency, semantic and phonematic paraphasias, and syntax. In order to keep these assessment batteries as short as possible, subtests usually do not consist of many items. Therefore, further assessments, created to investigate a specific language area in more detail are often used. This was also the case in the current study. The individual variation of PWA was confirmed by the non-significant relationships between aphasia severity and lexical production and aphasia severity and non-verbal semantics (see 6.7.1.1). This indicates that participants with lower skills on lexical production or non-verbal semantics did not automatically have severe aphasia. Lexical production skills, however, seem to have had an influence on the production of gestures as the correlations analyses in 6.7.1.1 showed (see 7.1.5.1.2 as well). Consequently, it is likely that it is not the construct of aphasia severity itself that is related to the production of gestures during conversation, but more individual language skills, such as fluency of speech and lexical semantics.

7.1.5.2.2 Motor skills.

Similar to the aphasia severity, there was no significant relationship between participants' motor skills and the overall number of gestures. This finding is line with previous research studies, which have indicated that both participants with and without limb apraxia produced a similar number of spontaneous gestures (e.g., Borod et al., 1989; R. J. Duffy et al., 1984; Macauley & Handley, 2005; Pritchard et al., 2013; Rose & Douglas, 2003). On the other hand, studies investigating the quality of spontaneously produced gestures in participants with limb apraxia have found reduced complexity and reduced comprehensibility of gestures though (e.g., Hogrefe et al., 2012; Hogrefe et al., 2013). This suggests that limb apraxia does not influence the overall number of gestures produced during conversation but the type of gestures and/or their comprehensibility. The studies by Hogrefe and colleagues only included participants with severe global aphasia. This may also have had an influence on the quality of the gestures produced. In other words, those with severe motor impairments may also have had the most profound language difficulties. In the present study, the influence of limb apraxia on neither type nor comprehensibility of gestures was investigated. Furthermore, participants with global aphasia were excluded from the study (see criteria in 5.2.1 and screening in 5.3.1.1). To find out more about the influence of limb apraxia on the quality of gestures, it would be interesting to investigate this in a broader range of PWA.

7.1.5.2.3 Semantic skills.

Surprisingly, there were non-significant relationships between semantic skills (verbal & non-verbal) and the production of gestures (overall & semantically rich gestures). Based on previous findings, a significant relationship between gesture and both types of semantic skills was anticipated, with participants with better semantic skills producing more semantically rich gestures than participants with poorer semantic skills (e.g., Carlomagno & Cristilli, 2006; Cocks, Dipper, et al., 2013; Fucetola et al., 2006; Glosser et al., 1986; Hadar, Wenkert-Olenik, et al., 1998; Hogrefe et al., 2012; Hogrefe et al., 2013). Furthermore, the fact that a link between non-verbal cognitive skills and the overall production of gestures was established, would lead to the expectation that a similar relationship would exist between (especially) non-verbal semantic skills and gesture production. This stems from the discussion that non-verbal semantic processing cannot clearly be assigned to either language or cognitive processing (Jackendoff, 1983) (see 2.4.2.4).

These non-significant links between gesture production and semantic skills may be explained by ceiling effects. On average, PWA scored 88.59% on the tests of non-verbal semantic skills (between 75.05% and 98.10%, SD = 7.032). According to both Bak and

Hodges (2003) and Howard and Patterson (1992), the cut-off score of the KDT and the PPTT is 90%. Therefore, the group was close to the cut-off with 12 of 20 PWA scoring over 90%. The participants' performance on the verbal semantic tests was similarly high. Here, PWA scored on average 86.69% (between 71.34% and 97.08%, SD = 8.419). Unlike the non-verbal semantic tasks, there are no specific cut-off scores for the tasks used to assess the verbal semantic skills. Nevertheless, assuming a similar threshold of 90%, 10 of 20 PWA scored over 90% on the verbal semantic skills as well. Seven PWA even scored over 90% on both semantic skills.

Given these ceiling effects the applied semantic tests may not have been sensitive enough to capture subtle impairment that may cause problems in gesture production. In fact, the test of non-verbal cognitive skills may be a better proxy for a subtler semantic test as it revealed a significant relationship with the overall number of gestures produced (see 6.7.1.2.3). As has already been argued, these tests may probe the executive skills that are needed to switch modalities in gesture. Such skills, however, may also be required to identify the relevant semantic properties that will be encoded in that gesture (e.g., Glosser & Goodglass, 1990; Purdy, 1992, 2002; Purdy et al., 1994; Purdy & Koch, 2006; Yoshihata et al., 1998). Support for this explanation comes from the observation that participants who scored highly on semantic assessments also reached higher scores on the non-verbal cognitive tasks. This indicates a link between semantic and cognitive skills in aphasia. The test of lexical production may also have provided a more sensitive measure of underlying semantic competence. Participants who scored more highly on these tasks, also reached higher scores on semantic skills (both verbal and non-verbal).

Alternatively, it may be the case that the semantic information needed to produce semantically rich gestures was not the same as the semantic information assessed by the verbal and non-verbal semantic tests. The major difference between the tasks in the study and the tasks in the assessments was the manner in which participants were tested. While expressive skills were needed in the conversations, only receptive skills were assessed on the verbal and non-verbal semantic tasks. The PWA were provided with pictures and had to relate these either to given words (PALPA #47 and #49 by Kay et al. (1992)) or other associated pictures (PPTT by Howard and Patterson (1992)). The conversation task, however, was purely based on the output: In order to generate gestures, participants had to retrieve the meaning and combine it with the action of gesture. This is a creative process, as co-speech gestures are not codified, as emblems are, but instead are created on the spot. As mentioned before, non-verbal cognition tasks may be a better proxy for a semantic task and might be a better proxy for the complexity of semantic processing needed to underpin successful communication in the conversation tasks in this study. Nevertheless, more research regarding this issue is needed.

7.1.5.3 Summary.

Unsurprisingly, there were no relationships between the participant factors examined in the NHP group and their production of gestures. For PWA on the other hand, fluency of speech, lexical production skills, and cognitive skills all revealed significant relationships with the overall number of gestures produced. Due to inter-correlations between several of these participant factors, interpretation was difficult. Interestingly, no significant relationship between semantic skills and gesture production could be revealed, which was probably due the semantic tasks assessing receptive semantic skills while participants needed their expressive semantic skills to employ gestures into conversation. Additionally, there were no links between gesture production and either aphasia severity or motor skills and gesture production. These null-findings are in line with previous research studies investigating the influence of participant factors on gesturing.

7.2 Contributions made by the study

The findings from the current study have a number of theoretical and clinical implications. A selection of these will be reviewed and discussed in the following sections.

7.2.1 Theoretical implications.

7.2.1.1 Gesture processing.

The finding that all participants used gesture that served different functions during conversation can be accommodated by the two gesture processing models briefly outlined in 2.1.4: (1) the *Sketch Model* by de Ruiter (2000) (as an example for the *Interface Hypothesis* by de Ruiter and de Beer (2013)) and (2) the *Lexical Facilitation Model* by Krauss et al. (2000). Both models accommodate the main findings of the current study, even though they differ in their understanding of the primary gesture function: While the *Sketch Model* allows gestures to be produced in an augmentative, communicative, and compensatory manner, the *Lexical Facilitation Model* sees the primary gesture function as facilitation.

Although the aim of the current study was not to adjudicate between these models, it is theoretically informative to relate the findings to them. These relevant findings can be summarised as follows:

(1) Participants produced different gesture functions.
(2) Augmentative gestures were produced to supplement speech.
(3) Potentially facilitative gestures occurred in resolved WFD.
(4) There were only few compensatory gestures to replace speech.

The first key finding is that participants used different gesture functions. This can be accommodated by the *Interface Hypothesis* because, according to de Ruiter and de Beer (2013), gestures can serve both compensatory and augmentative functions due to the fact that gesture and speech originate from the same communicative intention. The *Lexical Facilitation Model* does not account for functions other than facilitative. Augmentative gestures are dealt within the *Interface Hypothesis* during the lexical production process, during the retrieval of propositional and imagistic knowledge stored in the working memory, the speaker decides which part of the message will be spoken and which will be gestured. Consequently, the part of the message that is difficult to be conveyed verbally will be gestured and vice versa. This way, gesture and speech support each other. Facilitative gestures, however, can be accommodated by the *Lexical Facilitation Hypothesis*. According to Krauss et al. (2000), these gestures usually occur just before the lexical affiliate to support lexical retrieval. All semantically rich gestures that occurred during a resolved WFD were coded as facilitative. This gesture function can, however, be explained by the *Interface Hypothesis* as well, though without the temporal aspect: Because of three different feedback loops, the speaker knows early about an occurring error. In this case, the semantic information of the concept is boosted by producing a gesture. This works well with the current study, as only semantically rich gestures were checked for their function within the conversations. Therefore, the finding of facilitative gestures can be explained by both models.

Compensatory gestures did not occur very often in this study, in fact, both PWA and NHP produced a very small number of compensatory gestures overall. Nevertheless, gestures produced without speech are not accounted for by the *Lexical Facilitation Hypothesis*, as discussed above. According to the *Sketch Model*, gestures may compensate for speech based on the earlier decision which part of the message will be conveyed verbally and which gesturally. Ideas that are difficult to be expressed verbally, for example, may be gestured instead.

These four findings relating to the functions of gestures are not the only ones of the current study that are relevant for gesture processing models. There are other important findings, such as that participants used different types of gestures alongside speech. While the *Lexical Facilitation Model* mainly accounts for iconic and metaphoric gestures, the *Interface Hypothesis* includes other types of gestures as well, such as deictic, emblem, and pantomime gestures. Neither of the two models specifically account for the production of beat gestures, which were very common in PWA and NHP.

The findings of the current study showed that there were pragmatic influences, such as the conversation topic or the familiarity of the conversation partner, that had an influence on the number and type of gestures produced, and this was the case in both impaired and neurologically healthy language. Indeed, the architecture of both models allows for pragmatic information to be taken into consideration during gesture processing. The starting point of each model is long-term memory containing, for example, the discourse model, situational knowledge, and encyclopaedic knowledge. This information feeds into working memory, where spatial and propositional information are integrated. It may therefore be the case that at these early processing stages, information, such as the familiarity of the conversation partner and the conversation topic, are taken into consideration. Subsequently, this may have an influence on gesture production. Alternatively, it may be that the pragmatic information of conversation partner and topic mainly influence the processing of language which then in turn affected the number and type of gestures.

7.2.1.2 Participant factors.

Previous studies have sought to find out more about predictive factors for the use of gesture in spontaneous speech (e.g., Carlomagno et al., 2005; Cicone et al., 1979; Cocks et al., 2011; Cocks, Dipper, et al., 2013; J. R. Duffy & Watkins, 1984; R. J. Duffy et al., 1984; Glosser et al., 1986; Goodglass & Kaplan, 1963; Hadar, Wenkert-Olenik, et al., 1998; M. Herrmann et al., 1988; Kadish, 1978; Le May et al., 1988; Lott, 1999; Mol et al., 2013; Pickett, 1974; Pritchard et al., 2013; Sekine & Rose, 2013; Sekine et al., 2013; Wang & Goodglass, 1992). These factors help to shed light onto the processing of gesture as they give an indication about which skills are needed in order to effectively produce gestures in spontaneous speech.

In the current study, a number of participant factors were assessed, such as aphasia severity, fluency of speech, lexical production skills, verbal and non-verbal semantic skills, motor skills and cognition. The findings point to an interdependence between gesture and language. While the complex concept of aphasia severity did not reveal a relationship with gesture production, specific language skills, such as speech fluency and lexical production did. This is not surprising given the type of gestures investigated in the current study: co-speech gestures. They are known to be very tightly linked to language, hence can be more influenced by specific language impairments. However, studies investigating the use of gestures in people with very severe aphasia who often have no speech output, indicate that some of these people may still be able to gesture (e.g., Hogrefe et al., 2012; Hogrefe et al., 2013), although their gestures are stand-alone gestures, such as emblems and pantomimes.

It is interesting that not only language skills per se, such as speech fluency and lexical production skills, revealed a relationship with gesture production, but cognition as well. In the current study, the cognitive assessment used non-verbal tasks only to test range of skills, such as working memory and executive function. Both functions have been found to have an influence on gesture production (e.g., Barquero & Logie, 1999; Bartolo et al., 2003; Glosser & Goodglass, 1990; Pearson et al., 1999; Purdy, 1992, 2002; Purdy et al., 1994; Purdy & Koch, 2006; Yoshihata et al., 1998). Both gesture processing models include working memory as important part in the generation of language and gesture. This means, that even if language is unimpaired, gesture production may suffer if working memory is impaired. Studies by Barquero and Logie (1999) and Pearson et al. (1999), for example, found that especially the production of pantomime gestures was influenced by working memory. The way, working memory is incorporated in the gesture processing models, makes it serve as a buffer where spatial, propositional, and other information is gathered in order to adapt the language and gesture style to the situation (e.g., depending on the conversation partner and/or topic). The role of executive function on gesture production might invite some revisions to the gesture models. Both reviewed models incorporate memory systems, but do not refer to wider executive skills.

As expected, there was no link between motor skills and gesture production, suggesting that limb apraxia did not have an influence on the spontaneous production of gestures in terms of the overall number. Motor control is also incorporated in both gesture processing models. This suggests that if motor control is impaired, the production of gestures is impaired as well. Interestingly, this is not the case as limb apraxia does not have an influence on the production of co-speech gestures. This finding may be explained by the automaticity of the gesture process leading to unimpaired gesture production despite an impairment in motor planning. For example, pantomime and emblem gestures are less automatic than gesticulations, and hence more likely to be impacted by limb apraxia. Nevertheless, more research including a larger group of participants with a wider range of different participant skills may be able to find out more of the influence of limb apraxia on gesture production (see 7.3 for more details).

7.2.2 Clinical implications.

The findings of the current study also have implications for clinical practice. Most importantly, results revealed that all participants produced a number of gestures in their conversations, independent from impaired or neurologically healthy language. This shows that gesturing is a natural process and plays a vital part in human communication. Because of the importance of gesture production, it is questionable, whether gesturing should be inhibited during rehabilitation attempts, as is the case in constraint-induced therapy (e.g., Maher et al., 2006; Meinzer et al., 2005; Pulvermüller & Berthier, 2008; Pulvermüller et al., 2001).[44] If gesturing is restricted in this way, PWA may be forced to use an unnatural communicative behaviour and may be deprived of the facilitative function of gestures during WFD.

Gestures in spontaneous speech come in different forms and have a variety of functions. They may augment speech, add communicative value, help to overcome WFD, or even compensate for speech. It was interesting to find only a very small number of compensatory gestures produced by PWA in the current study. At least for some PWA, more productive use might have been made of this gesture function. One explanation for this low number of compensatory gestures may be due to the very few severely impaired participants. However, severity of the language impairment did not play a role in that finding. It may be that participants did not think to use gestures as a compensatory modality and instead tried to convey information verbally. This is supported by the low numbers of speech replacing gestures, such as emblems and pantomimes and the relationship between cognitive skills and the number of compensatory gestures revealed by the current study. This last finding is in line with previous research finding a link between executive functions and the ability to switch between modalities (e.g., Glosser & Goodglass, 1990; Purdy, 1992, 2002; Purdy et al., 1994; Purdy & Koch, 2006; Yoshihata et al., 1998). Alternatively, apraxic difficulties may have impeded on the strategic use of gesture. Previous studies have shown that limb apraxia did not have an influence on the production of spontaneous gestures (e.g., Borod et al., 1989; R. J. Duffy et al., 1984; Macauley & Handley, 2005; Pritchard et al., 2013; Rose & Douglas, 2003). Using gestures as a strategy to compensate for the language impairment may turn the unconscious process of gesturing into a conscious one. Nevertheless, this may be

[44] For a discussion of constraint-induced therapy versus multi-modality therapy in aphasia, see Rose (2013) and Rose, Attard, Mok, Lanyon, and Foster (2013).

exactly what the role of the SLT may be: Encouraging PWA to actively use gesture in therapy may help them to raise their awareness, improve their communication skills, train their ability to switch between modalities, and maybe even overcome motor planning impairments. Previous research studies have found gestures of PWA to be qualitatively different to those of NHP, to be vague, and therefore more difficult to interpret (e.g., Cocks et al., 2011; Cocks, Dipper, et al., 2013; Glosser et al., 1986; Mol et al., 2013). Often, this was linked to a semantic impairment. To successfully use gesture in communication, they have to be clear and informative in order for the conversation partner to understand them. By actively encouraging the PWA to use gestures during a conversation, it may be the role of the SLT as well, to shape the gestures.

The findings that conversation parameters, such as conversation topic and conversation partners, elicited different numbers and types of gestures suggests that they need to be taken into consideration when assessing gesture use in aphasia. To get a full picture of a participant’s ability to use gesture in spontaneous speech, both the topic of the conversation and the familiarity of the conversation partner play an important role. Nevertheless, SLT usually have limited time to assess language skills. Therefore, taking the results of the current study into consideration, the least time consuming way to assess gesture production is to ask PWA to talk about a procedural topic, such as how to make scrambled eggs or how to wrap a parcel for a present, ideally combined with an unfamiliar conversation partner. In both situations, participants in the current study produced most gestures overall. Additionally, procedural conversation topics elicited more semantically rich gestures. These gestures are presumably very important for PWA to facilitate, supplement and/or replace speech.

7.3 Limitations and further research

Despite its novel findings, the current study had limitations. Although being a moderately-sized study in the context of aphasia studies, the current study only included 20 PWA and 21 NHP. Additionally, only three participants with severe aphasia took part and most PWA had good semantic skills (both verbal and non-verbal). Therefore, in order to find out more about the relationship between aphasia and gesture production, a larger-scale study including a larger variety of aphasia severity and language domain impairments is necessary.

Adaptations to the design could further illuminate why the conversation partner affected gesture production, particularly because it is possible that aspects of their behaviour had an influence, an aspect that was not investigated. Observations suggest that even though an effect of conversation partner familiarity on gesture production was found, there was huge variation in behaviour of the conversation partners. For example, while some conversation partners remained passive and were mainly listening to what the participant was saying, others engaged more with the conversation and sometimes even helped to structure the narrative, especially in procedural conversation topics. Similar observations were made during WFD: While some CP tried to help immediately either by saying the attempted word or asking specific questions for the participant to get the word him/herself, others gave the participant more time, sometimes even ignoring the WFD. These differences in the behaviour are not surprising given the large number of conversation partners taking part in the current study. It is possible that such differences were influenced by conversation partner familiarity, with knock on effects for gesture. Therefore, it would be interesting to find out more about the behaviour of the conversation partner with respect to the performance of the participant. Areas of interest may include, for example, what the CP did during a WFD. Did they offer their help? Did they maybe even stimulate repair events? But also, did they pay attention to the gestures, for example, when the PWA used them to compensate for speech? Answers to these and other questions may shed light on how PWA react to the gestures of the CP and the general role of the CP in conversations.

PWA produced a significant proportion of communicative gestures (i.e., gestures in unresolved WFD). There are two explanations for these gestures: Either PWA attempted lexical retrieval which failed or they actively communicated content to the conversation partner and asked for their help. This study, however, did not investigate the degree to which gestures communicated information to the conversation partner. This needs to be investigated further, for example, by categorising gestures according to their contained information. Alternatively, the degree to which the gesture is communicative could be established, for example, by coding whether the CP gets the intended meaning. There may be instances when the CP will not get the meaning of the intended message. This way, one could validate that these type of gestures (i.e., communicative gestures during unresolved WFD) carry information and are indeed communicative. This finding would underscore the importance of gesture production and their relevance for clinical context. Of further interest would be, whether conversation partner training to pay more attention to the gestures of the PWA would lead to a decrease in gestures that were not picked up by the conversation partner. Key points for this training could include (1) how to support the participant in conversation, (2) how to help during WFD, or (3) how to help structuring the conversation. That way, the examiner could make sure that all participants had similar support during conversation despite having different conversation partners. The gesture production in conversations with trained conversation partners could be compared to conversations with untrained conversation partners. It is hypothesised, that due to their training and attentiveness to gestures, there would be more communicative gestures produced by the participants in the conversations with the trained conversation partners. Of course, one may wonder about the necessity for such training if the interest is the conversational behaviour in spontaneous speech. If conversation partners were given too many rules of how to behave, the conversation itself might not be considered naturally and spontaneous. Alternatively, a study with the same conversation partner for all participants could be conducted. This would reduce the individual variation in the behaviour of the conversation partner. Nevertheless, the difference between conversation partners, for example, in terms of their familiarity to the participant could not be investigated.

Several important issues relate to the role of gestures produced during WFD. In the current study, semantically rich gestures that occurred during a resolved WFD were coded as facilitative. Nevertheless, the relationship between the gesture and the lexical affiliate was not investigated, neither their timing (i.e., whether the gesture preceded the word or not) nor their content (i.e., whether they conveyed the same concept). This was the main concept investigated in the studies by Hadar and colleagues (e.g., Hadar, Burstein, et al., 1998; Hadar, Wenkert-Olenik, et al., 1998; Hadar & Yadlin-Gedassy, 1994). Knowing more about these relationships in impaired and neurologically healthy language would shed more light onto the facilitative feature of gesture production during WFD. Alternatively, the role of gesture production during lexical retrieval may be investigated by means of a gesture cueing paradigm (e.g., Altmann et al., 2014; Boo & Rose, 2011; Enright, 2015). This way, gesture production during lexical retrieval could be controlled. However, a major disadvantage of such a paradigm is that it cannot be applied to spontaneous speech. It would therefore not help to find out more about the role of gesture production in WFD in spontaneous speech production.

The length and type of the WFD is another issue that was not investigated in detail in the current study. The criteria used to define a WFD did not distinguish between failures in lexical retrieval (which are prominent in aphasia) and the disfluencies more likely to occur in neurologically healthy speech. Observations indeed suggested a different type of WFD between PWA and NHP, as those of NHP were much shorter and could mostly be resolved in an instant. Consequently, NHP produced a similar number of WFD as PWA. One way to correct for this, may be to apply finer criteria for categorising different types of WFD or disfluencies respectively, such as pause lengths, employment of filler word, circumlocution, or the length of the delay.

Another limitation in this study is the method of comparing PWA and NHP in terms of their gesture production. A common way is to count the number of gestures and set them in relation to the length of the speech sample. Alternatively, the number of gestures could also be set in relation to the number of words produced by the participants. Both methods lead to similar results (e.g., Carlomagno & Cristilli, 2006; Cocks, Dipper, et al., 2013; Kong et al., 2015; Pritchard et al., 2013; Sekine et al., 2013). Differences were revealed though when comparing participants with fluent and non-fluent speech as it was the case in the current study. For a finer analysis it would have been interesting to compare both methods and to find out whether they interacted with different conversation parameters, such as conversation partner and conversation topic.

For gesture classification, an 'other' category was included for gestures that could not be otherwise assigned. These 'other' gestures mainly occurred in PWA, suggesting that aphasia did have an effect on the classifiability of gestures. Nevertheless, this group of gestures contained different types of unclassifiable gestures: Some were unclear, that is vague and some were incomplete. In order to find out more about the quality of gestures in aphasia, more research is needed with the focus on incomplete and abandoned gestures. It may be that these incomplete gestures occurred alongside more profound instances of WFD. Therefore, it would be interesting to see if they occur during problematic derailments of the conversation. Consequently, gesture therapy may be able to help PWA reducing their number of unclassifiable gestures.

The current study used a variety of language, cognition, and motor assessments to find out more about the links between different impairments and the production of gestures. Results showed several factors that were related to gesture production (i.e., speech fluency, lexical production skills, cognition). Nevertheless, conducting different analyses, such as regression analyses could be helpful in teasing apart different factors influence on gesture production. Because of the small sample size, this was not possible to conduct in the current study. Teasing apart the different influences on gesture production may also shed light onto the direct and indirect influences in gesture processing. Therefore, a larger-scale studies with a larger range of aphasia severity, semantic skills, cognition and limb apraxia is needed to highlight the important 'domain' that drives gesture.

Finally, a mixed methods design including both quantitative and qualitative data could provide further insights on the processes involved in gesture use in conversation. In addition to investigating the quantitative relationship between the number of resolved WFD and the overall number of semantically rich gestures in aphasia, transcripts of these conversations could highlight the importance of semantically rich gestures for successful lexical retrieval. They could, furthermore, provide examples of how PWA implement these semantically rich gestures to resolve WFD. For example, the timing of gestures in relation to speech could be explored and the semantic information expressed in the gesture. In this way, it could be determined whether the target of the WFD matched the content of the semantically rich gesture produced during the WFD. If this was the case, it adds weight to the suggestion that the gesture helped to solve the WFD. Qualitative analyses might also be informative about whether or not the conversation partner responds to gestures. Although this was not analysed in the current study, CP responded to gestures in different ways. Further analyses of their responses might illuminate how a collaborative resolution of WFD could be stimulated.

7.4 Summary

This study was set out to explore the production of spontaneous gestures in conversations by PWA and NHP. This was important in order to find out more about the spontaneous production of gestures in aphasia and the influence of conversation parameters, such as conversation topic and conversation partner, on gestures. Results revealed a number of interesting findings:

(1) PWA and NHP used many gestures spontaneously in conversation.
(2) All participants produced significantly more semantically rich than semantically empty gestures to facilitate, supplement, and/or replace speech.
(3) Gesture production was influenced by both conversation topic and conversation partner.
(4) For all participants, there was a significant relationship between the production of gestures during WFD and the resolution of those.
(5) PWA and NHP used gestures with different functions: While both groups used a high proportion of facilitative gestures which helped them resolve WFD, the next largest category was augmentative gestures (those produced alongside fluent speech) for NHP and communicative gestures (those produced during unsuccessful word-finding) for PWA.
(6) Fluency of speech, lexical production skills skills, and cognition all had an influence on the number of gestures produced in aphasia, whereas semantic skills did not.

Almost all of these findings fitted into the evidence base like this. All participants produced gestures spontaneously during conversation, independent from impaired or neurologically healthy language. It was surprising though to find a similar number of gestures in PWA and NHP. Based on previous studies it was hypothesised that PWA would produce more gestures than NHP.

The fact that the gesturing of all participants was affected by conversation topic and conversation partner is in line with language analyses. All participants produced significantly more gestures in procedural conversations, especially semantically rich gestures, than in narrative conversations. Similarly, all participants produced significantly more gestures in conversations with an unfamiliar conversation partner than with a familiar conversation partner.

Surprisingly, NHP experienced as many WFD as PWA, which is only partly in line with the existing literature. There are several explanations for this findings. Nevertheless, the significant link between the gestures during WFD and their resolution indicated that participants were more likely to gesture in a resolved WFD. Nevertheless, the role of gesture in facilitating lexical retrieval is difficult to interpret.

Furthermore, this study showed that both PWA and NHP used semantically rich gestures in different contexts and ascribed them different functions. The distribution of the different functions differed between PWA and NHP. While NHP produced a similar proportion of semantically rich gestures in resolved WFD (i.e., facilitative) and alongside fluent speech, PWA produced many facilitative and communicative gestures (i.e., gestures in unresolved WFD) but not as many augmentative gestures. PWA produced only a small number of compensatory gestures.
As expected, there was no relationship between gesture production and the severity of the aphasia as well as the limb apraxia. Surprisingly, there was no influence of semantic skills (both verbal and non-verbal) on the production of semantically rich gestures either. Instead, fluency of speech, lexical production and cognition showed significant relationships with the overall number of gestures produced. The latter two may have been a better proxy to assess semantic skills.

These findings extend the understanding of spontaneous gesture production in aphasic and neurologically healthy speech in different ways. For one, it sheds light on gesture processing and the fact that gestures can take different functions within conversation. The influence of conversational parameters highlights the complexity of the two reviewed gesture processing models. It remains unclear though, whether pragmatics influences gesture in a direct or indirect (through language) way.

Additionally, the significantly related participant factors to gesture production in aphasia extend the understanding of relevant skills needed to successfully employ gestures in conversation. Next to language skills, such as speech fluency and lexical retrieval, cognitive skills affected gesture production as well. Furthermore, cognition was linked to the number of resolved WFD that included gesture. This finding suggests that participants with good cognitive skills could employ gestures as a modality to resolve WFD.

These findings are important for the understanding of gesture production in aphasia as they highlight the importance of using gestures spontaneously to communicate. This is relevant for aphasia therapy as the SLT may have to encourage PWA to actively use gesture alongside speech. This may improve their communication skills by raising their awareness and train them to actively switch between gesture and speech.

“At the origin language was a unity of gesture and speech. If for some reason it is suppressed the inner gesture, imagery in actional form, remains and leaks out through some other part of the body.”

(McNeill, 2014, p. 70)

Appendices

Appendix A: Synonym judgement tasks

To create the synonym judgement tasks, 110 verbs and 100 adjectives were selected as stimuli for an online norming study. All stimuli were distributed alphabetically to five lists. Each list consisted of 22 verbs and 20 adjectives (see Table 0.1 and Table 0.2):

Table 0.1. ***Stimuli for verb norming study.***

List 1	List 2	List 3	List 4	List 5
accepting	appearing	asking	baking	barking
becoming	beginning	bending	bleeding	blushing
borrowing	bouncing	bringing	burning	camping
carrying	charging	cheating	climbing	coming
complaining	cooking	covering	crossing	cutting
describing	developing	digging	drawing	drilling
dripping	dropping	enjoying	explaining	feeling
fetching	fishing	flying	forgetting	giving
glowing	growing	guessing	helping	holding
hurrying	imagining	inventing	ironing	jumping
kissing	knitting	knowing	laughing	learning
leaving	licking	marching	meaning	nodding
opening	ordering	paying	peeling	placing
planting	pointing	pouring	pulling	raining
reaching	reading	remembering	ringing	rocking
sailing	searching	sending	shaving	showing
singing	sitting	skiing	sleeping	smiling
sneezing	sounding	speaking	stirring	stroking
suggesting	swinging	taking	talking	tasting
telling	touching	travelling	typing	using
visiting	waiting	washing	watering	wearing
weaving	whispering	working	writing	yelling

Table 0.2. ***Stimuli for adjective norming study.***

List 1	List 2	List 3	List 4	List 5
afraid	ambitious	ancient	annual	anxious
beautiful	big	bitter	blaring	brief
broad	cold	comfortable	confused	considerable
cruel	cute	dangerous	delicious	determined
dull	early	empty	fair	fast
fearless	few	filthy	flat	frank
fresh	frustrated	generous	great	handsome
happy	hard	heavy	hollow	horrible
hot	huge	hurt	icy	ill
jealous	kind	large	late	loose
loud	many	miniature	modern	multiple
narrow	nervous	old	perfect	pleasant
proud	quiet	rapid	round	scattered
sharp	shrill	silent	silly	skinny
slow	smooth	snobbish	soft	spicy
squeaking	steep	sticky	substantial	successful
sweet	talented	tall	tasteless	tasty
tense	thin	tiny	tired	uneven
unwell	upset	warm	wet	wrong
wide	wild	wonderful	worried	young

The stimuli were entered into SoSci Survey (Leiner, 2013), a German software package for conducting online surveys. Native speakers of British English were invited via email and social networks (e.g., Facebook and Twitter) to take part in an online norming study. Once they clicked on the link to the questionnaire, SoSci Survey chose the list of stimuli randomly. It was the responsibility of the examiner to make sure that every list got a similar amount of responses by temporarily disabling one or two lists.

Over a period of eight weeks in spring 2013, the online survey was accessed 146 times and 77 participants (72 female, 5 male) completed the norming study. On average, participants were 33.19 years old (range = 20-65, *SD* = 9.497). Sixty-seven participants had completed tertiary education, eight participants had reached and finished secondary education, and three participants had indicated their education with *other*. Lists 1, 4 and 5 were completed by 15 participants, lists 2 and 3 by 16 participants. Demographic data of all participants, including gender, age, level of education[45], and list on SoSci are given in Table 0.3 below:

[45] (1) no formal education, (2) GCSE/O levels, (3) A levels/apprenticeship, (4) Bachelor's degree, (5) Diploma/College degree, (6) Master's degree, (7) Doctoral degree, and (8) Other

Table 0.3. ***Demographics of participants of norming study.***

ID	Gender	Age	Level of education	List on SoSci
1N	Female	32	6	1
2N	Female	50	4	1
3N	Male	33	6	1
4N	Male	41	6	1
5N	Female	27	5	1
6N	Female	27	5	1
7N	Female	25	4	1
8N	Female	22	4	1
9N	Female	21	3	1
10N	Female	43	7	1
11N	Female	26	4	1
12N	Female	31	4	1
13N	Female	24	4	1
14N	Female	30	7	1
15N	Female	42	4	1
16N	Female	22	4	2
17N	Female	24	6	2
18N	Female	26	3	2
19N	Female	33	4	2
20N	Female	43	7	2
21N	Female	48	4	2
22N	Female	52	7	2
23N	Female	18	3	2
24N	Female	28	8	2
25N	Female	26	6	2
26N	Female	33	6	2
27N	Female	28	2	2
28N	Female	29	6	2
29N	Female	36	4	2
30N	Female	34	4	2
31N	Female	42	6	2
32N	Female	30	4	3
33N	Female	27	4	3
34N	Female	21	4	3
35N	Female	38	5	3
36N	Female	28	4	3
34N	Female	31	4	3
38N	Female	35	4	3
39N	Female	25	4	3
40N	Female	39	7	3
41N	Female	21	8	3
42N	Female	33	6	3
43N	Female	31	4	3
44N	Female	41	8	3

Table 0.3. *Demographics of participants of norming study* (*continued*).

ID	Gender	Age	Level of education	List on SoSci
45N	Female	26	2	3
46N	Male	42	6	3
47N	Female	26	5	3
48N	Female	38	6	4
49N	Female	47	4	4
50N	Male	53	6	4
51N	Female	23	5	4
52N	Female	25	4	4
53N	Female	33	6	4
54N	Female	20	3	4
55N	Female	31	7	4
56N	Female	31	7	4
57N	Female	46	4	4
58N	Female	34	6	4
59N	Male	33	6	4
60N	Female	25	6	4
61N	Female	44	6	4
62N	Female	41	6	4
63N	Female	24	3	5
64N	Female	44	4	5
65N	Female	28	3	5
66N	Female	25	5	5
67N	Female	32	6	5
68N	Female	30	6	5
69N	Female	28	5	5
70N	Female	26	5	5
71N	Female	55	7	5
72N	Female	47	6	5
73N	Female	29	5	5
74N	Female	37	5	5
75N	Female	27	4	5
76N	Female	65	4	5
77N	Female	45	4	5

Participants were presented with 12 verbs on the first page and 10 adjectives on the second page of the survey which varied depending on the list that was chosen (see Table 0.1 and Table 0.2). They were asked to come up with up to 10 synonyms per stimuli. Prior to this, participants were given an example (see Figure 0.1):

thinking

Please write down as many synonyms as you can think of for this word:

- *cogitating*
- *mulling*
- *musing*
- *pondering*
- *…*

Figure 0.1. *Example of the norming study.*

After eight weeks, the survey was deactivated and the gathered data were downloaded and analysed. The first step then was to identify the words that had been mentioned most often for each stimulus. Depending on the frequency of the word, this was between one and 16 times.

Based on the auditory synonym judgement task (PALPA #49; Kay et al., 1992), synonym pairs were matched for imageability. Therefore, imageability values were taken from Cortese and Fugett (2004) and Schock et al. (2012) for the verbs and from the MRC database (Wilson, 1987) and Bird et al. (2001) for the adjectives in the second step of the analysis. Synonym pairs were matched on imageability values (high and low imageability). According to the authors of the databases, verbs were considered as being highly imageable with a rating between 4.5 and 7 for both verbs and adjectives (Bird et al., 2001; Cortese & Fugett, 2004; Schock et al., 2012; Wilson, 1987) for verbs and 4.5 and 7. Only stimuli and synonyms that matched on imageability were entered into the synonym judgement tasks.

Each synonym judgement task consists word pairs in four different conditions:

(1) High-imageable synonym pairs
(2) Low-imageable synonym pairs
(3) High-imageable non-synonym pairs
(4) Low-imageable non-synonym pairs

Every word appears twice: one time with a synonym and one time with the synonym of another word. For the non-synonym pairs, synonyms were randomised across the stimuli.

Depending on the agreement of the participants of the norming study and the available imageability ratings, 15 word pairs per condition were identified for the verbs and 14 word pairs for the adjectives. The words for the first two conditions (high-imageable and low-imageable synonym pairs) for both verbs and adjectives are given in Table 0.4 and Table 0.5 below:

Table 0.4. *Verb synonym pairs and imageability ratings according to Cortese and Fugett (2004) and Schock et al. (2012).*

High-imageable				Low-imageable			
Stimulus	Rating	Synonym	Rating	Stimulus	Rating	Synonym	Rating
baking	5.1	cooking	5.4	asking	2.7	requesting	2.7
bouncing	4.7	jumping	4.8	beginning	2.2	starting	2.9
cutting	5.1	slicing	5.3	complaining	4	moaning	3.9
digging	5.4	shovelling	6.9	dropping	4.3	falling	4.8[46]
drawing	5	sketching	5.4	enjoying	3.6	liking	2.7
dripping	4.9	leaking	4.9	fetching	4	getting	1.7
glowing	4.7	shining	4.7	giving	2.8	donating	4.4
laughing	4.9	giggling	5.6	helping	2.8	assisting	3.6
marching	5.1	walking	5.2	holding	4	grasping	4.1
raining	6.3	pouring	4.9	hurrying	4.1	rushing	3.9
ringing	6.2	phoning	6.6	inventing	3.7	creating	3.8
sailing	6	boating	6.7	leaving	3.9	going	2.2
sleeping	5.5	snoozing	4.8	placing	3.7	putting	2.2
smiling	6.5	grinning	5.6	searching	3.3	looking	3.9
washing	5.1	cleaning	4.5	yelling	4.2	shouting	3.8

There was no significant difference in the imageability scores between verb stimuli (M = 4.46, SD = 1.11) and verb synonyms (M = 4.40, SD = 1.33), t (29) = 0.39, p = .700.

[46] High-imageable according to cut-offs but matched on group.

Table 0.5. ***Adjective synonym pairs and imageability ratings according to Bird et al. (2001) and Wilson (1987).***

High-imageable				Low-imageable			
Stimulus	Rating	Synonym	Rating	Stimulus	Rating	Synonym	Rating
ancient	4.51	old	4.78	brief	2.94	short	4.31
beautiful	5.32	pretty	5.20	cruel	4.22	mean	4.19
big	4.63	large	4.49	fair	4.39	just	2.21
bitter	4.57	sour	4.95	fast	4.11	quick	3.63
broad	4.63	wide	4.55	frank	4.19	honest	3.66
cold	4.83	chilly	4.60	generous	3.48	giving	4.06
hollow	4.78	empty	4.79	great	3.90	brilliant	4.82
ill	4.72	sick	4.56	jealous	4.46	envious	3.61
narrow	4.91	thin	5.02	late	3.87	tardy	2.77
nervous	4.65	anxious	3.76	loud	4.48	noisy	2.15
round	5.12	circular	5.43	modern	3.68	new	4.18
spicy	4.94	hot	5.51	pleasant	3.90	nice	3.75
tall	5.14	high	4.63	silly	3.46	stupid	3.81
tense	4.22	tight	4.95	upset	4.16	sad	4.19

There was no significant difference in the imageability scores between adjective stimuli either (M = 436.46, SD = 56.08) and adjective synonyms (M = 423.43, SD = 84.98), t (27) = 0.846, p = 0.405.

Control data were collected from 89 NHP, FCP, and UFCP who took part in this study (71 female, 18 male). All participants spoke English fluently[47] and were on average 47.48 years old (range = 16-89, SD = 19.320). Seventy-five controls had finished tertiary education and 14 controls had reached and finished secondary education. More details on participants can be found in Table 5.2, Table 0.9 and Table 0.10. Table 0.6 summarises maximum score, mean (M), range and standard deviation (SD) achieved on the synonym judgement tasks:

Table 0.6. ***Standardisation scores for synonym judgement tasks.***

Test	Maximum score	*M*	Range	*SD*
Synonym judgement tasks for verbs	60	58.74	51 – 60	1.63
Synonym judgement tasks for adjectives	56	54.60	50 – 56	1.32

Note. M = mean; *SD* = standard deviation.

[47] For eight participants, English was not their native language. Nevertheless, they did not score significantly different from the native English speakers, U = 310.000, z = -0.212, p > 0.05 (verbs) and U = 281.500, z = -0.633, p > 0.05 (adjectives). Therefore, their data was included into the standardisation analysis.

The score forms of the two synonym judgement tasks are displayed in Table 0.7 and Table 0.8 below:

Table 0.7. ***Synonym judgement task verbs.***

No.	Word pair		Type	Y/N	No.	Word pair		Type	Y/N
1	beginning	starting	LI	Y	31	dropping	looking	LI	N
2	sleeping	snoozing	HI	Y	32	asking	moaning	LI	N
3	smiling	slicing	HI	N	33	drawing	grinning	HI	N
4	marching	phoning	HI	N	34	sailing	boating	HI	Y
5	bouncing	jumping	HI	Y	35	baking	sketching	HI	N
6	helping	assisting	LI	Y	36	smiling	grinning	HI	Y
7	yelling	shouting	LI	Y	37	dropping	falling	LI	Y
8	holding	starting	LI	N	38	digging	pouring	HI	N
9	glowing	shining	HI	Y	39	drawing	sketching	HI	Y
10	giving	requesting	LI	N	40	dripping	leaking	HI	Y
11	complaining	moaning	LI	Y	41	hurrying	rushing	LI	Y
12	enjoying	assisting	LI	N	42	baking	cooking	HI	Y
13	ringing	phoning	HI	Y	43	complaining	grasping	LI	N
14	sailing	leaking	HI	N	44	laughing	walking	HI	N
15	cutting	slicing	HI	Y	45	placing	putting	LI	Y
16	fetching	rushing	LI	N	46	washing	cleaning	HI	Y
17	raining	jumping	HI	N	47	sleeping	shovelling	HI	N
18	leaving	going	LI	Y	48	cutting	cleaning	HI	N
19	giving	donating	LI	Y	49	searching	looking	LI	Y
20	bouncing	snoozing	HI	N	50	inventing	falling	LI	N
21	washing	shining	HI	N	51	marching	walking	HI	Y
22	helping	getting	LI	N	52	ringing	cooking	HI	N
23	placing	going	LI	N	53	yelling	donating	LI	N
24	leaving	liking	LI	N	54	fetching	getting	LI	Y
25	searching	creating	LI	N	55	hurrying	putting	LI	N
26	laughing	giggling	HI	Y	56	digging	shovelling	HI	Y
27	enjoying	liking	LI	Y	57	inventing	creating	LI	Y
28	holding	grasping	LI	Y	58	glowing	giggling	HI	N
29	asking	requesting	LI	Y	59	dripping	boating	HI	N
30	raining	pouring	HI	Y	60	beginning	shouting	LI	N

Note. LI = low-imageable; HI = high-imageable; Y = yes; N = no.

Table 0.8. ***Synonym judgement task adjectives.***

No.	Word pair		Type	Y/N
1	frank	mean	LI	N
2	broad	wide	HI	Y
3	generous	giving	LI	Y
4	jealous	envious	LI	Y
5	cold	sour	HI	N
6	cruel	mean	LI	Y
7	narrow	hot	HI	N
8	beautiful	old	HI	N
9	pleasant	nice	LI	Y
10	frank	honest	LI	Y
11	fair	just	LI	Y
12	tense	tight	HI	Y
13	fast	new	LI	N
14	round	thin	HI	N
15	fair	brilliant	LI	N
16	cruel	just	LI	N
17	modern	tardy	LI	N
18	bitter	pretty	HI	N
19	nervous	empty	HI	N
20	great	brilliant	LI	Y
21	brief	short	LI	Y
22	ill	sick	HI	Y
23	loud	noisy	HI	Y
24	modern	new	LI	Y
25	generous	envious	LI	N
26	tall	sick	HI	N
27	nervous	anxious	LI	Y
28	tense	large	HI	N
29	tall	high	HI	Y
30	round	circular	HI	Y
31	ancient	old	HI	Y
32	fast	quick	LI	Y
33	late	noisy	LI	N
34	jealous	sad	LI	N
35	upset	short	LI	N
36	cold	chilly	HI	Y
37	beautiful	pretty	HI	Y
38	pleasant	stupid	LI	N
39	loud	quick	LI	N
40	ancient	chilly	HI	N
41	spicy	tight	HI	N
42	big	anxious	HI	N
43	silly	giving	LI	N
44	great	nice	LI	N
45	broad	high	HI	N
46	spicy	hot	HI	Y
47	hollow	empty	HI	Y
48	upset	sad	LI	Y
49	narrow	thin	HI	Y
50	big	large	HI	Y
51	brief	honest	LI	N
52	late	tardy	LI	Y
53	ill	wide	HI	N
54	silly	stupid	LI	Y
55	bitter	sour	HI	Y
56	hollow	circular	HI	N

Note. LI = low-imageable; HI = high-imageable; Y = yes; N = no.

Appendix B: Demographics of conversation partners

Table 0.9. ***Demographics of FCP.***

ID	Gender	Age	Level of education	Profession	PWA/NHP
1F	female	54	4	life coach, masseuse, housing officer	1A
2F	female	67	2	estate agent	2A
3F	female	32	7	lecturer, researcher	3A
4F	female	71	4	secretary, accountant	4A
5F	female	73	2	dressmaker, copy typist, administrator	5A
6F	female	32	4	traveling advisor	6A
7F	male	69	6	lecturer, artist	7A
8F			*no consent for data collection*		8A
9F	female	58	5	psychological counsellor	9A
10F	male	58	5	businessman	10A
11F	female	38	5	administrator	11A
12F	male	50	3	composer	12A
13F	male	70	7	geophysicist	13A
14F	female	16	2	pupil	14A
15F	female	25	4	PG SLT student	15A
16F	female	43	6	social worker	16A
17F	male	51	4	construction site manager	17A
18F	female	54	5	social media manager	18A
19F	female	47	5	teacher	19A
20F	female	33	6	researcher, SLT, PhD student	20A
21F	female	69	4	examination invigilator	1C
22F	female	56	5	telephonist, deputy manager	2C
23F	female	71	6	architecture, teacher, lecturer	3C
24F	female	63	3	air hostess	4C
25F	female	69	4	nursery nurse, social worker	5C
26F	male	66	5	potter, teacher, lecturer, tutor	6C
27F	female	60	4	social worker	7C
28F	female	64	5	personal assistant	8C
29F	female	83	2	politician	9C
30F	female	85	2	window dresser, retailer, hair dresser, stylist	10C
31F	female	70	3	clerk	11C
32F	male	31	4	software engineer	12C
33F	female	70	6	teacher trainer	13C
34F	female	38	5	teacher, investigator	14C
35F	female	33	6	researcher, SLT, PhD student	15C
36F	female	33	4	physiotherapist	16C
37F	male	35	4	music publisher	17C
38F	female	32	6	researcher, SLT	18C
39F	male	46	6	web developer	19C
40F	female	62	2	banker	20C
41F	female	56	7	lecturer, researcher, SLT	21C

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; FCP = familiar conversation partner/s; SLT = speech and language therapist; PG SLT = post-graduate SLT student.

Table 0.10. ***Demographics of UFCP.***

ID	Gender	Age	Level of education	Profession	PWA/NHP
1UF	female	36	6	chartered surveyor, PG SLT student	1A
2UF	female	41	7	researcher, lecturer, PG SLT student	2A
3UF	female	23	4	PG SLT student	3A
4UF	female	25	4	PG SLT student	4A
5UF	female	32	7	lecturer, researcher	5A
6UF	female	28	4	teaching assistant, PG SLT student	6A
7UF	female	33	4	PG SLT student	7A
8UF	female	42	3	artist, teaching assistant, UG SLT student	8A
9UF	female	24	4	learning support assistant, PG SLT student	9A
10UF	female	20	3	UG SLT student	10A
11UF	female	26	4	PG SLT student	11A
12UF	female	23	4	PG SLT student	12A
13UF	female	39	6	researcher, PhD student	13A
14UF	female	41	7	researcher, lecturer, PG SLT student	14A
15UF	female	27	4	teaching assistant	15A
16UF	female	33	6	researcher, SLT, PhD student	16A
17UF	female	33	6	researcher, SLT, PhD student	17A
18UF	female	26	4	teaching assistant, PG SLT student	18A
19UF	female	28	5	research assistant	19A
20UF	female	35	6	researcher, SLT, PhD student	20A
21UF	female	33	5	teacher, PG SLT student	1C
22UF	female	25	4	mental health professional, PG SLT student	2C
23UF	female	29	6	researcher, psychomotor therapist, PhD student	3C
24UF	female	35	6	researcher, SLT, PhD student	4C
25UF	female	33	5	teacher, PG SLT student	5C
26UF	female	23	4	PG SLT student	6C
27UF	female	31	6	researcher, SLT, PhD student	7C
28UF	female	42	4	architect, PG SLT student	8C
29UF	female	26	6	researcher, PhD student	9C
30UF	female	42	3	artist, teaching assistant, UG SLT student	10C
31UF	female	31	6	researcher, SLT, PhD student	11C
32UF	female	35	6	researcher, SLT, PhD student	12C
33UF	female	49	6	researcher, SLT, PhD student	13C
34UF	female	25	4	teaching assistant, PG SLT student	14C
35UF	female	23	4	PG SLT student	15C
36UF	female	25	4	teaching assistant, PG SLT student	16C
37UF	female	23	4	PG SLT student	17C
38UF	female	29	6	researcher, psychomotor therapist, PhD student	18C
39UF	female	33	6	researcher, SLT, PhD student	19C
40UF	female	32	6	researcher, SLT	20C

Table 0.10. ***Demographics of UFCP (continued).***

ID	Gender	Age	Level of education	Profession	PWA/NHP
41UF	female	29	6	researcher, psychomotor therapist, PhD student	21C

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; UFCP = unfamiliar conversation partner/s; SLT = speech and language therapist; PG SLT = post-graduate SLT student; UG SLT = undergraduate SLT student.

Table 0.11. ***List of FCP and UFCP who took part in more than one conversation session.***

Conversation partner	Participants and familiarity of conversation partner
3F/5UF	3A (FCP), 5A (UFCP)
20F/35F/39UF	20A (FCP), 15C (FCP), 19C (UFCP)
2UF/14UF	2A (UFCP), 14A (UFCP)
3UF/12UF	3A (UFCP), 12A (UFCP)
8UF/30UF	8A (UFCP), 10C (UFCP)
16UF/17UF	16A (UFCP), 17A (UFCP)
20UF/24UF/32UF	20A (UFCP), 4C (UFCP), 12C (UFCP)
21UF/25UF	1C (UFCP), 5C (UFCP)
23UF/38UF/41UF	3C (UFCP), 18C (UFCP), 21C (UFCP)
26UF/35UF/37UF	6C (UFCP), 15C (UFCP), 17C (UFCP)
27UF/31UF	7C (UFCP), 11C (UFCP)
34UF/36UF	14C (UFCP), 16C (UFCP)

Note. FCP = familiar conversation partner/s; UFCP = unfamiliar conversation partner/s.

Appendix C: Detailed results of PWA

Table 0.12. ***WAB-R results of PWA (max. score).***

ID	AQ	Syndrome	Severity	Spontaneous Speech (20)	Auditory verbal comprehension (10)	Repetition (10)	Naming & Word Finding (10)
1A	68.2	Conduction aphasia	moderate	14	8.9	5.6	5.8
2A	86.6	Anomic aphasia	mild	18	9.3	9	7
3A	62.7	Broca's aphasia	moderate	13	5.95	6	6.4
4A	75.6	Conduction aphasia	moderate	14	8.9	6.4	8.5
5A	76.6	Transcortical Motor aphasia	mild	13	9	8.2	8.1
6A	82.9	Anomic aphasia	mild	18	9.15	7.2	7.1
7A	90.8	Anomic aphasia	mild	18	9.9	8.4	9.1
8A	66.9	Conduction aphasia	moderate	14	8.65	5	5.8
9A	68.8	Conduction aphasia	moderate	14	7	6	7.3
10A	84.2	Anomic aphasia	mild	15	9.4	9.2	8.5
11A	81.1	Anomic aphasia	mild	14	9.45	7.6	9.5
12A	76.6	Conduction aphasia	mild	14	8.7	6.4	9.2
13A	36.7	Broca's aphasia	severe	5	4.7	4.8	3.85
14A	37.2	Broca's aphasia	severe	7	5.85	2.5	3.25
15A	63	Broca's aphasia	moderate	12	7.3	6.4	5.8
16A	31.6	Broca's aphasia	severe	6	6.875	1.6	1.3
17A	77.2	Transcortical motor aphasia	mild	13	9.05	8.8	7.75
18A	64.1	Broca's aphasia	moderate	13	9.35	3.4	6.3
19A	53	Broca's aphasia	moderate	11	6.55	4.3	4.65
20A	77.8	Transcortical motor aphasia	mild	13	9.2	8.6	8.1

Note. PWA = participant/s with aphasia; WAB-R = Western Aphasia Battery – Revised; AQ = aphasia quotient.

Table 0.13. ***Lexical production skills of PWA (max. score).***

ID	OANB – Objects List A							OANB – Actions List A							Composite score in %
	Score (81)	%	Error analysis					Score (50)	%	Error analysis					
			HF (16)	MF (37)	LF (28)	HI (79)	LI (2)			HF (12)	MF (26)	LF (12)	HI (15)	LI (35)	
1A	74	91.4%	2	3	7	7	0	35	70.0%	3	15	4	5	17	80.70%
2A	65	80.3%	3	7	6	15	1	34	68.0%	2	9	6	3	14	74.15%
3A	44	54.3%	7	15	15	35	2	30	60.0%	3	13	6	5	17	57.15%
4A	77	95.1%	0	1	3	4	0	41	82.0%	3	5	1	3	6	88.55%
5A	61	75.3%	3	10	7	20	0	34	68.0%	3	8	5	4	12	71.65%
6A	64	79.0%	3	7	7	15	2	38	76.0%	3	8	2	2	11	77.50%
7A	72	88.9%	1	5	3	9	0	41	82.0%	0	6	3	0	9	85.45%
8A	34	42.0%	4	19	19	46	1	19	38.0%	5	18	8	8	23	40.00%
9A	68	83.9%	2	8	3	11	2	35	70.0%	4	9	2	1	14	76.95%
10A	74	91.4%	4	1	2	7	0	41	82.0%	0	6	3	2	7	86.70%
11A	69	85.2%	0	5	7	12	0	42	84.0%	1	6	1	2	6	84.60%
12A	77	95.1%	1	2	1	3	0	39	78.0%	3	8	0	2	9	86.55%
13A	35	43.2%	8	20	18	44	2	19	38.0%	5	9	5	5	14	40.60%
14A	35	43.2%	7	21	18	45	1	19	38.0%	6	17	8	8	23	40.60%
15A	41	50.6%	4	21	15	39	1	9	18.0%	9	22	10	10	31	34.30%
16A	10	12.3%	14	32	25	69	2	0	0.0%	12	26	12	15	35	6.15%
17A	59	72.8%	2	11	9	22	0	39	78.0%	1	8	2	2	9	75.40%
18A	69	85.2%	0	6	6	12	0	42	84.0%	2	5	1	2	6	84.60%
19A	38	46.9%	7	20	16	43	0	22	44.0%	7	13	8	3	15	45.45%
20A	78	96.3%	0	2	1	3	0	32	64.0%	5	8	4	4	14	80.15%

Note. PWA = participant/s with aphasia; OANB = Object and Action Naming Battery; HF = high-frequent; MF = medium-frequent; LF = low-frequent; HI = high-imageable; LI = low-imageable.

Table 0.14. *Verbal semantic skills (1) of PWA (max. score).*

ID	PALPA #47							VAST-verb comprehension							
	Score (40)	%	Error analysis					Score (40)	%	Error analysis					
			Close sem. (40)	Sem. & visual (20)	Distant sem. (40)	Visual (40)	Unrelated (40)			HF (17)	LF (23)	T (27)	I (13)	NR (11)	NNR (29)
1A	35	87.5%	3	2	0	0	0	37	92.5%	1	2	3	0	1	2
2A	34	85.0%	4	3	1	1	0	34	85.0%	0	6	5	1	1	5
3A	36	90.0%	2	1	1	0	0	33	82.5%	2	6	5	2	2	5
4A	39	97.5%	1	1	0	0	0	40	100.0%	0	0	0	0	0	0
5A	39	97.5%	1	0	0	0	0	31	77.5%	5	4	9	0	5	4
6A	40	100.0%	0	0	0	0	0	35	97.5%	1	4	4	1	2	3
7A	39	97.5%	0	0	0	0	0	37	92.5%	0	3	3	0	1	2
8A	39	97.5%	1	1	0	0	0	30	75.0%	5	5	5	5	6	4
9A	38	95.0%	1	0	0	0	0	37	92.5%	2	1	2	1	1	2
10A	40	100.0%	0	0	0	0	0	39	97.5%	0	1	1	0	0	1
11A	40	100.0%	0	0	0	0	0	39	97.5%	0	1	1	0	1	0
12A	39	97.5%	1	1	0	0	0	39	97.5%	0	1	1	0	1	0
13A	33	82.5%	6	3	0	0	1	28	70.0%	5	7	12	0	5	7
14A	33	82.5%	6	3	1	0	0	33	82.5%	2	5	5	2	4	3
15A	35	87.5%	4	3	0	0	0	21	52.5%	9	10	14	5	6	13
16A	35	87.5%	5	2	0	0	0	27	67.5%	7	6	10	3	5	8
17A	38	95.0%	1	1	0	0	0	36	90.0%	2	2	3	1	1	3
18A	37	92.5%	1	1	2	0	0	40	100.0%	0	0	0	0	0	0
19A	36	90.0%	2	1	0	2	0	35	87.5%	1	4	4	1	3	2

Table 0.14. ***Verbal semantic skills (1) of PWA (max. score)*** *(continued)*.

ID	PALPA #47							VAST-verb comprehension								
	Score (40)	%	Error analysis					Score (40)	%	Error analysis					
			Close sem. (40)	Sem. & visual (20)	Distant sem. (40)	Visual (40)	Unrelated (40)			HF (17)	LF (23)	T (27)	I (13)	NR (11)	NNR (29)
20A	37	92.5%	0	0	1	0	0	37	92.5%	0	3	2	1	1	2

Note. PWA = participant/s with aphasia; PALPA = Psycholinguistic Assessments of Language Processing in Aphasia; close sem. = close semantically related; sem. & visual = semantically and visually related; distant sem. = distant semantically related; visual = visually related; VAST = Verb And Sentence Test; HF = high-frequent; LF = low-frequent; T = transitive; I = intransitive; NR = name related; NNR = not name related.

Table 0.15. ***Verbal semantic skills (2) of PWA (max. score).***

ID	PALPA #49				Synonym judgement task verbs				Synonym judgement task adjectives				Composite score in %
	Score (60)	%	Error analysis		Score (60)	%	Error analysis		Score (56)	%	Error analysis		
			HI (30)	LI (30)			HI (30)	LI (30)			HI (28)	LI (28)	
1A	57	95.0%	1	2	52	86.7%	2	6	44	78.6%	6	7	87.68%
2A	59	98.3%	1	0	58	96.7%	2	0	54	96.4%	0	2	92.42%
3A	44	73.3%	3	13	52	86.7%	2	6	46	82.1%	3	7	82.92%
4A	58	96.7%	0	2	55	91.7%	2	3	54	96.4%	0	2	96.46%
5A	47	78.3%	5	8	44	73.3%	7	9	35	62.5%	8	13	77.82%
6A	49	81.7%	3	8	57	95.0%	1	2	53	94.6%	1	2	91.76%
7A	51	85.0%	5	4	53	88.3%	1	6	49	87.5%	2	5	90.16%
8A	58	96.7%	0	2	56	93.3%	1	3	53	94.6%	3	0	91.42%
9A	58	96.7%	0	2	54	90.0%	2	4	51	91.1%	0	5	93.06%
10A	54	90.0%	2	4	56	93.3%	1	3	52	92.9%	0	4	94.74%
11A	57	95.0%	2	1	59	98.3%	0	1	53	94.6%	0	3	97.08%
12A	57	95.0%	2	1	50	83.3%	2	8	51	91.1%	1	4	92.88%
13A	51	85.0%	3	6	47	78.3%	3	10	48	85.7%	3	5	80.30%
14A	35	58.3%	10	15	42	70.0%	11	7	39	69.6%	7	10	72.58%
15A	46	76.7%	5	9	39	65.0%	11	10	42	75.0%	4	10	71.34%
16A	40	66.7%	7	13	42	70.0%	9	9	39	69.6%	5	12	72.26%
17A	56	93.3%	1	3	49	81.7%	2	9	48	85.7%	1	7	89.14%
18A	57	95.0%	2	1	58	96.7%	1	1	54	96.4%	1	1	96.12%
19A	53	88.3%	4	4	44	73.3%	5	11	49	87.5%	4	3	85.32%
20A	53	88.3%	3	3	49	81.7%	6	5	49	87.5%	3	4	88.50%

Note. PWA = participant/s with aphasia; PALPA = Psycholinguistic Assessments of Language Processing; HI = high-imageable; LI = low-imageable.

Table 0.16. *Non-verbal semantic skills of PWA.*

ID	PPTT		KDT		Composite
	Score (52)	%	Score (52)	%	score in %
1A	49	94.2%	51	98.1%	96.15%
2A	48.5	93.3%	47	90.4%	91.85%
3A	47	90.4%	47	90.4%	90.40%
4A	51	98.1%	49	94.2%	96.15%
5A	50	96.2%	45	86.5%	91.35%
6A	46	88.5%	40.5	77.9%	83.20%
7A	46.5	89.4%	47	90.4%	89.90%
8A	45	86.5%	34	65.4%	75.95%
9A	49	94.2%	51	98.1%	96.15%
10A	49	94.2%	46	88.5%	91.35%
11A	52	100.0%	47	90.4%	95.20%
12A	52	100.0%	50	96.2%	98.10%
13A	42.5	81.7%	41.5	79.8%	80.75%
14A	39	75.0%	42	80.8%	77.90%
15A	42	80.8%	35	67.3%	74.05%
16A	48	92.3%	39	75.0%	83.65%
17A	48	92.3%	48	92.3%	92.30%
18A	50	96.2%	50	96.2%	96.20%
19A	49	94.2%	46.5	89.4%	91.80%
20A	49	94.2%	48	82.3%	88.25%

Note. PWA = Participant/s with aphasia; PPTT = Pyramids and Palm Trees Test; KDT = Kissing and Dancing Test.

Table 0.17. *CLQT – visuospatial skills of PWA (max. score).*

ID	Weighed score (105)	%	Severity	Symbol cancellation (12)	Trails (10)	Memory (6)	Mazes (8)	Design generation (13)
1A	93	88.6%	WNL*	12	10	5	8	5
2A	90	85.7%	WNL*	11	6	4	8	6
3A	96	91.4%	WNL	12	8	6	8	8
4A	68	64.8%	WNL*	12	5	4	6	0
5A	75	71.4%	WNL*	10	8	4	8	1
6A	70	66.7%	mild	12	9	3	4	4
7A	75	71.4%	mild	5	10	5	7	4
8A	43	41.4%	mild	1	10	2	4	1
9A	92	87.6%	WNL	12	10	5	8	4
10A	81	77.1%	mild	12	10	3	6	7
11A	97	92.4%	WNL	12	10	6	8	5
12A	99	94.3%	WNL	12	10	6	8	7
13A	52	49.5%	mild*	0	8	3	8	0
14A	58	55.2%	mild	0	5	6	7	7
15A	41	39.0%	mild	11	5	2	0	1
16A	77	73.3%	mild	12	6	4	7	4
17A	85	81.0%	WNL*	11	10	4	8	3
18A	97	92.4%	WNL	12	10	5	8	9
19A	90	85.7%	WNL	12	10	5	7	5
20A	98	93.3%	WNL	12	10	6	8	6

Note. PWA = participant/s with aphasia; CLQT = Cognitive Linguistic Quick Test; WNL = within normal limits; * = participants of the older group (see Table 5.5).

Table 0.18. ***ARAT results of PWA (max. score).***

ID	Score (52)	%	Grasp (18)	Grip (12)	Pinch (18)	Gross Movement (9)
1A	52	100%	18	12	18	9
2A	52	100%	18	12	18	9
3A	52	100%	18	12	18	9
4A	52	100%	18	12	18	9
5A	52	100%	18	12	18	9
6A	52	100%	18	12	18	9
7A	52	100%	18	12	18	9
8A	52	100%	18	12	18	9
9A	52	100%	18	12	18	9
10A	52	100%	18	12	18	9
11A	52	100%	18	12	18	9
12A	52	100%	18	12	18	9
13A	52	100%	18	12	18	9
14A	52	100%	18	12	18	9
15A	52	100%	18	12	18	9
16A	52	100%	18	12	18	9
17A	52	100%	18	12	18	9
18A	52	100%	18	12	18	9
19A	52	100%	18	12	18	9
20A	52	100%	18	12	18	9

Note. PWA = Participant/s with aphasia; ARAT = Action Research Arm Test.

Appendix D: Detailed results of NHP

Table 0.19. ***CLQT – visuospatial skills of NHP (max. score).***

ID	Weighed score (105)	%	Severity	Symbol cancellation (12)	Trails (10)	Memory (6)	Mazes (8)	Design generation (13)
1C	99	94.3%	WNL	11	10	5	8	13
2C	99	94.3%	WNL*	12	10	6	7	10
3C	80	76.2%	WNL*	11	8	6	4	6
4C	85	81.0%	WNL*	12	5	6	7	6
5C	99	94.3%	WNL*	12	10	5	8	11
6C	98	93.3%	WNL*	12	10	6	8	6
7C	102	97.1%	WNL*	12	100	6	8	10
8C	79	75.2%	WNL*	9	10	5	6	3
9C	85	81.0%	WNL*	10	10	6	5	6
10C	83	79.0%	WNL*	11	10	4	78	4
11C	96	91.4%	WNL*	12	10	6	8	4
12C	105	100%	WNL	12	10	6	8	13
13C	96	91.4%	WNL	11	10	6	8	6
14C	103	98.1%	WNL	12	10	6	8	11
15C	102	97.1%	WNL	12	10	6	8	10
16C	105	100%	WNL	12	10	6	8	13
17C	105	100%	WNL	12	10	6	8	13
18C	91	86.7%	WNL	11	9	4	8	11
19C	101	96.2%	WNL	12	10	6	7	12
20C	97	92.4%	WNL	11	9	6	8	9
21C	94	89.5%	WNL	11	10	6	8	4

Note. NHP = neurologically healthy participant/s; CLQT = Cognitive Linguistic Quick Test; WNL = within normal limits; * = participants of the older group (see Table 5.5).

Table 0.20. ***ARAT results of NHP (max. score).***

ID	Score (52)	%	Grasp (18)	Grip (12)	Pinch (18)	Gross Movement (9)
1C	52	100	18	12	18	9
2C	52	100	18	12	18	9
3C	52	100	18	12	18	9
4C	52	100	18	12	18	9
5C	52	100	18	12	18	9
6C	52	100	18	12	18	9
7C	52	100	18	12	18	9
8C	52	100	18	12	18	9
9C	52	100	18	12	18	9
10C	52	100	18	12	18	9
11C	52	100	18	12	18	9
12C	52	100	18	12	18	9
13C	52	100	18	12	18	9
14C	52	100	18	12	18	9
15C	52	100	18	12	18	9
16C	52	100	18	12	18	9
17C	52	100	18	12	18	9
18C	52	100	18	12	18	9
19C	52	100	18	12	18	9
20C	52	100	18	12	18	9
21C	52	100	18	12	18	9

Note. NHP = neurologically healthy participant/s; ARAT = Action Research Arm Test.

Appendix E: Detailed results of FCP

Table 0.21. *CLQT – visuospatial skills of FCP (max. score).*

ID	Weighed score (105)	%	Severity	Symbol cancellation (12)	Trails (10)	Memory (6)	Mazes (8)	Design generation (13)
1F	99	94.3%	WNL	12	10	6	8	7
2F	81	77.1%	mild	11	8	4	7	6
3F	97	92.4%	WNL	12	10	6	7	8
4F	91	87.6%	WNL*	12	10	6	8	6
5F	100	95.2%	WNL*	12	10	6	8	8
6F	101	96.2%	WNL	12	10	6	8	9
7F	90	85.7%	WNL	12	10	5	7	5
8F				*no consent for data collection*				
9F	99	94.3%	WNL	12	10	6	8	7
10F	96	91.4%	WNL	12	10	6	7	7
11F	103	98.1%	WNL	12	10	6	8	11
12F	101	96.2%	WNL	11	10	6	8	11
13F	101	96.2%	WNL*	12	10	6	8	9
14F	97	92.4%	WNL	12	10	6	8	5
15F	102	97.1%	WNL	12	10	6	8	10
16F	99	94.6%	WNL	12	10	6	8	7
17F	104	99.0%	WNL	12	10	6	8	12
18F	101	96.2%	WNL	12	10	6	8	9
19F	88	83.8%	WNL	12	8	6	8	4
20F	103	98.1%	WNL	12	10	6	8	11
21F	85	81.0%	WNL	12	7	5	7	2
22F	98	93.3%	WNL	12	10	5	7	9
23F	98	93.3%	WNL*	11	10	6	8	8
24F	85	81.0%	WNL*	12	7	6	7	6
25F	92	87.6%	WNL	12	10	6	7	7
26F	102	97.1%	WNL	12	10	4	8	10
27F	99	94.3%	WNL	12	10	6	8	7
28F	97	92.4%	WNL	12	10	6	6	11
29F	73	69.5%	WNL*	12	10	6	4	1
30F	98	93.3%	WNL*	12	10	6	8	6
31F	99	94.3%	WNL*	12	10	6	8	7
32F	105	100%	WNL	12	10	6	8	13
33F	94	93.7%	WNL*	11	10	6	7	7
34F	105	100%	WNL	12	10	6	8	13
35F	103	95.9%	WNL	12	10	6	8	11
36F	100	93.3%	WNL	12	10	6	7	11
37F	99	91.8%	WNL	12	8	6	8	11
38F	99	91.8%	WNL	12	10	6	7	10
39F	104	98.0%	WNL	12	10	6	8	12
40F	99	87.8%	WNL	12	10	6	8	7

Table 0.1. ***CLQT - visuospatial skills of FCP (max. score)*** *(continued)***.**

ID	Weighed score (105)	%	Severity	Symbol cancellation (12)	Trails (10)	Memory (6)	Mazes (8)	Design generation (13)
41F	98	91.5%	WNL	12	10	5	8	10

Note. FCP = familiar conversation partner/s; CLQT = Cognitive Linguistic Quick Test; WNL = within normal limits; * = participants of the older group (see Table 5.5).

Table 0.22. ***ARAT results of FCP (max. score).***

ID	Score (52)	%	Grasp (18)	Grip (12)	Pinch (18)	Gross Movement (9)
1F	52	100%	18	12	18	9
2F	52	100%	18	12	18	9
3F	52	100%	18	12	18	9
4F	52	100%	18	12	18	9
5F	52	100%	18	12	18	9
6F	52	100%	18	12	18	9
7F	52	100%	18	12	18	9
8F	52	100%	18	12	18	9
9F	52	100%	18	12	18	9
10F	52	100%	18	12	18	9
11F	52	100%	18	12	18	9
12F	52	100%	18	12	18	9
13F	52	100%	18	12	18	9
14F	52	100%	18	12	18	9
15F	52	100%	18	12	18	9
16F	52	100%	18	12	18	9
17F	52	100%	18	12	18	9
18F	52	100%	18	12	18	9
19F	52	100%	18	12	18	9
20F	52	100%	18	12	18	9
21F	52	100%	18	12	18	9
22F	52	100%	18	12	18	9
23F	52	100%	18	12	18	9
24F	52	100%	18	12	18	9
25F	52	100%	18	12	18	9
26F	52	100%	18	12	18	9
27F	52	100%	18	12	18	9
28F	52	100%	18	12	18	9
29F	52	100%	18	12	18	9
30F	52	100%	18	12	18	9
31F	52	100%	18	12	18	9
32F	52	100%	18	12	18	9
33F	52	100%	18	12	18	9
34F	52	100%	18	12	18	9
35F	52	100%	18	12	18	9
36F	52	100%	18	12	18	9
37F	52	100%	18	12	18	9
38F	52	100%	18	12	18	9
39F	52	100%	18	12	18	9
40F	52	100%	18	12	18	9
41F	52	100%	18	12	18	9

Note. FCP = familiar conversation partner/s; ARAT = Action Research Arm Test.

Appendix F: Detailed results of UFCP

Table 0.23. *ARAT results of UFCP (max. score).*

ID	Score (52)	%	Grasp (18)	Grip (12)	Pinch (18)	Gross Movement (9)
1UF	52	100%	18	12	18	9
2UF	52	100%	18	12	18	9
3UF	52	100%	18	12	18	9
4UF	52	100%	18	12	18	9
5UF	52	100%	18	12	18	9
6UF	52	100%	18	12	18	9
7UF	52	100%	18	12	18	9
8UF	52	100%	18	12	18	9
9UF	52	100%	18	12	18	9
10UF	52	100%	18	12	18	9
11UF	52	100%	18	12	18	9
12UF	52	100%	18	12	18	9
13UF	52	100%	18	12	18	9
14UF	52	100%	18	12	18	9
15UF	52	100%	18	12	18	9
16UF	52	100%	18	12	18	9
17UF	52	100%	18	12	18	9
18UF	52	100%	18	12	18	9
19UF	52	100%	18	12	18	9
20UF	52	100%	18	12	18	9
21UF	52	100%	18	12	18	9
22UF	52	100%	18	12	18	9
23UF	52	100%	18	12	18	9
24UF	52	100%	18	12	18	9
25UF	52	100%	18	12	18	9
26UF	52	100%	18	12	18	9
27UF	52	100%	18	12	18	9

*Note. U*FCP = unfamiliar conversation partner/s; ARAT = Action Research Arm Test.

Appendix G: Conversation order

Table 0.24. ***Order of conversation topics of PWA and NHP.***

ID	1st topic	2nd topic	3rd topic	4th topic	CP
1A	N1 – Memory	N2 – Weekend	P1 – Parcel	P2 – Eggs	FCP – UFCP
2A	N1 – Memory	N2 – Weekend	P1 – Parcel	P2 – Eggs	FCP – UFCP
3A	N1 – Memory	N2 – Weekend	P1 – Parcel	P2 – Eggs	FCP – UFCP
4A	N1 – Memory	N2 – Weekend	P1 – Parcel	P2 – Eggs	FCP – UFCP
5A	N1 – Memory	N2 – Weekend	P1 – Parcel	P2 – Eggs	FCP – UFCP
6A	P1 – Parcel	P2 – Eggs	N1 – Memory	N2 – Weekend	FCP – UFCP
7A	P1 – Parcel	P2 – Eggs	N1 – Memory	N2 – Weekend	FCP – UFCP
8A	P1 – Parcel	P2 – Eggs	N1 – Memory	N2 – Weekend	UFCP – FCP
9A	P1 – Parcel	P2 – Eggs	N1 – Memory	N2 – Weekend	FCP – UFCP
10A	P1 – Parcel	P2 – Eggs	N1 – Memory	N2 – Weekend	FCP – UFCP
11A	N2 – Weekend	N1 – Memory	P2 – Eggs	P1 – Parcel	FCP – UFCP
12A	N2 – Weekend	N1 – Memory	P2 – Eggs	P1 – Parcel	FCP – UFCP
13A	N2 – Weekend	N1 – Memory	P2 – Eggs	P1 – Parcel	FCP – UFCP
14A	N2 – Weekend	N1 – Memory	P2 – Eggs	P1 – Parcel	FCP – UFCP
15A	N2 – Weekend	N1 – Memory	P2 – Eggs	P1 – Parcel	UFCP – FCP
16A	P2 – Eggs	P1 – Parcel	N2 – Weekend	N1 – Memory	UFCP – FCP
17A	P2 – Eggs	P1 – Parcel	N2 – Weekend	N1 – Memory	UFCP – FCP
18A	P2 – Eggs	P1 – Parcel	N2 – Weekend	N1 – Memory	UFCP – FCP
19A	P2 – Eggs	P1 – Parcel	N2 – Weekend	N1 – Memory	UFCP – FCP
20A	P2 – Eggs	P1 – Parcel	N2 – Weekend	N1 – Memory	UFCP – FCP
1C	N1 – Memory	N2 – Weekend	P1 – Parcel	P2 – Eggs	FCP – UFCP
2C	N1 – Memory	N2 – Weekend	P1 – Parcel	P2 – Eggs	FCP – UFCP
3C	N1 – Memory	N2 – Weekend	P1 – Parcel	P2 – Eggs	FCP – UFCP
4C	N1 – Memory	N2 – Weekend	P1 – Parcel	P2 – Eggs	FCP – UFCP
5C	N1 – Memory	N2 – Weekend	P1 – Parcel	P2 – Eggs	FCP – UFCP
6C	P1 – Parcel	P2 – Eggs	N1 – Memory	N2 – Weekend	FCP – UFCP
7C	P1 – Parcel	P2 – Eggs	N1 – Memory	N2 – Weekend	FCP – UFCP
8C	P1 – Parcel	P2 – Eggs	N1 – Memory	N2 – Weekend	FCP – UFCP
9C	P1 – Parcel	P2 – Eggs	N1 – Memory	N2 – Weekend	FCP – UFCP
10C	P1 – Parcel	P2 – Eggs	N1 – Memory	N2 – Weekend	FCP – UFCP
11C	N2 – Weekend	N1 – Memory	P2 – Eggs	P1 – Parcel	UFCP – FCP
12C	N2 – Weekend	N1 – Memory	P2 – Eggs	P1 – Parcel	UFCP – FCP
13C	N2 – Weekend	N1 – Memory	P2 – Eggs	P1 – Parcel	UFCP – FCP
14C	N2 – Weekend	N1 – Memory	P2 – Eggs	P1 – Parcel	UFCP – FCP
15C	N2 – Weekend	N1 – Memory	P2 – Eggs	P1 – Parcel	UFCP – FCP
16C	P2 – Eggs	P1 – Parcel	N2 – Weekend	N1 – Memory	UFCP – FCP
17C	P2 – Eggs	P1 – Parcel	N2 – Weekend	N1 – Memory	UFCP – FCP
18C	P2 – Eggs	P1 – Parcel	N2 – Weekend	N1 – Memory	UFCP – FCP
19C	P2 – Eggs	P1 – Parcel	N2 – Weekend	N1 – Memory	UFCP – FCP
20C	P2 – Eggs	P1 – Parcel	N2 – Weekend	N1 – Memory	UFCP – FCP
21C	N1 – Memory	N2 – Weekend	P1 – Parcel	P2 – Eggs	FCP – UFCP

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; CP = conversation partner/s; N = narrative; P = procedural.

Appendix H: Gesture coding procedure

Videos were coded using ELAN, a gesture and sign language analysis program. Sixteen different tiers were created below the video, each serving a specific function. The order of the tiers gives an indication of the order of the coding procedure. The video was watched several times in order to fill in all relevant tiers. On the first watch, gestures were identified, along with the co-occurring speech. They were marked on tier (a), alongside co-occurring speech. If gestures occurred without speech, an empty annotation was created on this tier. When watching the video for the second time, the type of the gesture was identified. The gesture type was then marked on tiers (b) to (h), in line with the modified version of Kendon's continuum displayed in Figure 5.6 in 5.4.3.1. Gestures that did not fit into any category were marked on tier (i) as other gestures. For the identification of WFD, accompanying gestures and their resolution, the video was watched for a third time. The length of the WFD was marked on tier (j). Each instance was judged on whether it could be resolved or not by the speaker and marked on tier (k). Depending on the circumstances the WFD could include a number of turns between the speaker and the conversation partner. On tier (l) it was indicated whether the WFD was accompanied by gestures. In the last step, the role of semantically rich gestures was marked on tiers (m) to (p) by going through all semantically rich gestures (i.e., iconic, metaphoric, pantomime, emblem, and air writing & number gestures), checking for the co-occurrence of speech and WFD and whether the latter could be resolved or not. Depending on that, semantically rich gestures could be either facilitative, communicative, augmentative or compensatory.

Appendix I: Descriptive statistics

Table 0.25: ***Descriptive statistics of the variables for PWA and NHP.***

Variable	Group	*M*	*SD*	Skewness	Range	Shapiro-Wilk	Normal distribution (yes/no)
WAB-R AQ (%)	PWA	68.07	16.946	-0.979	31.60-90.80	$W(20) = .895, p = .033$	no
WAB-R fluency	PWA	4.80	2.093	0.983	2.00-9.00	$W(20) = .826, p = .002$	no
Lexical production (%)	PWA	65.86	23.326	-1.115	6.15-88.55	$W(20) = .835, p = .003$	no
Verbal semantics (%)	PWA	86.69	8.419	-0.626	71.34-97.08	$W(20) = .907, p = .055$	yes
Non-verbal semantics (%)	PWA	88.58	7.032	-0.648	75.05-98.10	$W(20) = .919, p = .095$	yes
Cognition (%)	PWA	75.09	17.608	-0.837	39.00-94.30	$W(20) = .889, p = .026$	no
	NHP	90.88	7.963	-0.797	75.20-100.00	$W(21) = .886, p = .019$	no
Motor (%)	PWA	80.37	15.140	-2.509	26.20-97.60	$W(20) = .743, p < .001$	no
	NHP	93.57	4.437	-0.646	83.30-100.00	$W(21) = .937, p = .191$	yes
Gestures overall	PWA	355.32	92.519	-0.879	131.00-469.00	$W(19) = .931, p = .183$	yes
	NHP	384.10	76.674	0.082	244.00-502.00	$W(20) = .955, p = .445$	yes
Gestures FCP	PWA	160.84	43.816	-0.403	66.00-231.00	$W(19) = .971, p = .802$	yes
	NHP	180.85	32.437	0.432	125.00-245.00	$W(20) = .963, p = .596$	yes
Gestures UFCP	PWA	194.00	51.946	-0.808	65.00-280.00	$W(20) = .956, p = .471$	yes
	NHP	196.90	58.009	-0.392	70.00-284.00	$W(21) = .961, p = .531$	yes
Narrative gestures overall	PWA	157.89	55.966	-0.214	48.00-250.00	$W(19) = .973, p = .836$	yes
	NHP	152.19	55.949	0.248	49.00-267.00	$W(21) = .973, p = .836$	yes
Procedural gestures overall	PWA	197.32	48.333	-1.482	58.00-257.00	$W(19) = .884, p = .025$	yes
	NHP	226.75	40.153	0.451	157.00-319.00	$W(20) = .979, p = .927$	yes
Semantically rich gestures overall	PWA	205.42	71.246	-0.533	67.00-331.00	$W(19) = .946, p = .332$	yes
	NHP	239.00	79.385	0.210	106.00-382.00	$W(20) = .967, p = .688$	yes
Semantically rich gestures overall (%)	PWA	57.14	11.302	-1.198	29.64-73.23	$W(19) = .900, p = .049$	no
	NHP	61.67	13.529	-0.899	28.80-78.13	$W(20) = .913, p = .072$	yes

Table 0.25. *Descriptive statistics of the variables for PWA and NHP* *(continued)***.**

Variable	Group	*M*	*SD*	Skewness	Range	Shapiro-Wilk	Normal distribution (yes/no)
Semantically rich gestures narrative (%)	PWA	45.84	14.083	-0.673	12.50-63.06	$W(20) = .931, p = .159$	yes
	NHP	49.42	19.654	-0.306	16.39-80.80	$W(21) = .939, p = .209$	yes
Semantically rich gestures procedural (%)	PWA	62.60	15.130	0.889	31.70-83.56	$W(20) = .901, p = .042$	no
	NHP	68.30	12.319	-1.124	35.43-83.09	$W(21) = .897, p = .030$	no
Semantically empty gestures overall	PWA	149.89	54.158	1.440	64.00-311.00	$W(19) = .892, p = .036$	no
	NHP	145.10	52.072	0.656	77.00-262.00	$W(20) = .943, p = .271$	yes
WFD +gesture/+resolved (%)	PWA	47.02	14.129	-0.579	18.84-69.34	$W(20) = .946, p = .312$	yes
	NHP	53.31	16.251	-0.614	17.95-73.05	$W(21) = .932, p = .149$	yes
WFD +gesture/-resolved (%)	PWA	17.59	11.053	1.274	5.83-47.06	$W(20) = .867, p = .010$	no
	NHP	1.41	1.621	1.289	0.00-5.79	$W(21) = .828, p = .002$	no
WFD -gesture/+resolved (%)	PWA	23.30	10.299	0.153	4.12-42.50	$W(20) = .980, p = .937$	yes
	NHP	40.92	15.624	0.337	19.15-68.70	$W(21) = .931, p = .141$	yes
WFD -gesture/-resolved (%)	PWA	12.09	8.606	1.554	3.28-37.68	$W(20) = .843, p = .004$	no
	NHP	3.34	1.402	0.012	0.93-5.83	$W(21) = .968, p = .691$	yes
Gestures during WFD	PWA	71.58	25.446	-0.370	22.00-109.00	$W(19) = .958, p = .530$	yes
	NHP	67.15	24.618	0.323	34.00-108.00	$W(20) = .920, p = .097$	yes
Gestures outside WFD	PWA	36.36	14.628	-0.209	13.00-59.00	$W(19) = .941, p = .277$	yes
	NHP	50.65	19.645	0.912	28.00-93.00	$W(20) = .898, p = .038$	no
Facilitative gestures (%)	PWA	50.23	12.489	-1.456	13.86-63.04	$W(20) = .852, p = .006$	no
	NHP	47.96	11.963	0.349	30.08-73.26	$W(21) = .960, p = .513$	yes
Communicative gestures (%)	PWA	27.25	13.072	0.427	6.28-55.22	$W(20) = .974, p = .837$	yes
	NHP	1.28	1.574	2.604	0.00-7.04	$W(21) = .725, p < .001$	no
Augmentative gestures (%)	PWA	19.14	10.173	0.342	3.54-41.29	$W(20) = .969, p = .727$	yes
	NHP	50.59	12.511	-0.445	25.19-68.59	$W(21) = .947, p = .295$	yes

Table 0.25. *Descriptive statistics of the variables for PWA and NHP* (continued).

Variable	Group	*M*	*SD*	Skewness	Range	Shapiro-Wilk	Normal distribution (yes/no)
Compensatory gestures (%)	PWA	3.38	7.797	4.310	0.00-36.14	$W(20) = .365$, $p < .001$	no
	NHP	0.73	0.536	-0.020	0.00-1.63	$W(21) = .365$, $p = .114$	yes

Note. PWA = participant/s with aphasia; NHP = neurologically healthy participant/s; WAB-R = Western Aphasia Battery – Revised; AQ = aphasia quotient; WFD = word-finding difficulty/ies; *M* = mean; *SD* = standard deviation

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