Title: Integration of speech and gesture in aphasia

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**What is already known on this subject.**
A previously published study (Cocks et al., 2009) explored a single participant with aphasia's ability to integrate gesture and speech. This single participant had difficulty integrating speech and gesture. When this participant had difficulty integrating, he more frequently relied on the gesture channel.
**What this study adds.**
The current study replicates and extends the study of gesture and speech integration by Cocks et al. (2009) by including 31 participants with aphasia and 30 control participants. Participants with aphasia were significantly worse at integrating gesture and speech, than the control participants. When the participants had difficulty integrating, they more frequently relied on the verbal channel.
**Clinical implications of this study.**
There are some therapy approaches that encourage communication partners to use gesture alongside language in order to facilitate comprehension for the person with aphasia. The findings of this study suggest that when the person with aphasia is required to integrate speech and gesture in order to obtain meaning, then using gesture alongside speech will not facilitate comprehension.

***Abstract***

*Background:* Information from speech and gesture is often integrated to comprehend a message. This integration process requires the appropriate allocation of cognitive resources to both the gesture and speech modalities. People with aphasia are likely to find integration of gesture and speech difficult. This is due to a reduction in cognitive resources, a difficulty with resource allocation or a combination of the two. Despite it being likely that people who have aphasia will have difficulty with integration, empirical evidence describing this difficulty is limited. Such a difficulty was found in a single case study (Cocks *et al.*, 2009), and is replicated here with a greater number of participants.

*Aims:* To determine whether individuals with aphasia have difficulties understanding language with integrated speech and gesture.

*Methods/Procedures:* 31 participants with aphasia (PWA) and 30 control participants watched videos of an actor communicating a message in three different conditions: verbal only, gesture only, and verbal and gesture message combined. The message related to an action in which the name of the action (e.g. 'eat') was provided verbally and the manner of the action (e.g. hands in a position as though eating a burger) was provided gesturally. Participants then selected a picture that 'best matched' the message conveyed from a choice of four pictures that represented a gesture match only (G match), a verbal match only (V match), an integrated verbal-gesture match (Target) and an unrelated foil (UR). To determine the gain that participants obtained from integrating gesture and speech, a measure of multi-modal gain (MMG) was calculated.

*Outcomes & Results:* The PWA were less able to integrate gesture and speech than the control participants and had significantly lower multi-modal gain scores. When the PWA had difficulty integrating they more frequently selected the verbal match.

*Conclusions & Implications:* The findings of this study suggest that people with aphasia can have difficulty integrating speech and gesture in order to obtain meaning. Therefore when encouraging communication partners to use gesture alongside language when communicating with people with aphasia, education regarding the types of gestures that would facilitate understanding is recommended.

## Introduction

We often produce gesture alongside speech, and these gestures are referred to as co-speech gestures. Some co-speech gesture is iconic, meaning that the hand movements visually resemble the entity or action that they depict and also "bear a close formal relationship to the semantic content of speech" (McNeill, 1992, p 12). For example, moving arms back and forth in a running motion to communicate that the person being discussed was running. Co-speech iconic gestures increase the listener's understanding of the speaker's intention (Hostetter, 2011), aid in memory of the communicative message (Hostetter, 2011), and increase the attention the listener pays to the speaker (Preisig *et al.*, 2015).

Speakers can present information in speech and in gesture in various ways. The information in co-speech iconic gesture can be redundant (also referred to as congruent), incongruent or additive. In experimental studies of gesture comprehension, redundant or congruent gesture tasks are those in which a listener is presented with the same meaning in both speech and gesture, for example, 'brush your teeth' said verbally, and combined with a stereotypical tooth brushing gesture. In incongruent gesture comprehension tasks, a listener is presented with opposing information provided in gesture and speech, and the listener is directed to follow the verbal message. For example, a listener might be presented with the verbal message 'read your book', and a stereotypical tooth brushing gesture. Additive gesture tasks are those in which the gesture adds additional meaning to the verbal message, for example, the verbal message 'I cleaned them', with a stereotypical tooth brushing gesture adding the specific information about the nature of the cleaning.

Additive iconic gestures in particular benefit communication between a speaker and a listener (Hostetter, 2011). In this scenario, the listener must integrate the information provided by the gesture and the co-occurring speech to obtain the full meaning of the speaker's intention (Cassell *et al.*, 1999, Hostetter, 2011). For example, when someone says 'birthday cake' and gestures a round shape, the listener needs to integrate the information from speech and from gesture to determine that the speaker is talking about 'a round birthday cake'. To do this, the listener needs to attend to both gesture and language, obtain meaning from both modalities, and then integrate this meaning. The process of integration results in a gain in understanding of the speaker's intention, this gain is referred to as 'multi-modal gain' (Cocks *et al.*, 2011b, Cocks *et al.*, 2009). If the listener only understands one modality or does not integrate the two modalities then they only understand part of the speaker's message.

The integration of speech and iconic gesture during language comprehension requires attention to be divided between two modalities (Hostetter, 2011). Thus, the process of simultaneously processing and then integrating gesture and language is likely to result in competition for cognitive processes. A growing body of research suggests that individuals with aphasia have difficulty with tasks that require divided attention (see Murray, 1999 for review). It is likely that people with aphasia experience difficulties when performing dual tasks either due to a difficulties with allocating attentional resources, due to a reduction in resources available or a combination (see Murray, 1999 for review). In particular, task performance is negatively affected when there is competition for shared resources (McNeil *et al.*, 1991, Erickson *et al.*, 1996). But these studies have mainly used a dual task paradigm in which two *different* tasks are performed simultaneously or in which two *different* messages need to be processed (see Murray, 1999 for review). A task in which speech and gesture needs to be integrated for language comprehension, on the other hand, requires attention to be divided between two modalities in the *same* task, and requires the simultaneous processing and then integration of gesture and language containing different aspects of the *same* message. While such a task will not distinguish between the different theories of attention difficulties, the findings have important clinical implications.

Previous research has found that some individuals with aphasia have difficulties comprehending iconic gesture in isolation (e.g. Lambier and Bradley, 1991). However, as only one modality is processed in these tasks, such findings does not explore whether difficulties with attention extend to comprehending messages conveyed by both gesture and speech.

The understanding of redundant gesture and the effect of incongruent gestures has also been explored in two previous studies on aphasia (Yorkston *et al.*, 1979, Eggenberger *et al.*, 2016). They found that the addition of redundant gesture increased the accuracy of comprehension for people with aphasia (Yorkston *et al.*, 1979, Eggenberger *et al.*, 2016) and that comprehension accuracy decreased when an incongruent gesture was present for both people with aphasia and healthy controls (Eggenberger *et al.*, 2016). However, neither of these tasks investigated the relative contribution made by speech and gesture in comprehension tasks, and so neither set of findings extend to comprehending messages in which different information is conveyed by both gesture and speech.

There is only one single case study exploring the ability of individuals with aphasia to integrate speech and iconic gesture (Cocks *et al.*, 2009). Cocks *et al.* (2009) explored whether an individual with aphasia and a group of control participants could integrate iconic gesture and speech to comprehend a message. Participants were presented with a series of videos which included scenes in which an actor both spoke and produced iconic gesture; scenes where she only spoke; and scenes where she only gestured. In this study the researchers used a measure of integration termed *multi-modal gain* (MMG). This measure was used because integration is more than the sum of the two parts. When integration occurs, the certainty in decoding the message from multimodal input is higher than the certainty derived from separate considerations of each modality. We refer to such an increase as 'multimodal gain'. Such a gain occurs when two modalities mutually enhance their informativeness, in other words when there is a synergistic effect of considering two modalities together while decoding (Kelly *et al.*, 1999). To determine the gain in comprehension of the message in the scenes in which both speech and gestures were used (the multi-modal condition), multi-modal gain was calculated. For a more detailed explanation of the calculation of multi-modal gain, see the data analysis section below.

The findings from the single case indicated that the participant with aphasia had a significantly lower multi-modal gain score than the control participants. When he was unable to integrate, he frequently chose the gesture match rather than the target, suggesting that he was allocating his attention to the gesture modality. In the current study we aimed to extend these findings with more participants with a range of aphasia profiles.

While we hypothesised that the findings of the current study would be useful theoretically in further understanding the attention difficulties people with aphasia have, there are also clinical implications. There are some therapy approaches for people with aphasia where conversation partners are encouraged to use gesture alongside verbal language. For example, in ‘Supported Conversation for Aphasia’, described by Kagan (1998), the conversation partners of people with aphasia are trained to *reveal competence* in the speaker with aphasia by ‘ensuring comprehension, e.g., using gesture, written key words, drawing, or resource material to make the topic of conversation clear’ (p. 820). The details of what types of gestures to use are not clearly specified and the contribution these gestures make to the person with aphasia’s understanding in these therapy approaches has not been formally investigated. It is likely however, that the listener would need to integrate gesture and speech to obtain meaning in some scenarios. It is therefore essential to know whether people with aphasia are able to integrate gesture and language to aid in the design of similar therapy approaches.

The current study therefore aimed to determine whether a group of participants with aphasia had more difficulty with an iconic gesture and speech integration task than a group of control participants. The study used the same methodology as Cocks *et al.* (2009) with a larger group of participants with aphasia. It was hypothesised that the participants with aphasia would have greater difficulty with the integration task than a group of healthy controls.

**Method**

*Participants*

Thirty-one participants with aphasia (PWA) aged 36-93 (M=60, SD=14.63) were compared to 30 control participants aged 39-89 years (M= 60.8, SD=12.88). Control participants self-reported that they had no difficulty with hearing or vision that was not able to be corrected with a hearing aid or glasses. PWA were only included if they had no other neurological diagnoses other than a history of CVA. PWA had a range of aphasia types: anomic (15); conduction (8); Broca's (4); Wernicke's (4) and severities (Mean Aphasia Quotient score= 72.56, Range 40.1-89.7) as indicated by the Western Aphasia Battery- Revised (WAB-R) (Kertesz, 2006). One of the PWA had previously taken part in a study on gesture production, and their integration results were published as background assessment information in Cocks *et al.* (2011a). Table 1 summarises the participant data.

-----------------------------Insert Table 1 here-----------------------------------------------------

*Materials & Procedure*

The participants were shown 21 video vignettes of an actor producing iconic gestures depicting common everyday actions (G), 21 video vignettes of an actor producing an iconic gesture that depicted common everyday actions accompanied by a verbal phrase (VG), 21 still images of an actor accompanied by a verbal phrase (V). The same procedure and resources that was used as in Cocks *et al.* (2009). The still image was an image of the actor standing still with their hands by their sides. The actor's face was covered in each of the conditions to reduce the effect of facial expression on comprehension. The verbal phrases consisted of simple subject-verb or subject-verb-object sentences of high frequency, semantically simple verbs e.g. 'I paid'; 'I cut it'. To reflect gesture produced in spontaneous speech, the gestures produced by the actor were vague and less detailed than pantomime gestures or simple signing systems. For example, the gesture for 'I cut it' involved a vague 'cutting with a knife' like gesture. Participants were shown the 63 test items in a randomised order which was the same as Cocks *et al.* (2009). After each item, they were asked to select an image that 'best matched' the item from a selection of four photographs. Of the four photographs, one represented a gesture match only (G match), one a verbal match only (V match), one an integrated verbal-gesture match (Target) and one unrelated foil (UR). The UR was semantically related to the gesture match and therefore unlikely to be selected in any of the conditions. Each test phrase was presented in each of the three conditions: V, G and VG. When presented in the VG condition, the target item was selected if the participant integrated the speech and gesture information. The target item could also be selected if the participant focused on just one modality (i.e., speech or gesture) and did not integrate the speech and gesture information. To determine any gain the participants obtained from integrating gesture and speech, as opposed to uni-modal processing, multi-modal gain (MMG) was calculated.

As in Cocks *et al.* (2009), the probability of the participants choosing the target item in the VG condition without integrating two modes of information was calculated (i.e. the probability that only one modality was utilised). This was referred to a P(Unimodal). This probability is estimated as a weighted mean of the proportion of trials in which the target item was selected in the V condition (WV) and the proportion of trials in which the target item was selected in the G condition (WG). It was assumed that the modality, which the participants were more likely to use, was stronger and provided more accurate information, therefore WV and WG were estimated as normalised. Normalisation ensures that the sum of the weights equals to one. Multimodal gain (MMG) was used as an index to ascertain the extent that the two modalities were integrated in the VG condition. MMG therefore represents the likelihood that the VG condition was chosen by means of both modalities being integrated.

The G and V conditions were examined in more detail to determine whether the participants who had difficulty integrating were the participants who also had difficulty with these tasks in isolation.

Outliers in the data were identified by examining how often control participants chose the integrated target in the VG condition. For most items the target was chosen by nearly all of the control participants in the VG condition, however 'I walked' fell more than two standard deviations below the mean and was therefore removed from the analysis. Similarly to Cocks *et al.* (2009), one control participant was also removed from the analysis as this participant only selected the target on six occasions in the VG condition. It is unclear why this participant had difficulties with integration.

## Statistics

MMG scores, and VG scores were compared between PWA and control participant groups using two t-tests, with a threshold of $p<0.05$. The relationship between the number of participants from each group who selected the target in VG compared with either the V condition or the G condition, or both the V and G conditions, was explored using a Fisher's exact test, with a threshold of $p<0.05$.

## Results

### *Multi-modal Gain*

The MMG percentages were compared between the control participants and the PWA. The PWA had a significantly lower MMG score than the control participants, $t(58)=5.06$, $p<0.05$ (See Figure 1).

-----------------------------------Insert Figure 1 about here----------------------------------------

### *The multi-modal condition*

The number of times the target was selected in the VG condition was compared between the two groups of participants. Levene's test for equality of variance was significant ($p$=0.03), so equal variance was not assumed and the degrees of freedom were adjusted from 58 to 53.44. The PWA selected the target in the VG condition significantly less than the control participants $t(53.44)=2.46$, $p<0.05$. Error pattern analysis revealed that both groups frequently selected the verbal match when they did not select the target in the VG condition (See Figure 2). There were four participants with aphasia who selected the gesture match more frequently than the verbal match or unrelated foil.

----------------------------------Insert Figure 2 about here----------------------------------------

How often the target was chosen in the VG condition compared to the other modalities was then compared between the two groups. Fourteen of the 31 PWA selected the target in the VG condition less often than in either the V condition or the G condition, or both V and G conditions. Comparatively only two of the 29 control participants selected the target in VG less often than either the V condition or the G condition, or both V and G conditions (See Table 2). An inspection of the demographic information about these two control participants did not indicate that there was anything unique about them. A Fisher's exact test indicated that there was a significant relationship for the number of participants from each group who selected the target in VG less often than either the V condition or the G condition, or both the V and G conditions, $p<0.05$. Inspection of the profiles of the 15 PWA who selected the target in the VG condition less often than either the V condition or the G condition, or both the V and G conditions, revealed that this subgroup included participants with a range of aphasia types (Anomic=6; Conduction=5; Wernicke's=3; Broca's=1).

----------------------------------Insert Table 2 about here--------------------------------------

*The verbal and gesture only tasks*

To determine whether participants were comprehending the verbal message in the verbal only task, the verbal match and target scores were combined. The control participants all obtained near ceiling scores of 90-100% accuracy (*M=98.79%; STDEV=2.55%)*. There was a greater range of scores from the participants with aphasia with scores ranging from 75-100%, however the majority obtained near ceiling scores (*M=95%; STDEV=6.83%).* The two participants who obtained scores of 75% were visually examined more closely to determine whether they also obtained the lowest MMG scores. They did not obtain lowest MMG scores.

To determine whether the participants were comprehending the gesture message in the gesture only task, the gesture match and target scores were combined. The control participants again obtained near ceiling scores ranging from 85%-100% (*M=96.2%; STDEV=4.93%*). The participants with aphasia obtained scores ranging from 75-100% (*M=92.74%; STDEV=8.14%*)*.* Again the two participants who obtained scores of 75% were visually examined more closely, to determine whether they also obtained lowest MMG scores. They did not obtain the lowest MMG scores.

**Discussion**

This study is the first to look at how a large group of speakers with aphasia integrate gesture and speech, and has findings of theoretical and clinical interest. The participants with aphasia were less able to integrate iconic gesture with speech than the control participants, suggesting reduced overall comprehension of the speaker's messages. Furthermore, almost half of the participants selected the target less often in the integration condition than in the single modality conditions, indicating that understanding the message was worse in the integration task than in the single modality conditions. That is to say, when the participants with aphasia were presented with visual *and* auditory information, they were less likely to understand the message accurately than they did when presented with either visual or auditory information. This suggests that there is not a 'multi-modal gain' associated with integration but instead a 'multi-modal loss'. This seemingly counterintuitive finding supports the suggestion that people with aphasia have either reduced attentional resources, difficulties with allocating attention or a combination of these two difficulties (Murray, 1999) because it suggests they are not processing all of the available information.

The findings of the current study extend that of the single case study (Cocks *et al.*, 2009) in which the participant who had comprehension difficulties most frequently chose the gesture match when he was unable to integrate. Specifically, the data from the current study suggest that there is not one error pattern of all people with aphasia.

Determining whether the difficulty lay with attention allocation, reduced resources or a combination is extremely difficult and indeed drawing a stark contrast between the different theories of attention difficulties was not the main aim of our research. We do suggest however, that an attentional difficulty most likely lies at the core of the gesture-speech integration difficulty. The process of integrating speech and gesture requires an individual to attend to two modalities, obtain meaning from them and then integrate the information received from both modalities (Cocks *et al.*, 2011b, Cocks *et al.*, 2009). Difficulties with attention allocation, reduced resources or a combination of these would result in the listener either attending to one modality more than another, not having sufficient attention to attend to either of the modalities, or not allocating or not having sufficient resources in order to integrate and obtain meaning. Current models of gesture and speech for the most part deal with production of language rather than comprehension and thus can provide little insight into the interpretation of our findings.

Where our research has more to offer is that the findings of the study have important clinical implications. There is evidence that encouraging conversation partners to use gesture alongside verbal language is a component of some therapy approaches (Kagan, 1998). The findings from the current study suggest that if the person with aphasia is required to integrate gesture and speech to obtain meaning, then using gesture alongside language may not aid comprehension. These findings contradict the guidance around using iconic gesture alongside language to support clients' comprehension if the gesture is not redundant. As there is evidence to suggest that redundant gestures can aid comprehension (Yorkston *et al.*, 1979, Eggenberger *et* *al.*, 2016), this suggests that communication partners should have training regarding what would be appropriate and inappropriate gestures to use alongside verbal language in order to facilitate comprehension.  Appropriate gestures would be redundant gestures and inappropriate gestures would be additive gestures.

While the current study makes an important contribution to the field of research, it had some limitations.  The stimuli were artificial in that an actor produced selected gestures alongside a chosen verbal message.  This was required for the experimental design.  Although this decision meant participants used identical resources, and that additional contextual information could not be used for to aid interpretation, it might be argued that this means the results cannot be generalised to naturally produced gestures. However, comparing how a listener understands information in speech, gesture, and integrating speech and gesture naturalistically is likely to be challenging. This is because any more naturalistic study regarding speech and gesture is likely to introduce additional variables which may act as confounds (e.g., facial expression, tone of voice, contextual cues).

It is interesting that in both this study and that of Cocks *et al.* (2009), one control participant was removed as an outlier.  It was unclear why these participants had difficulty with integrating speech and gesture. For example, these participants may have made a swift initial decision that the information in gesture was redundant, and thus stopped attending to the gesture modality; they may have had difficulties with the task; or they may have presented with cognitive difficulties they were not aware of. However, the presence of such participants in both studies suggests that this task may be difficult even for healthy controls.

This current study was the first to investigate how a group of participants with aphasia integrate speech and gesture.  The findings suggest that future research in this area should focus attention on difficulties with resource allocation, resource capacity or a combination of both impacts on the ability of the people with aphasia to integrate gesture and speech. Clinical implications of the research suggest that caution should therefore be applied when recommending communication partners use gesture alongside language in order to facilitate a person with aphasia's comprehension.

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Table 1:

Participants with aphasia background information

| Participant | Gender | Age | Aphasia Type According to WAB-R | WAB-R AQ Score | Auditory Verbal Comprehension Score | Error Preference |
|---|---|---|---|---|---|---|
| 1 | M | 65 | Wernicke's | 55.7 | 4.75 | Gesture |
| 2 | M | 64 | Wernicke's | 62.8 | 5.6 | Gesture and Unrelated with equal frequency |
| 3 | F | 50 | Wernicke's | 72.5 | 5.85 | Both Verbal and Gesture with equal frequency |
| 4 | M | 54 | Brocas | 58.4 | 5.9 | Verbal |
| 5 | M | 46 | Brocas | 69.6 | 6.1 | Gesture |
| 6 | M | 63 | Wernicke’s | 74.2 | 6.1 | Verbal |
| 7 | M | 73 | Brocas | 40.1 | 6.45 | Verbal |
| 8 | F | 39 | Anomic | 71.2 | 6.9 | Verbal |

| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | M | 65 | Anomic | 80 | 7 | Verbal |
| 10 | M | 62 | Brocas | 62.5 | 7.15 | Gesture |
| 11 | M | 93 | Anomic | 84.5 | 7.35 | Verbal |
| 12 | F | 75 | Conduction | 46.1 | 7.35 | Verbal |
| 13 | M | 78 | Anomic | 72.3 | 7.55 | Verbal |
| 14 | M | 36 | Anomic | 82.3 | 7.55 | Gesture |
| 15 | F | 73 | Conduction | 58 | 7.6 | Unrelated |
| 16 | F | 58 | Anomic | 85.2 | 7.8 | Verbal |
| 17 | F | 82 | Conduction | 54 | 7.9 | Verbal |
| 18 | M | 46 | Anomic | 86.8 | 8 | Verbal |
| 19 | M | 83 | Conduction | 80 | 8 | Verbal |
| 20 | M | 48 | Anomic | 86.8 | 8.1 | Verbal |

| | | | | | | |
|---|---|---|---|---|---|---|
| 21 | F | 61 | Conduction | 78.8 | 8.3 | Verbal |
| 22 | F | 49 | Anomic | 89.5 | 8.65 | Verbal |
| 23 | M | 80 | Conduction | 70.1 | 8.65 | Verbal |
| 24 | M | 73 | Anomic | 88.5 | 8.75 | Verbal |
| 25 | F | 48 | Anomic | 83.2 | 8.9 | Verbal |
| 26 | F | 47 | Conduction | 55.6 | 9 | Verbal |
| 27 | F | 42 | Anomic | 81.4 | 9 | Verbal |
| 28 | F | 44 | Conduction | 56 | 9 | Verbal |
| 29 | M | 57 | Anomic | 85.2 | 9.5 | Verbal |
| 30 | M | 67 | Anomic | 88.4 | 9.5 | Verbal |
| 31 | F | 52 | Anomic | 89.7 | 9.95 | Verbal |

Table 2:

Selection of target in VG compared to V and G conditions by group

| | Selected the target more often in VG condition than V or G conditions | Selected the target more often in V or G, or both V and G conditions than VG |
|---|---|---|
| Participants with Aphasia | 17 | 14 |
| Control Participants | 27 | 2 |

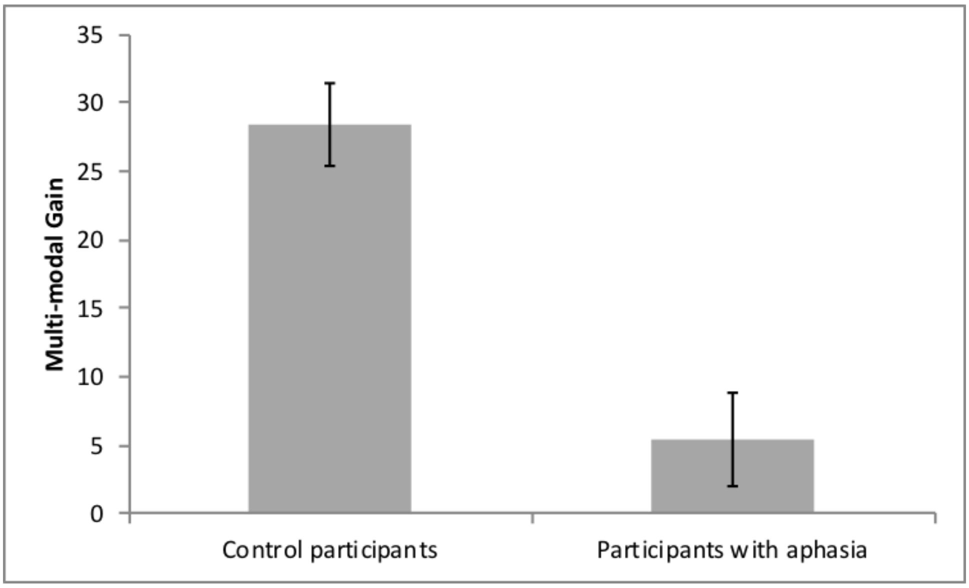


Figure 1. Mean multi-modal gain percentages for the control participants and participants with aphasia. Errors bars represent standard error. The higher the percentage the greater the gain obtained from integration.

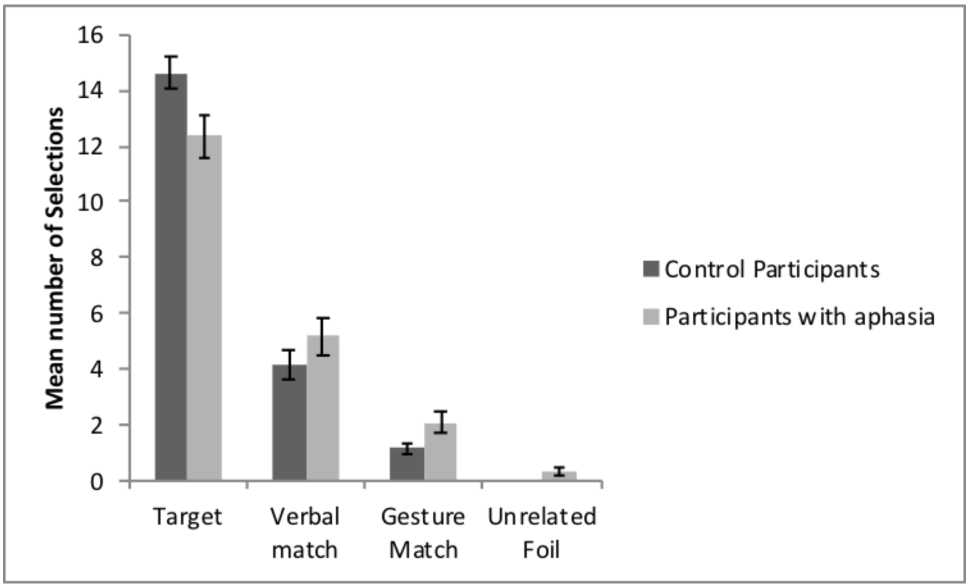


Figure 2. Mean number of selections by control participants and participants with aphasia of the target (the correct response), the verbal match, gesture match and unrelated foil in the VG condition (21 items). Error bars represent standard error.