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REVIEW

# Language and gesture neural correlates: A meta-analysis of functional magnetic resonance imaging studies

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## Abstract

**Background:** Humans often use co-speech gestures to promote effective communication. Attention has been paid to the cortical areas engaged in the processing of co-speech gestures.

**Aims:** To investigate the neural network underpinned in the processing of co-speech gestures and to observe whether there is a relationship between areas involved in language and gesture processing.

**Methods & Procedures:** We planned to include studies with neurotypical and/or stroke participants who underwent a bimodal task (i.e., processing of co-speech gestures with relative speech) and a unimodal task (i.e., speech or gesture alone) during a functional magnetic resonance imaging (fMRI) session. After a database search, abstract and full-text screening were conducted. Qualitative and quantitative data were extracted, and a meta-analysis was performed with the software GingerALE 3.0.2, performing contrast analyses of uni- and bimodal tasks.

**Main Contribution:** The database search produced 1024 records. After the screening process, 27 studies were included in the review. Data from 15 studies were quantitatively analysed through meta-analysis. Meta-analysis found three clusters with a significant activation of the left middle frontal gyrus and inferior frontal gyrus, and bilateral middle occipital gyrus and inferior temporal gyrus.

**Conclusions:** There is a close link at the neural level for the semantic processing of auditory and visual information during communication. These findings encourage the integration of the use of co-speech gestures during aphasia treatment as a strategy to foster the possibility to communicate effectively for people with aphasia.

KEYWORDS

aphasia, adults, imaging techniques, stroke, gesture

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## WHAT THIS PAPER ADDS

*What is already known on this subject*

- Gestures are an integral part of human communication, and they may have a relationship at neural level with speech processing.

*What this paper adds to the existing knowledge*

- During processing of bi- and unimodal communication, areas related to semantic processing and multimodal processing are activated, suggesting that there is a close link between co-speech gestures and spoken language at a neural level.

*What are the potential or actual clinical implications of this work?*

- Knowledge of the functions related to gesture and speech processing neural networks will allow for the adoption of model-based neurorehabilitation programs to foster recovery from aphasia by strengthening the specific functions of these brain networks.

## INTRODUCTION

Gestures are an integral part of human communication. Indeed, when we speak, we typically use co-speech gestures, that is, hand movements that accompany speech and allow the speaker and the listener to exchange thoughts and ideas in two modalities (Marstaller & Burianova, 2015). McNeill proposed a general classification of four types of hand gestures: beat, deictic, iconic and metaphoric. Among them, iconic hand gestures represent meanings closely related to the semantic content of the speech that they accompany (McNeill, 1985), whereas metaphoric gestures are related to physical representation of an abstract idea (Andric & Small, 2012). As to their complexity, investigation of gestures' role during speaking and its relationship with the speech they accompany is still challenging. Several hypotheses on the functioning of iconic gestures have been proposed. The first, lexical retrieval facilitation (LRF) hypothesis, postulates that gesture production facilitates the retrieval of phonological word forms from the mental lexicon while speaking; thus, the primary function of gesture is to facilitate lexical retrieval (Butterworth & Hadar, 1989; Krauss et al., 2000). However, authors sustaining the LRF hypothesis claimed also that gesture is not communicative (Krauss et al., 2000). Contrarily, another hypothesis assumes that co-speech gestures could help the listener in decoding the communicative intention of the speaker during communication, therefore highlighting a communicative function aimed to content transmission (Beattie & Shovelton, 2011; Goodwin, 2000; Holler et al., 2013). A third view is that iconic gestures are multifunctional: in this case, iconic gestures seem to have both a communicative function and a LRF function supporting speech production (Brady et al., 2016).

The debate on the function of co-speech gestures is still ongoing not only at a behavioural level. Indeed, to explain the functions of gestures and the relationship between gestures and language, it is useful to look at different levels. Thus, while at a behavioural level the debate is focused on many different theories that address the relationship between gestures and language, making assumptions about the primary function of co-speech gestures, at a neural level researchers have turned to investigating the underlying neurological components of each (i.e., language processing and gesture processing). Brain data can help researchers find whether processing information (contained in both auditory and visual modalities) depends on the same or different brain networks, shedding lights and giving information supporting the relationship between gestures and language processing. In fact, there is evidence that a fronto-temporal network for language processing involves the inferior frontal gyrus (IFG) and the temporal cortex of the left hemisphere, as well as their respective homologues in the right hemisphere (Bookheimer, 2002; Vigneau et al., 2011). On the other hand, studies investigating brain activation during gesture processing indicate that the left IFG (pars opercularis), bilateral IFG (pars tri-angularis), bilateral ventral and dorsal premotor cortex (PMv and PMd), left posterior middle temporal gyrus (pMTG) and bilateral superior temporal gyrus (STG), are involved in gesture comprehension (Andric & Small, 2012). In addition to functional

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magnetic resonance imaging (fMRI) studies, electroencephalography has been used to evaluate co-speech gesture perception, suggesting that there is a temporal coordination between speech and gestures, and that the meaning of speech is shaped by the related co-speech gestures (Habets et al., 2011; Obermeier et al., 2011).

Taken together, these findings can play a key role when translated into clinical practice. Indeed, in the rehabilitation field there are many therapies that foster the use of co-speech gestures as an ally to effectively communicate, in people with aphasia (PWA) (Rose et al., 2013). Findings from fMRI could clarify the neural substrates involved in language and gesture processing. Knowledge of brain networks involved in gesture and language processing in neurotypical systems can directly provide a framework for understanding, developing and implementing treatment approaches that can foster recovery in pathological conditions, such as aphasia, by strengthening the functions of these brain networks and targeting the structures involved in both processing. Indeed, there is a wide literature that supports the use of gestures as facilitators of language production in PWA, and knowing the neural substrates that underlie the relationship between speech and gesture can help in developing model-based neurorehabilitation approaches that strengthen the brain networks involved in gestures and speech processing. Understanding the role and relationship between gesture and language would therefore allow the implementation of rehabilitation strategies aimed at promoting effective communication and at using multiple communication channels, that could lead to greater generalization of language performance.

## OBJECTIVES

Our research question was developed by thinking about whether there are shared brain networks between language and co-speech gesture processing. Thus, by conducting a meta-analysis, we aim to quantitatively synthesize evidence from fMRI studies to investigate whether there are shared brain networks between language and gesture processing. In particular, we investigate whether co-speech gestures processing and language processing rely on partially overlapping brain networks.

## METHODS

The protocol of this systematic review was registered in the PROSPERO database (registration number CRD42021269629).

### Criteria for considering studies for this review

At the protocol stage, we planned to include studies on the use of gestures, in neurotypical adults (i.e., > 18 years old) or stroke survivors performing tasks during an fMRI session. The tasks have to consist of a bimodal condition involving the processing of beat, iconic or metaphoric gestures and their relative speech (e.g., watching video of an actor performing a co-speech gesture, with content related speech), compared with a unimodal condition involving the use of isolated gesture or speech (e.g., watching video of an actor performing only gestures, without speech or speech alone). We planned to include in cross-sectional studies considering the blood oxygen level-dependent (BOLD) signal or arterial spin labelling (ASL).

We excluded studies with tasks including sign language or emblems, as they can be understood independently from speech.

### Search methods for the identification of studies

We searched for articles written in English in PUBMED, EMBASE, WEB OF SCIENCE and the Cochrane Library. The last search was conducted on 3 March 2023. For a detailed description of the search strategy, see Appendix A.

### Data collection and analysis

Records obtained after search strategy were screened, based on title and abstract, by two independent authors using the free online tool Rayyan (https://www.rayyan.ai/). A third reviewer was involved to solve any disagreement. The same procedure was applied for full-text screening. After the screening process, qualitative and quantitative data were extracted by filling data-extraction tables specifically created for this review.

We then performed an activation likelihood estimation (ALE) meta-analysis using the software Ginger ALE 3.0.2 (http://www.brainmap.org/ale/). ALE is a method for coordinate-based meta-analysis which considers brain activation coordinates (i.e., foci reported with $x$, $y$, $z$ coordinates) as centres of probability distribution. This means that each activation coordinate gives information on the probability of brain activation in a particular area, but it could be that brain activation is actually in areas close to the coordinates (Yang et al., 2015). During meta-analysis the ALE models included foci as centres for three-dimensional Gaussian probability distribution

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(Eickhoff et al., 2009). Coordinates of foci reported in Talairach space were converted into standard Montreal Neurological Institute (MNI) space using icbm2tal transformation (Lancaster et al., 2007). For the meta-analysis, the coordinates $x, y, z$ and the number of subjects were used as input. We performed the following three contrasts:

- Speech only (unimodal) versus null.
- Gesture only (unimodal) versus null.
- Speech + gesture (bimodal) versus speech only (unimodal).

Significance was tested using 1000 permutations with a cluster forming threshold of $p < 0.001$ (uncorrected). Significance was corrected with a cluster-level family-wise error threshold of $p < 0.05$.

## RESULTS

The search strategy identified 1024 records from the four electronic databases. After the removal of duplicates, 732 records were screened based on title and abstracts. After removing 689 records with unrelated target topics, 43 papers remained for screening. At the end of the process, we collected qualitative data from 27 studies, all involving neurotypical subjects, whereas data from 15 studies were quantitatively analysed through meta-analysis.

The PRISMA flow diagram of the review process is displayed in Figure 1.

## Description of the studies

### Included studies

Among the included studies, we did not find studies that involved post-stroke aphasia patients performing the tasks. All the included studies involved neurotypical adults, with 536 enrolled participants overall. All studies presented bimodal tasks, during which participants were exposed to a condition with co-speech gestures and their relative speech, and unimodal tasks, in which the condition involved speech or gesture only. In relation to the type of task, in 23 studies participants were asked to watch videos of actors producing gestures and/or speech, while performing an implicit or explicit comprehension task (Biau et al., 2016; Cuevas et al., 2019; Dick et al., 2009, 2014; Enrici et al., 2011; Green et al., 2009; He et al., 2015; Holle et al., 2008, 2010; Hubbard et al., 2009; Josse et al., 2012; Jouravlev et al., 2019; Kircher et al., 2009; Nagels et al., 2013; Redcay et al., 2016; Skipper et al., 2009; Steines et al., 2021; Straube et al., 2009, 2011, 2012, 2018; Willems et al., 2007, 2009). Conversely, in the remaining four studies the task involved the production of speech, with related or unrelated co-speech gestures (Brown & Yuan, 2018; Committeri et al., 2015; Hamzei et al., 2003; Marstaller & Burianova, 2015). With regard to gestures used during the tasks, all studies but four (Biau et al., 2016; Committeri et al., 2015; Hamzei et al., 2003; Willems et al., 2009) tested the processing of iconic or metaphoric co-speech gestures. Action words accompanied by gestures were used by Hamzei et al. (2003), whereas Biau et al. extracted video clips from a political discourse containing beat and cohesive gestures, and created four different conditions for each video in which beat gestures were synchronized or desynchronized with visual information (Biau et al., 2016). In the study performed by Committeri and colleagues, pointing gestures were used during a production task (Committeri et al., 2015). Finally, in the study by Willems and colleagues, pantomimes were used as stimuli during both unimodal pantomime condition and bimodal speech–gesture and speech–pantomime combinations (Willems et al., 2009).

For a detailed description of the characteristics of the included studies, see Table S1 in the Supplementary materials.

### Excluded studies

After full-text screening, 16 studies were excluded from the review. Four of them had different aims (Cuevas et al., 2021; Häberling et al., 2016; Krönke et al., 2013; Wolf et al., 2017), whereas three studies did not use fMRI during the tasks (Akbıyık et al., 2018; Bernard et al., 2015; Vigliocco et al., 2020). Six studies did not compare bi- with unimodal tasks (de Zubicaray et al., 2017; Kable et al., 2005; Miyahara et al., 2013; Peran et al., 2010; Postle et al., 2008; Straube et al., 2014). Okamoto and colleagues focused their research on hand gesture imitation, so their study was excluded (Okamoto et al., 2021). Finally, we excluded two studies in which emblems were used during the tasks (Andric et al., 2013; Straube et al., 2013).

## Contrast analysis

Meta-analyses were conducted by merging data from studies all involving neurotypical adults, as we did not find studies with post-stroke aphasia patients.

The meta-analysis performed for the two unimodal conditions found no significant clusters.

The meta-analysis contrasting bi- and unimodal conditions found three clusters, showing a significant activation

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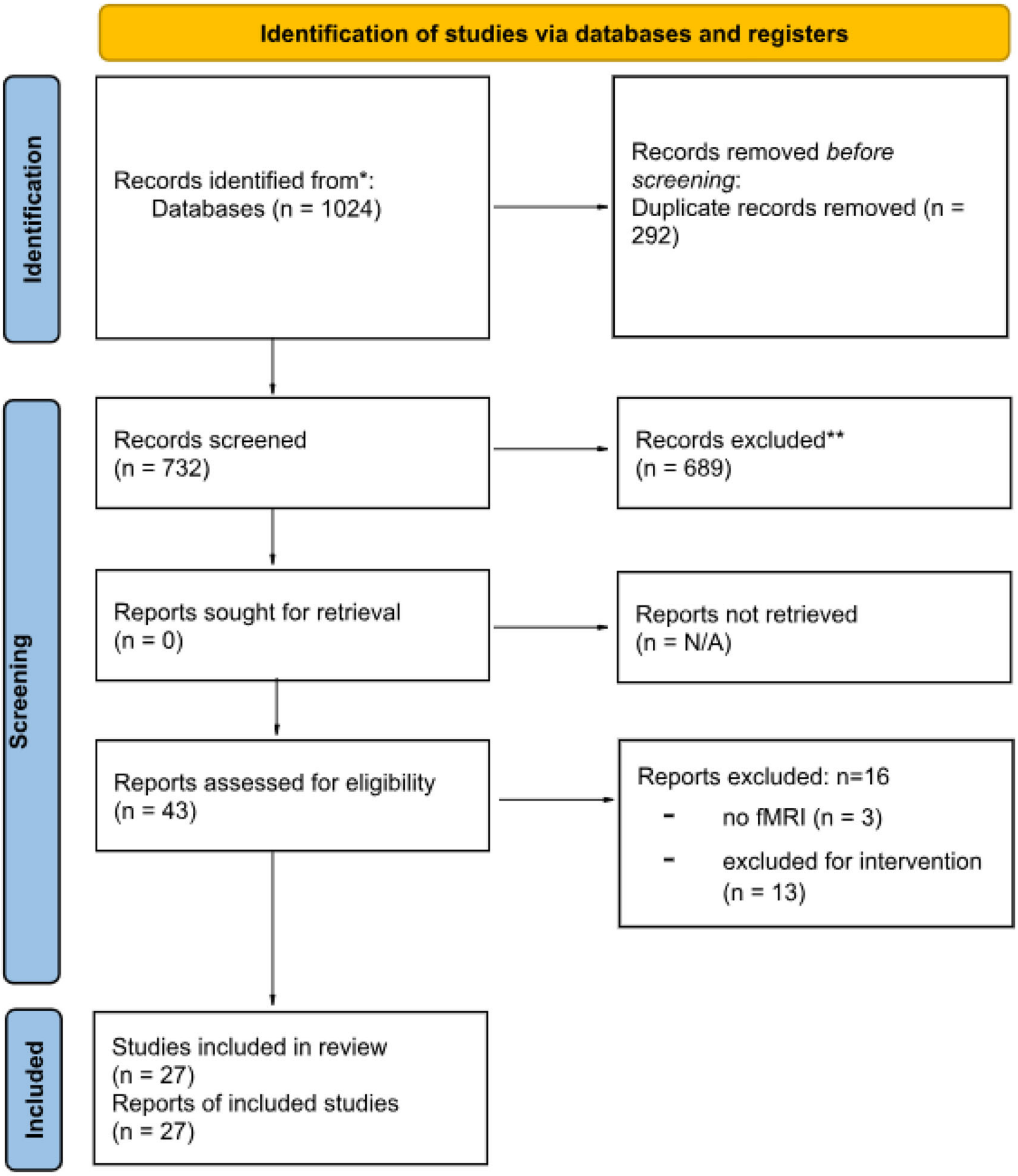

**FIGURE 1** Prisma flow diagram. [Colour figure can be viewed at wileyonlinelibrary.com]

**TABLE 1** Results of activation likelihood estimation (ALE) meta-analysis activation peaks report (coordinates in MNI space).

| Cluster | Size (mm$^3$) | *x* | *y* | *z* | *P* | Brodmann area | Anatomical region |
|---|---|---|---|---|---|---|---|
| 1 | 1152 | 50 | −68 | 0 | 4.31E+00 | 37 | Right inferior temporal gyrus |
| 2 | 800 | −44 | 12 | 24 | 3.14E+01 | 9 | Left inferior frontal gyrus |
| 3 | 752 | −46 | −74 | 4 | 2.40E+01 | 37 | Left inferior temporal gyrus |

in the middle frontal gyrus (MFG) and the IFG of the left frontal lobe, in the left middle occipital gyrus (MOG) and inferior temporal gyrus (ITG) and in the ITG, MTG and MOG of the right occipital and temporal lobe. Details of the activation peaks are shown in Figure 2 and Table 1.

## DISCUSSION

The main aim of the present study was to identify the neural substrate of gestures and language processing. We provided a quantitative map of the brain areas involved in

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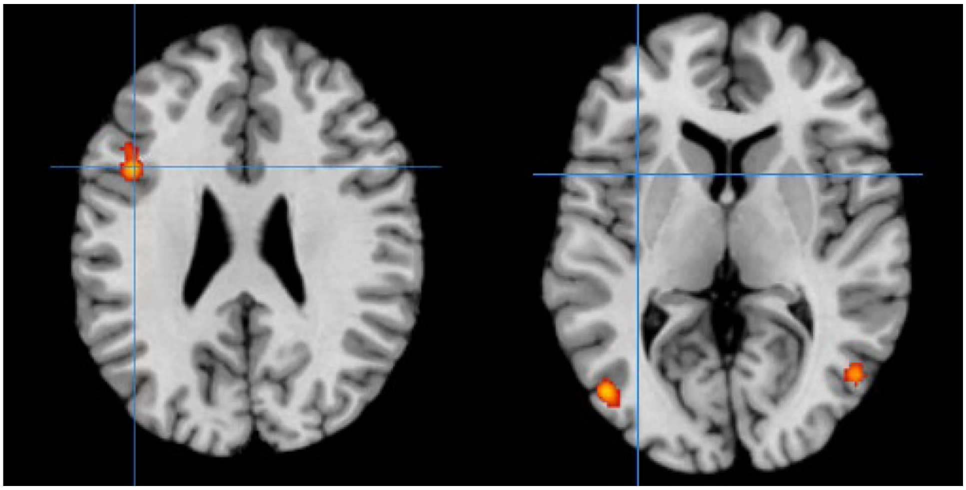

FIGURE 2 Activation likelihood estimation (ALE) effects for the contrast between bimodal co-speech gestures + speech versus unimodal speech or gesture only conditions. [Colour figure can be viewed at wileyonlinelibrary.com]

the processing of co-speech gestures and speech alone. We conducted an ALE meta-analysis on studies involving execution of a task with the use of iconic, metaphoric or beat gestures with their relative speech, compared to a speech only condition, while performing an fMRI scan session.

Results suggest that there is a general activity pattern related to co-speech and speech integration and processing, which involves the MFG and the IFG of the left hemisphere, and the ITG and the MOG of the left hemisphere and their homologues in the right hemisphere. These results are consistent with those found by authors who support the idea of the presence of a common neural substrate between the processing of these two communication modalities (Meghan & Allen, 2013; Straube et al., 2012). However, some authors suggest that co-speech gestures are processed in brain regions distinct from those supporting language comprehension, as language-processing related regions do not respond to co-speech gestures in the absence of speech, indicating that these regions are selectively driven by linguistic input (Jouravlev et al., 2019). In this regard, we know that gestures can express concrete meanings through iconic gestures, or abstract meanings through metaphoric gestures, and that they are semantically related to the speech they accompany. Indeed, the left MFG is involved in semantic processing (Demb et al., 1995; Kapur et al., 1996), whereas left IFG is known to be involved in semantic categorization, syntactic processing and metaphor comprehension (Hugdahl et al., 1999; Shibata et al., 2007; Wang et al., 2008). Therefore, we can propose the presence of a common neural network for gestures and language processing, which relies on the semantic processing and categorization of both speech and co-speech gestures. Indeed, iconic and metaphoric co-speech gestures provide information that are highly related to the semantic content of the speech they accompany and, reasonably, the relationship between gesture and language processing rely on this semantic component. The importance of the left IFG in processing meaning for both speech and gestures has already been documented, and activity of this region has been found in studies focused on language (Devlin et al., 2003; Friederici et al., 2000; Gold et al., 2005) and gestures (Kircher et al., 2009; Straube et al., 2011; Willems et al., 2007) processing in neurotypical subjects, as well as in studies enrolling stroke survivors (Weiss et al., 2016). Indeed, it has been shown that left frontoparietal lesions involving the IFG are associated with impaired action recognition, even when the action has to be recognized by sounds typically related to that action (Pazzaglia et al., 2008a, 2008b). Our analyses showed also a significant activation in bilateral MTG, which is known to be involved in the retrieval of lexical–semantic information during word processing (i.e., left MTG). At the same time, the left MTG seems to be involved in the processing of semantic information of iconic and metaphoric gestures (Yang et al., 2015), suggesting that MTG can play a role in retrieving lexical–semantic information from both speech and gesture. In previous research it was demonstrated that there was a common activation in the bilateral MTG during audiovisual observation of speech and gestures. These findings suggest that the MTG is involved in conceptual retrieval and integration regardless of the modality used (Binder et al., 2009). Consistently with current literature, we interpreted our findings as reflecting the contribution of gestures in reducing the ambiguity of the message and retrieval demands, as well as adding relevant semantic information to the message conveyed by the speaker. The involvement of areas supporting auditory and visual processing indeed reflects the fact that,

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during co-speech gesture processing, visual information about hand movements and auditory information about speech might be integrated in shared brain regions, highlighting a multisensory integration of speech sounds and gesture movements. In this sense, gestures play a crucial role not only for lexical retrieval, but also during social communication. Indeed, the use of gesture can maximize the communicative effectiveness of the speaker, but it can also help the listener to better understand the message conveyed. All these results support the idea that co-speech gestures are not perceived as a body language independent from speech, but rather as part of a multimodal communication closely linked to spoken language.

The facilitating effect and the functional role of gestures in natural communication are key factors when translating evidence into clinical practice for communication impairments resulted from different pathologies (i.e., aphasia, autism spectrum disorders, schizophrenia). Knowledge of the functions related to these neural networks will allow for the adoption of model-based neurorehabilitation programs to foster recovery from aphasia by strengthening the specific functions of these brain networks, potentiated with different intervention strategies (Berthier & Pulvermuller, 2011) (e.g., brain stimulation techniques such as transcranial magnetic stimulation or transcranial direct current stimulation can be used to improve gesture performance in neurological or psychiatric patients). We know that speech–language interventions aim at improving language or communication abilities, activities and participation, by improving the ability to communicate successfully a message that relies on spoken, written or non-verbal modalities (Brady et al., 2016). As it is frequently difficult, for a PWA, to access to the lexicon through spoken modality, it is important to provide treatment programmes aimed at stimulating the use of co-speech gestures to help language recovery, and also the use of emblems and pantomimes when attempts for verbal production fail. We can indeed exploit the use of gestures and the semantic information they add to the speech they accompany during rehabilitation treatments, for channelling lexical retrieval. That is, we can stimulate the use of gestures at the time an anomia occurs, thus facilitating verbal production. Furthermore, we can use co-speech gestures to foster the comprehension abilities of our listener. On the other hand, knowing the clinical–anatomical correlations and the fact that lesions in particular regions give rise to a set of symptoms can help clinicians to develop treatment approaches targeted at improving the specific functions. That is, in the case of gesture and language processing, a lesion in areas involved in multimodal processing and multisensory integration of speech and gesture can firstly provide information on the deficit we can expect to observe in PWA, and then guide the choice of the most appropriate treatment approach that should not consider language functions as separate to gestures.

## LIMITATIONS

Some limitations need to be addressed for this study. fMRI techniques register neuronal activity indirectly through the regional increases of the BOLD signal, and this signal could be confounded by biological, technical and methodological factors (e.g., fMRI acquisition technique, the behavioural and stimulation protocols, the fMRI data-analysis methods, how the neuronal activity itself is measured, respiration variations, head motion) (Birn et al., 2006; Heeger & Ress, 2002; Zeng et al., 2014). Furthermore, the BOLD signal needs some seconds to be detected, whereas neural processing occurs within milliseconds, setting a problem of temporal resolution of the fMRI technique. All these factors can be confounding, making results from a single underpowered fMRI study not reliable because of small sample size. Hence, the need to conduct meta-analyses to merge results from several single homogeneous studies, to improve the external validity by quantitative summary findings. Furthermore, the statistical power of these studies is relatively low due to small sample sizes from each study. Finally, it has to be considered that only 15 out of 30 included studies reported data that can be extracted for the meta-analysis, highlighting the existence of a gap between data analysed and quantitative findings summarized for quantification and localization of the cerebral regions activated, when communicating with co-speech gestures.

## CONCLUSIONS

Co-speech gestures play an important role during human communication. Our results showed that during processing of bi- and unimodal communication, areas related to semantic processing and multimodal processing are activated. A multisensory integration of speech sounds and gesture movements is highlighted by the involvement of areas supporting auditory and visual processing, which reflects the possibility that visual information about hand movements and auditory information about speech may be integrated at neural level during co-speech gesture processing. These findings suggest not only that there is a close link between co-speech gestures and spoken language at neural level, but they can also give insights for the choice of the most appropriate treatment approach that can consider multimodal communication as an ally to foster language recovery. However, no studies were found on participants after stroke, and this could be an interesting population

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to focus on for future research. Furthermore, it would be equally interesting for future research to investigate how brain areas are mutually interconnected to support the processing of a communicative message.

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## CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

## DATA AVAILABILITY STATEMENT

The datasets for meta-analysis that support the findings of this study are available from the corresponding author upon request.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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## APPENDIX A: SEARCH SYNTAX

### PUBMED

1. 'Adult'[Mesh] OR cerebrovascular disorders [MeSH] OR stroke [MeSH] OR brain infarction [MeSH] OR 'Aphasia'[Mesh] OR 'Aphasia, Broca'[Mesh] OR 'Anomia'[Mesh] OR 'Aphasia, Conduction'[Mesh] OR 'Aphasia, Wernicke'[Mesh]OR poststroke OR post-stroke OR cerebrovasc* or 'cerebral vascular' OR adult* OR stroke OR 'healthy adult*' OR healthy OR aphasia
2. 'Magnetic Resonance Imaging'[Mesh] OR fMRI OR 'Functional Magnetic Resonance Imaging' OR 'Functional MRIs'
3. 'Gestures'[Mesh] OR 'gesture comprehension' OR 'gesture perception' OR 'gesture recognition' OR 'gesture decoding' OR 'action recognition' OR 'iconic gesture*' OR 'co-speech gesture*' OR 'metaphoric gesture*' OR gesture* OR 'gesture production' OR 'action word*'

#1 AND #2 AND #3

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### EMBASE

1. 'Adult'/de OR cerebrovascular disorders/de OR stroke/de OR brain infarction/de OR 'Aphasia'/de OR 'Aphasia, Broca'/de OR 'Anomia'/de OR 'Aphasia, Conduction'/de OR 'Aphasia, Wernicke'/de OR poststroke OR post-stroke OR cerebrovasc* or 'cerebral vascular' OR adult* OR stroke OR 'healthy adult*' OR healthy OR aphasia
2. 'Magnetic Resonance Imaging'/de OR fMRI OR 'Functional Magnetic Resonance Imaging' OR 'Functional MRIs'
3. 'Gestures'/de OR 'gesture comprehension' OR 'gesture perception' OR 'gesture recognition' OR 'gesture decoding' OR 'action recognition' OR 'iconic gesture*' OR 'co-speech gesture*' OR 'metaphoric gesture*' OR gesture* OR 'gesture production' OR 'action word*'

#1 AND #2 AND #3

### WEB OF SCIENCE

1. WC = (Neuroimaging)
2. TS = ('Adult' OR cerebrovascular disorders OR stroke OR brain infarction OR 'Aphasia' OR 'Aphasia, Broca' OR 'Anomia' OR 'Aphasia, Conduction' OR 'Aphasia, Wernicke' OR poststroke OR post-stroke OR cerebrovasc* or 'cerebral vascular' OR adult* OR stroke OR 'healthy adult*' OR healthy OR aphasia)
3. TS = ('Magnetic Resonance Imaging' OR fMRI OR 'Functional Magnetic Resonance Imaging' OR 'Functional MRIs')
4. TS = ('Gestures' OR 'gesture comprehension' OR 'gesture perception' OR 'gesture recognition' OR 'gesture decoding' OR 'action recognition' OR 'iconic gesture*' OR 'co-speech gesture*' OR 'metaphoric gesture*' OR gesture* OR 'gesture production' OR 'action word*')

#1 AND #2 AND #3 AND #4

### COCHRANE

#1 MeSH descriptor: [Adult] this term only
#2 MeSH descriptor: [Cerebrovascular Disorders] explode all trees
#3 MeSH descriptor: [Stroke] explode all trees
#4 MeSH descriptor: [Brain Infarction] explode all trees
#5 MeSH descriptor: [Aphasia] explode all trees
#6 MeSH descriptor: [Aphasia, Broca] explode all trees
#7 MeSH descriptor: [Anomia] explode all trees
#8 MeSH descriptor: [Aphasia, Conduction] explode all trees
#9 MeSH descriptor: [Aphasia, Wernicke] explode all trees
#10 (poststroke OR post-stroke OR cerebrovasc* or 'cerebral vascular' OR adult* OR stroke OR 'healthy adult*' OR healthy OR aphasia):ti,ab,kw (Word variations have been searched)
#11 #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10
#12 MeSH descriptor: [Magnetic Resonance Imaging] explode all trees
#13 (fMRI OR 'Functional Magnetic Resonance Imaging' OR 'Functional MRIs'):ti,ab,kw (Word variations have been searched)
#14 #12 OR #13
#15 MeSH descriptor: [Gestures] explode all trees
#16 ('gesture comprehension' OR 'gesture perception' OR 'gesture recognition' OR 'gesture decoding' OR 'action recognition' OR 'iconic gesture*' OR 'co-speech gesture*' OR 'metaphoric gesture*' OR gesture* OR 'gesture production' OR 'action word*'):ti,ab,kw (Word variations have been searched)
#17 #15 OR #16
#18 #11 AND #14 AND #17

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