Gestures and metaphor – evidence for gestures' self-oriented functions and hemispheric involvement for speech production

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October 2015

Abstract

The current thesis investigates the link between gestures and representation of abstract meaning in the form of metaphor. The big question addressed in the thesis is whether gestures with a particular hand, enhance cognitive processing in the contra-lateral hemisphere, such that left-hand gestures compared to right-hand gestures enhance metaphor processing which particularly involves the right hemisphere. In Chapter 3, we investigated whether left-hand co-speech gestures improve explanation of metaphorical phrases compared to right-hand gestures or not gesturing at all. Additionally, we collected individual measurements for hemispheric involvement during speech production using the mouth asymmetry technique. We found a left-over-right hand gesturing advantage, which was higher for those with stronger right hemispheric involvement during speech production. This finding suggested that gestures with the left hand help the metaphorical mapping of concrete to abstract concepts which particularly involves the right-hemipshere. In Chapter 4, we investigated whether co-speech left-hand gestures rather than meaningless tapping movements trigger metaphorical language use. We found no evidence that left-hand gestures compared to left-hand taps increase the likelihood for metaphorical language use. However, we found that gestures compared to taps increased the number of words uttered, which in turn led to the use of more metaphors. This finding points towards gestures' facilitative effect on speech production, but further research is needed to pin-point exactly what process is facilitated. In Chapter 5, we investigated whether action gestures with a particular hand, when produced without speech, prime semantic categorisation of sentences (metaphorical and literal). We found no evidence for priming effects, and further research is needed to examine the effects that gestures, when produced alone might have on semantic processing. Finally, in Chapter 6 we found that producing content words related to metaphor compared to function words, makes metaphor processing right hemisphere specific. This indicated that semantic processing is the key to the

lateralisation of metaphor processing. The results validated the use of the mouth asymmetry technique as a measurement of hemispheric involvement during speech production tasks.

Acknowledgments

First and foremost, I would like to thank my supervisor Prof Sotaro Kita for his guidance throughout my PhD. His passion, positive attitude, patience and research ethos have been motivating even during the tough times of my PhD. I am also thankful to Dr Peter Hansen for our fruitful discussions about future projects. Special thanks to all the members of the “language and cognition group” at the University of Birmingham for the comments and feedback I received during lab meetings, and to Nuredin Ibrahim for his advice on linear mixed effects model analysis.

I would also like to thank Sarah Byfield, Louisa Hughes, and Hsiang-Ting Chen for their help with recruitment, testing, and reliability coding (Chapter 3, 4, 6). Also, Sam Westwood for his assistance with reliability coding (Chapter 3), and Kazuki Sekine for his help with stimuli creation (Chapter 5). Finally, I thank Olivia Andrade for proofreading Chapters 2 and 7 of my thesis.

I am thankful to the ESRC and the Alexander S. Onassis Public Benefit Foundation for funding this PhD. Without their funding support I could not complete this research.

Finally, I thank my family and all my friends who supported me throughout the PhD by listening to my worries or spending time with me. I am deeply grateful to my mother and sister, for always being there for me and showing me the silver linings.

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The following list includes the papers published and/or submitted for publication taken from this thesis.

Chapter 3

Argyriou, P., Mohr, C., & Kita, S. (invited to resubmit). Hand matters: Left-hand gestures enhance metaphor explanation. *Journal of Experimental Psychology: Language, Memory and Cognition.*

Chapter 3 (Experiment 1)

Argyriou, P. & Kita, S. (2013). The effect of left-hand gestures on metaphor explanation. In M. Knauff, M. Pauen, N. Sebanz, & I. Wachsmuth (Eds.), Proceedings of the 35th Annual Conference of the Cognitive Science Society (pp. 1762-1767). Austin, TX: Cognitive Science Society.

Chapter 6

Argyriou, P., Byfield, S., & Kita, S. (2015). Semantics is crucial for the right-hemisphere involvement in metaphor processing: Evidence from mouth asymmetry during speaking. *Laterality: Asymmetries of Body, Brain and Cognition*, *20*(2): 191-210.

1 Overview of thesis

The current thesis investigates the link between gestures and metaphor and provides evidence for gestures' self-oriented functions and the hemispheric involvement for metaphor processing. It contains seven chapters (including this one).

Chapter 2 contains the review of the literature. This chapter integrates semantic theories on the role of sensory-motor information for meaning representation. It also reviews research and theories on metaphor as a way of grounding abstract meaning into sensory-motor experience. In addition, it includes a review of theories on gestures and their functions. Finally, it contains a review of theories and studies about the involvement of brain hemispheres for gesture and speech production, and metaphor processing.

Chapter 3 includes the first experimental study in the form of an article. This study investigated whether left hand co-speech gestures improve explanation of metaphorical phrases as opposed to right hand gestures or not gesturing at all. It also investigated whether this left-over-right hand gesturing advantage relates with the right hemispheric involvement during speech production measured by asymmetric mouth movements.

Chapter 4 contains the second experimental study in the form of an article. This study investigated whether left hand co-speech gestures compared to left hand meaningless tapping movements trigger the use of metaphorical language.

Chapter 5 includes the third experimental study in the form of an article. This study examined whether gestures with a particular hand without speech, prime the semantic categorisation of metaphorical and literal sentences.

Chapter 6 contains the fourth experimental study in the form of an article. This study examined whether the right hemisphere is particularly involved in metaphorical as opposed to concrete speech production. It also investigated if semantics is crucial for this particular involvement. In this study we used the mouth asymmetry technique as a valid measurement of hemispheric involvement in speech production tasks.

Finally, the thesis contains a general discussion (Chapter 7). This chapter brings all the previous chapters together, outlines the findings and conclusions of the empirical studies, and puts them in the context of the literature. Additionally, it includes suggestions for future work.

2 Literature review

The next sections include the review of literature, which has informed and motivated the current thesis. Parts of the literature are reviewed (a) to set the background, which the thesis falls within and aims to extend, (b) to reveal gaps and new research questions, which the thesis aims to address, and (c) to inform methodologically the empirical studies conducted (e.g., choice of linguistic task and measurements; experimental manipulations).

The current thesis focuses on the link between gestures and metaphor processing and the issues surrounding this. It falls within the embodied semantic accounts, which acknowledge a functional role of sensory-motor information systems for processing meaning, and investigates whether gestures have an effect on the embodied representation of abstract meaning in the form of metaphor. In addition, it draws upon the approaches on gestures' self-oriented functions, and investigates whether hand choice for gesturing affects the degree of gestures' impact on metaphor processing. Finally, it sheds more light on the hemispheric involvement for metaphor processing, focusing on production tasks.

2.1 Embodied and disembodied semantic theories

Several theoretical accounts have been proposed to explain how meaning is represented, and whether sensory-motor information is necessary for processing and representing meaning (= semantics). The current thesis draws upon the "continuum" of semantic theories, as introduced in Meteyard, Cuadrado, Bahrami, and Vigliocco (2012), and falls in line with the embodied accounts. In the next section we describe the two extremes of the continuum (i.e., disembodiment and strong embodiment) and the accounts in the middle (i.e., secondary and weak embodiment).

Disembodiment

The disembodied theories suggest that sensory-motor information has no role for semantic representation. This means that there is a symbolic association between the meaning and the reference. This symbolic and arbitrary conceptual knowledge is all we need to know about the world. For example, Levelt's model of language production (1989) suggested that language is symbolic and propositional. The four components of language production (conceptualiser, formulator, articulator, speech comprehension system) are independent, autonomous modules. In particular, the conceptualiser, which is responsible for conceptually encoding information, does so by accessing declarative knowledge (i.e., encyclopaedic knowledge of the world), the situation and discourse. In turn, symbolic lexical representations are activated to generate messages (Levelt, 1989). Similarly, Landauer and Dumais (1997) introduced the Latent Semantic Analysis to explain knowledge representation and word learning. They proposed that what defines meaning representation is the relations between words, and the mechanisms to extract those relations (e.g., induction), rather than the word references.

Strong Embodiment

Theories of strong embodiment place simulation (i.e., re-creation of our direct experience with the world by modulation of primary sensory-motor areas) in the heart of meaning representation, hence semantic processing highly depends on sensory-motor systems. The Indexical Hypothesis (Glenberg & Kaschak, 2003) suggested that language and perception and action systems are tightly linked in such a way that language comprehension is achieved by performing simulations using the same neural systems responsible for action planning and execution. In the same line, Zwaan and Ross (2004) introduced the Immersed

Experiencer Framework according to which words activate referent-specific "vicarious" experiences. Perceptual and motor representations are necessary for language comprehension, to reconstruct an experience cued by the linguistic input and integrated with its referent. Finally, Gallese and Lakoff (2005) suggested that the sensory-motor systems characterise both concrete and abstract concepts. To understand the meaning of an action concept such as "grasp" we should be able to re-create the experience of grasping. This conceptualisation of grasping via imaginative simulation uses the same functional clusters as in real action and perception of grasping. Crucially, these functional clusters and imaginative simulations are used to perform abstract conceptual inferences and reasoning to represent abstract meaning.

Secondary Embodiment

The theories of secondary embodiment suggest that conceptual representation of meaning is abstract and amodal, but an instant-specific passive activation of sensory-motor information could be possible to make representations more specific. For example, Mahon and Caramazza (2008) introduced the general Domain-Specific Sensory-Motor Hypothesis and the "grounding-by-interaction" account for meaning representation. According to this account, conceptual knowledge has an abstract and symbolic level, which is not necessarily constituted by sensory-motor information (similarly to disembodied accounts). However, sensory-motor information can enrich and complement conceptual knowledge, and place it within a relational context (contrary to disembodied accounts). For example, apraxic patients see an object (e.g., hammer) and name it without difficulty or say that it is used with nails. However, they cannot demonstrate how the object is used, and this impairment is not due to peripheral motor deficits (for example patients produce meaningless movements). Part of what we know about the world is not dependent on sensory-motor information only, but other parts depend on the interaction between symbolic content and sensory-motor information

(Mahon & Caramazza, 2008). Therefore, the account is freeing cognition and conceptual representations from bodily experiences, but at the same time allows their interaction for enrichment of representations. Similarly, Patterson, Nestor, and Rogers (2007) suggested that sensory-motor systems are not necessary for abstract, general content (e.g., when seeing a robin name it "bird"), but sensory-motor specific representations are instantiated only when representing specific content (e.g., "robin"). The authors suggested that the anterior temporal lobe has a particular role for this process, acting as a semantic hub in combination with distributed sensory and motor regions (Patterson et al., 2007).

Weak Embodiment

Theories of weak embodiment acknowledge an active representational role for sensory-motor information (contrary to disembodiment and secondary embodiment), thus semantic processing partially depends on sensory-motor systems, but not primary sensory-motor cortical regions (contrary to strong embodiment).

One hypothesis (Featural and Unitary Semantic Space hypothesis; Vigliocco, Vinson, Lewis, & Garrett, 2004) suggests that the meanings of words derive at two levels which both interact with sensory-motor systems. At one level the meanings of words can be conceived as featural representations of conceptual knowledge, and they follow the organisation of the modality-specific sensory-motor systems (e.g., visual, motor). At a separate level, meaning derives by the organisation of the conceptual features into lexico-semantic representations, which are partly grounded into sensory-motor representations (Vigliocco et al., 2004). In addition, work by Damasio (1989) suggests that conceptual knowledge about an entity is held in convergence zones in the brain, which are the neurons that store the association between modalities. Low order convergence zones include regions responding to modality-specific features and high order zones include regions responding to patterns of these features for a specific input (e.g., visual for seeing an entity). Therefore, both of them are necessary for representations (Damasio, 1989). The perceptual model of knowledge (Barsalou, 1999) suggests that we create schematic representation of meaning based on the perceptual components we extract from our experience with the world. Then, limitless simulations of these components are created based on sensory-motor experience, proprioception and introspection. These simulators can be integrated to create a fully functional conceptual system to include representations of concrete and abstract concepts. Finally, Pulvermüller (1999) suggests that meaning representation is dependent on the association between cortical areas related to the word form and areas related to the word referent, hence highly dependent on sensory-motor information systems. This dependence occurs for some symbols but not all (e.g., abstract), hence Pulvermüller's account can not be considered as strongly embodied.

2.1.1 Empirical evidence for embodiment

The empirical evidence supporting the embodied cognition account is mainly of three types: (a) behavioural demonstrations for an inter-relation between language and action, (b) neurophysiological evidence that the motor system is activated during perceptual and conceptual processing and that sentence comprehension can trigger activation of the sensory-motor systems, and (c) cases that patients with deficits in the motor system exhibit poor processing of action verbs. In addition, most of the studies have sought to demonstrate that the activation of the motor system during conceptual processing is fast, automatic and somatotopic. Finally, evidence for the relationship between language and action comes from research on the link between gestures and language.

Behavioural studies provided evidence for the inter-relation between action and meaning by measuring performance during concurrent visuo-motoric and linguistic tasks.

Boulenger et al. (2006) measured participants' performance in a reaching task (i.e., lift your arm from a pad and grasp an object if a letter string is a word, and lift your arm but do not grasp the object if a letter string is a non-word). The reaching task was either concurrent with or followed the lexical decision task. Words were either action verbs (e.g., "paint") or concrete nouns (e.g., "star"). Results showed that processing action verbs, but not concrete nouns, interfered with the reaching movement when the motoric and linguistic tasks co-occurred, but facilitated it when the lexical decision preceded the reaching movement. This finding suggested that cortical motor regions are activated when processing action words. In addition, Meteyard, Bahrami, and Vigliocco (2007) measured participants' performance in a motion-detection task (i.e., participants had to indicate whether or not they saw movement in visually presented stimuli). During the task participants passively listened to verbs referring to upward or downward movement. Results showed that listening to verbs mismatching with the motion direction of the visual stimuli impaired perceptual sensitivity. Thus, low-level perception can be affected by language processing. Similarly, Kaschak et al. (2005) asked participants to listen and judge the sensibility of sentences representing motion towards (e.g., "the car approached you") or away (e.g., "the squirrel scurried away"), while watching visual stimuli representing motion direction. The sensibility judgement was slowed down when the sentence and the visual stimuli represented the same motion direction. Thus, there is an overlap between the systems of perceiving the motion and understanding the motion sentence. In Glenberg and Kaschak (2002), participants judged whether sentences were meaningful by making a response that required moving toward or away from their bodies. When a sentence implied action in one direction (e.g., "close the drawer" implies action away from the body), the participants performed worse in sensibility judgment that required a response in the opposite direction. This "action sentence compatibility effect" was demonstrated for three sentences types: imperative sentences, sentences describing the transfer of concrete objects, and sentences describing the transfer of abstract entities, such as "Liz told you the story" (in this phrase information is moving away from the body). Findings from these studies suggest that language processing (even when action is not explicitly encoded) share representations with the motor system.

A few additional behavioural studies have extended the previous findings to provide evidence for the inter-relation between action and metaphorical language. In particular, Wilson and Gibbs (2007) showed that real and imagined bodily movements congruent to metaphorical phrases facilitate people's immediate comprehension of these phrases. For example, when participants executed, or imagined the execution of, a "grasping" hand movement, they were faster to understand the meaning of a subsequently presented metaphorical phrase "to grasp a concept", as compared to when primed with a mismatching movement or no movement. In addition, Santana and de Vega (2011) found that reading an upward metaphor such as "rise to victory" reduced the time for eliciting a concurrent upward hand movement. The action-to-meaning and meaning-to-action effects obtained in these two studies suggest that the motor component is not only important for processing of concrete action meaning, but also for abstract action meaning in the form of metaphor.

Neurophysiological studies provide evidence that the motor system is activated during perceptual and conceptual processing and that sentence comprehension can trigger activation of the sensory-motor systems. For example, processing of body-part specific action words (e.g., "kick", "pick") includes neurons involved in the programming of the respective actions (e.g., leg- and arm- related areas) (Hauk, Johnsrude, & Pulvermüller, 2004; Hauk & Pulvermüller, 2004). Similarly, Aziz-Zadeh, Wilson, Rizzolatti, and Iacoboni (2006) extended these findings to the sentence level. The study found motor activations during conceptual processing (in a passive reading task) of phrases describing literal action (e.g., "grasping the scissors"). Along the same line, Tettamanti et al. (2005) showed that listening to sentences that describe actions (arm-, mouth-, leg- related) engaged the visuo-motor circuits, which also sub-serve action execution and observation. Furthermore, Glenberg et al. (2008) explored the role of the motor system during comprehension of concrete and abstract language using transcranial magnetic stimulation. They found greater motor system modulation, evidenced by larger motor evoked potentials, for transfer (including abstract transfer sentences such as “delegate responsibilities”) than non-transfer sentences. Finally, even comprehension of sentences that imply motor information but do not lexically encode it, such as indirect requests for action (e.g., “it is hot in here” – implying the opening of a window) activate cortical motor regions (van Ackeren, Casasanto, Bekkering, Hagoort, & Rueschemeyer, 2012).

A few additional neurophysiological studies have extended previous findings to include the inter-relation between perceptual-motor information and metaphorical meaning. Desai and colleagues explored the inter-relation between sensory-motor and conceptual system in the brain in two fMRI studies (Desai, Binder, Conant, Mano, & Seidenberg, 2011; Desai, Conant, Binder, Park, & Seidenberg, 2013). They compared brain activations during meaningful judgment of literal, metaphorical and abstract action sentences (e.g., “the thief bashed the table”, “the council bashed the proposal”, “the council criticised the proposal”, respectively). The literal and metaphorical sentences (but not the abstract) both activated secondary motor areas, which are also involved in action planning. This finding suggests that secondary sensory-motor systems play an important role for comprehension of literal and metaphorical action meaning (Desai et al., 2011; Desai et al., 2013). Similarly, Boulenger, Hauk, and Pulvermüller (2009) showed, for the first time[1], somatotopic semantic organisation and body-part specific motor cortex activation for the comprehension of idioms in a passive reading task. Leg-action idioms, such as “kick the habit”, activated the dorsal motor cortex

[1] Note that activation of the motor systems has not been found in other studies using idioms (Raposo, Moss, Stamatakis, & Tyler, 2009) and highly conventional metaphors (Aziz-Zadeh et al., 2006).

stronger than arm-action idioms, such as “grasp the idea”, which activated the lateral motor cortex.

Patient studies showed that deficits in the motor system also cause poor performance on processing action words. For example, Neininger and Pulvermüller (2003) showed that patients with deficits in the right frontal cortex (with no apparent aphasia) performed worse compared to healthy controls in the lexical decision of action verbs (but not in visually related nouns). Patients with right temporo-occipital deficits performed worse than healthy controls in the lexical decision of visually related nouns (but not in action verbs). Similarly, Boulenger et al. (2008) found impaired processing of action verbs for patients with Parkinson’s disease. They used a masked priming task to assess performance in a lexical decision task. Participants were patients with Parkinson disease in two groups: one being under treatment to activate motor cortices, and one receiving no treatment. The target stimuli were action verbs or concrete nouns. Findings showed that patients receiving no treatment performed worse, compared to those undergoing treatment, in the lexical decision of action verbs, but not nouns.

Finally, a distinct line of evidence for embodied semantics comes from gesture research. “Gestures are often considered to be valid evidence of the embodiment of language and cognition” (Hostetter & Alibali, 2008, p.495). According to embodied accounts of cognition, language processing (concrete and abstract) involves activation of images that rely on simulations of perception and action. Gestures emerge from these simulations of the motor and perceptual components of visuo-spatial imagery (Hostetter & Alibali, 2008). Gestures as bodily manifestation of these simulations can help the maintenance of mental images (Wesp, Hesse, Keutmann, & Wheaton, 2001), the identification and organisation of the features from these images to be uttered (Kita, 2000), the selection of words to be uttered (Rauscher, Krauss, & Chen, 1996), and the reduction of cognitive load for concurrent tasks (Goldin-

Meadow, 2003). Therefore, including gestures in the study of embodied semantics sheds more light in the inter-relation between perception, action, language and thought.

2.1.2 Embodiment: relevance to the thesis

The literature as reviewed in the above sections has motivated and informed the current thesis in several ways.

Firstly, *which side of the continuum of semantic theories is more likely to be correct*? Several studies provided evidence for the embodied accounts on the basis that the motor system is activated during conceptual processing (e.g., Aziz-Zadeh et al., 2006; Glenberg et al., 2008; Hauk et al., 2004; Hauk & Pulvermüller, 2004). But is this enough to falsify the disembodied accounts? It seems that the extreme disembodied and strongly embodied accounts cannot hold true. If disembodied accounts were true, how could encyclopaedic knowledge be enough to represent the whole range of knowledge? In addition, disembodied accounts, which rely on a system functionally detached from sensory-motor systems, cannot explain the process of semantic grounding. Namely how words and symbols are related to specific types of perceived objects and executable actions. On the other hand, evidence for embodied representation of abstract meaning is still weak (Kiefer & Pulvermüller, 2012). In addition, the bulk of the evidence for the embodied accounts comes from neuroimaging studies. This complicates interpretations, because brain activations are correlational and ambiguous with respect to the processing stage at which they occur. In addition, it is not clear whether sensory-motor activations reflect mental imagery processing or semantic processing. Furthermore, most studies supporting embodied accounts relate to language comprehension rather than production. The current thesis draws upon the embodied side of the continuum, and aims to provide more evidence for the embodied representation of abstract meaning in the form of metaphor, and from both comprehension and production of language. In addition, it investigates how important sensory-motor information is for semantic processing by focusing on the inter-relation between gestures and metaphor.

More specifically, in Chapters 3 and 4 we focused on metaphor as a way of semantically grounding abstract conceptual knowledge in sensory-motor experience. We measured two types of metaphorical processing, namely explanation of metaphorical phrases and spontaneous use of metaphorical expressions. We experimentally manipulated participants' hand movements (e.g., gesturing or tapping with different hands). If sensory-motor information is important for processing meaning and representing abstract meaning in the form of metaphor, then gestural representation of meaning should modulate the two types of metaphorical processing. Furthermore, in Chapter 5 we aimed to provide more direct evidence for the strong or weak embodied accounts by directly comparing the effects that gesture priming might have on the comprehension of metaphorical and literal action sentences. The priming paradigm addresses the issue of whether the two processes (gestural representation of visuo-spatial information and action sentence comprehension) interact: if so, they might prime each other.

To sum up, the current thesis focuses on metaphor and gesture as examples of embodied language and thought, and investigates their inter-relation. The next sections include review of the literature related to metaphor and gestures.

2.2 Metaphor: an example of abstract embodied semantics

2.2.1 Theories of metaphor

The pioneering work by Lakoff and Johnson almost thirty years ago challenged the traditional assumptions that metaphor is merely poetic and absent from everyday communication, and has no relation to the way we think. The current thesis follows the Conceptual Metaphor Theory (Lakoff & Johnson, 1980a), which is in line with embodied semantics, and suggests that knowledge is derived from sensory experience. The theory coherently explains the nature and structure of metaphor. However, we also acknowledge other theoretical accounts (Glucksberg, 1991; Searle, 1979), which are not necessarily mutually exclusive, rather complementary.

Conceptual Metaphor Theory

Metaphors are pervasive in our everyday thinking, speaking and acting. Lakoff and Johnson (1980a) suggested that our ordinary conceptual system when we think, speak and act is fundamentally metaphorical. They introduced the term of conceptual metaphors, which are reflected in language, and in the way we see and perceive the world. For example, the conceptual metaphor ARGUMENT IS WAR is lexically encoded in expressions such as "I demolished his argument", and it structures our understanding of someone we are arguing with as an opponent and our aggressive behaviour towards them.

According to the Conceptual Metaphor Theory, metaphor is a way to understand one concept in terms of another one (Lakoff, 1993; Lakoff & Johnson, 1980a). At the core of metaphor lie cross-domain mappings, which are central to ordinary natural language semantic processing. Metaphor can be understood as a mapping from a source domain to a target domain. The mappings are tightly structured and particular entities from the one domain, the target, (e.g., LOVE; the lovers, the relationship, their goals) correspond systematically to entities of the other, the source domain (e.g., JOURNEY; the travellers, the vehicle, destination). These mappings follow the Invariance Principle. That is "metaphorical mappings preserve the image-schema structure (i.e., the embodied prelinguistic structure of experience) of the source domain, in a way consistent with the inherent structure of the target domain" (Lakoff, 1993, p.199). In other words, mappings are under constraints for fixed correspondences (e.g., the battling aspects of an argument may include tension, hostility but not blood). Each mapping is fixed and conventional, however it creates limitless options for lexical items from each domain to be used and create novel metaphors. Mappings are motivated on an experiential basis such that “we see what someone means”, because in most cases only when we see something we understand it and we know it is true.

This view of metaphor raises two questions. First, are all concepts understood through metaphor? Lakoff’s and Johnson’s answer was that probably nothing is understood in its own terms; not even spatial concepts (like UP). Even these concrete, spatial concepts are understood through our constant spatial experiences and interaction with our physical environment (Lakoff & Johnson, 1980a). Second, does metaphorical speech really reflect metaphorical thought? In other words, how important are conceptual metaphors and mappings for the understanding and production of metaphor in everyday discourse? Different types of evidence confirm the importance of conceptual metaphors and mappings for understanding and producing meaning.

Firstly, from a historical perspective, metaphor is a mechanism for evolution of word meaning. Sweetser (1990) suggested that conceptual metaphors such as UNDERSTANDING IS SEEING explain the extension of the physical meaning of verbs like “see” towards a non-physical meaning (e.g., “I see your point”). Secondly, the systematicity of conventional metaphors as outlined in the work by Lakoff and Johnson provides evidence in favour of conceptual metaphors. This systematicity suggests that “metaphoric thought motivates linguistic meanings and has some role in people’s understanding of language”, and “metaphoric thought motivates an individual speaker’s use and understanding of why various words and expressions mean what they do” (Gibbs, 1998, p.92). In other words, the only way to explain why it is acceptable to talk about relationships using phrases such as “look how far we have come or we are at a crossroads” is by accepting that we understand the concept of love in terms of the concept of journey.

Thirdly, there is a line of empirical evidence suggesting that metaphoric thought and conceptual metaphors motivate why many expressions mean what they do, and influence people’s learning of linguistic meaning and immediate understanding. For example, in a mental imagery study, R. W. Gibbs and Obrien (1990) showed participants an idiomatic phrase (e.g., “flip your lid”) and asked them to explain it and then to form a mental image of the expression. They then had to verbally describe this image in detail. Findings showed that participants had similar schemas underlying their mental images for idioms with similar figurative meanings and those schemas were constrained to the underlying conceptual metaphor. For example, they would describe the mental image of both idioms “flip your lid” and “hit the ceiling” (meaning “to get angry”) with details about a container releasing pressure (based on the conceptual metaphor ANGER IS A HEATED FLUID IN A CONTAINER). Interestingly, participants were not consistent in their mental images of literal phrases (e.g., not everyone used the same detail when describing someone spilling peas). The authors suggested that the meaning of many idioms is not arbitrary, but motivated by speakers’ knowledge of the conceptual metaphors. However, they did not make strong claims about the automatic activation of mental imagery when listening, understanding and using idioms.

In addition, conceptual metaphorical mappings are a key part for metaphor interpretation. Nayak and Gibbs (1990) presented participants with short scenarios about an emotional concept, which were structured to include phrases priming a specific conceptual metaphor. For example, an emotional scenario about anger would include phrases such as “Mary was tense […] made her fume […] the pressure was building up” to prime the conceptual metaphor ANGER IS A HEATED FLUID IN A CONTAINER. After reading the texts participants had to select from two idioms, the one which more appropriately expressed the meaning of the scenario. The related idiom was motivated by the primed conceptual metaphor (e.g., “blew her top”) and the unrelated one had the same meaning but different underlying conceptual metaphor (e.g., “bit her head off”; ANGRY BEHAVIOUR IS ANIMAL BEHAVIOUR). Participants selected the related idiom thus suggesting that congruent conceptual mappings can prime each other. The authors suggested that the use of idioms can be conceptually motivated, however they did not make strong claims about conceptual metaphors being always instantiated when processing idioms.

Similarly, R. W. Gibbs, Bogdanovich, Sykes, and Barr (1997) showed that conceptual metaphors have a role in the on-line processing of idioms. In Experiment 1, participants performed a self-paced reading task of a short text finishing with an idiom (e.g., “he blew his stack”) or a literal paraphrase of the idiom (e.g., “he got very angry”) or a control sentence (e.g., “he saw many dents”). A visual lexical decision task followed. The words were either related to the conceptual metaphor underlying the preceding idiom (e.g., “heat”; motivated by the conceptual metaphor ANGER IS HEATED FLUID IN A CONTAINER) or unrelated (e.g., “lead”). Findings showed that participants’ lexical decision was faster when they responded to the related targets having read the idioms compared to reading literal paraphrases and control sentences. Thus, conceptual metaphors are accessed even when attention is not focused on metaphor. A control study further supported this suggestion. It could be that faster responses to the related target “heat” were because of the association of heat with the literal meaning of the idiom. However, it seems this was not the case. Participants read short texts followed by a literal use of idioms (e.g., “blow the stack”) or a literal paraphrase (e.g., “vacuum the dirt”) or a control phrase (e.g., “get a big truck”). Lexical decision of related (e.g., “heat”) and unrelated (e.g., “lead”) targets did not differ. In Experiment 2 participants read short stories, which ended with two idioms representing the same meaning but being motivated by different conceptual metaphors (e.g., “it was a shot in the arm”; motivated by the conceptual metaphor ENCOURAGEMENT IS GIVING SOMEONE A DRUG; “it really got her going”; motivated the conceptual metaphor ENCOURAGEMENT IS HELPING SOMEONE START A JOURNEY). They performed lexical decision on target words that were consistent with the one or the other idiom (e.g., “drug” was the related word consistent with the idiom “it was a shot in the arm” but not “it really got her going”). Findings showed that participants were faster only after reading idioms consistent and related to the target word. The authors suggested that conceptual metaphors can be quickly accessed during immediate idiom comprehension, however they did not make strong suggestions about the necessity for automatic access of conceptual metaphors in order to understand what an idiom means.

Finally, the conceptual metaphor theory has received support by brain-imaging research. The theory would predict that metaphor processing would trigger activity in sensory areas that are involved in processing the domain from which metaphors are motivated. In a recent study, Lacey, Stilla, and Sathian (2012) used a covert reading time task (i.e., “press a button once you understood the sentence”) and focused on metaphors motivated by the domain of texture (e.g., “she had a rough day”). Findings showed that compared to literal conditions, the textural metaphors activated somatosensory regions known to be texture-selective during haptic perception. Thus, metaphor processing selectively activates sensory areas in the modality from which the metaphorical meaning is motivated.

To conclude, Conceptual Metaphor Theory coherently describes the systematicity underlying metaphors and explains what motivates linguistic meaning. It allows understanding of conventional metaphors and creation of new metaphorical meaning through the systematic organisation of metaphorical mappings. In addition, empirical evidence, including recent brain-imaging studies, has shown that conceptual metaphors are able to motivate speakers' understanding and expression of meaning. The metaphorical mappings from source domains related to bodily experience with the environment on to abstract, target domains constitute the heart of metaphor processing. Therefore, the current thesis draws upon the Conceptual Metaphor Theory as a solid theory explaining the interaction between metaphorical thought and language, and that of linguistic form and physical experience. However, in the next sections, we acknowledge the existence of other metaphor theories.

Alternatives to the Conceptual Metaphor Theory

Contrary to the Conceptual Metaphor Theory (Lakoff & Johnson, 1980a), the first theories of metaphor mainly focused on metaphor in language use. The Standard Pragmatic Model, introduced by Searle's work, considered understanding of literal meaning granted and non-literal understanding complicated. This is because non-literal understanding requires derivation of the literal meaning and sensibility judgment (i.e., if sensible we stop, if not we seek for an extra-linguistic, non-literal interpretation) (Searle, 1979). However, this model studies metaphor in language use only (rather than thought), and implied that metaphorical interpretations always need additional and longer processing than literal, while several[2] studies have shown that metaphors may be processed faster than literal phrases (for a review see Gibbs, 2013). In addition, the Implicit Comparison view, introduced by Gentner (1983) proposed that metaphors are understood as comparisons of X is like Y, and once the comparison is made we look for matching between properties of X and Y. However, this view requires a priori knowledge of X. For example, if someone hears the expression "their

[2] For example, Gibbs (1980) reported that phrases such as "spill the beans" were read faster in a context biasing their idiomatic compared to their literal explanation. Similarly, Connine, Blasko, Brandt and Kaplan Layer (1992) showed that participants responded faster to the last word of idiomatic phrases such as "get off my back" compared to literal phrases such as "get off my pack".

marriage was a rollercoaster ride", and they do not know that the couple is going through difficulties, they could infer that their marriage is a funny and exciting one.

Furthermore, some scholars were sceptical about the view that conceptual metaphors really reveal how people ordinarily think. They rather suggested that when people speak metaphorically they do not necessarily refer to the underlying conceptual metaphor. Glucksberg and colleagues proposed the Attributive Categorisation Framework (Glucksberg, 1991; Glucksberg & McGlone, 1999). According to this proposal, when understanding metaphors, we create an attributive class in which the topic (equivalent to the target domain in Conceptual Metaphor Theory) of the metaphor can be included. The vehicle (equivalent to the source domain in Conceptual Metaphor Theory) of the metaphor exemplifies the class. For example, in the expression "the lawyer is a shark" the topic "lawyer" is not a member of the taxonomic category "fish" exemplified by the vehicle "shark", but a member of a an attributive category such as "vicious beings" (Glucksberg, 1991; Glucksberg & McGlone, 1999). This approach implies good knowledge of the topic and all the multiple attributive categories it may belong to, thus metaphorical interpretation might not be systematic (compared to Conceptual Metaphor Theory), and it can vary depending on context and individual differences.

Experimental support for the attributive approach was provided in several studies. For example, M. S. McGlone (1996) showed that reference to a conceptual metaphor is not the modal strategy that people use when they paraphrased metaphors, rated the similarity between metaphors, or retrieved metaphors from memory. In each of these situations, participants relied primarily on the stereotypical properties of the vehicle concept. In addition, reading time measurements indicated that conceptual metaphors do not necessarily motivate conventional meaning. Reading times of idioms were not facilitated even when their underlying conceptual metaphor was explicitly mentioned in the preceding text (Glucksberg, Brown, & McGlone, 1993; Keysar, Shen, Glucksberg, & Horton, 2000). Similarly, Keysar and Bly (1999) gave the same, new idioms to different groups. The context of the idioms implied a positive or negative meaning for each group. Both groups reported that the idioms made sense. This finding indicated that people's intuitions about idiom transparency can vary as a function of what they believe to be the meaning of the idiom, thus idiom meaning does not only derive from fixed, underlying conceptual metaphors. Along the same line, Glucksberg, McGlone, and Manfredi (1997) found that priming a metaphorical phrase with its topic or vehicle may facilitate comprehension of the metaphor only when they are unambiguous. For example, the phrase "life is a soap opera" has a low-constraint topic (i.e., many aspects of life could resemble a soap opera). Priming this phrase with the word "life" did not facilitate comprehension (Glucksberg et al., 1997). This finding suggested that metaphor comprehension relies on property attribution rather than conceptual metaphors.

In addition, Coulson and Van Petten (2002) proposed a "conceptual blending" approach for metaphor interpretation, which combined the role of metaphorical mappings and that of attributive categories. Their theory is based on the general theory of conceptual integration known as "conceptual blending" (Fauconnier & Turner, 1998). They provided empirical evidence by recording event related potentials (ERPs). Participants read sentences in the form of "X is Y" with literal (e.g., "he knows that whiskey is a strong intoxicant") and metaphorical (e.g., "he knows that power is a strong intoxicant") meaning, and sentences representing literal mappings, when one thing is substituted for another (e.g., "he has used cough syrup as an intoxicant"). They answered true or false questions probing their comprehension of the sentences. Results showed a graded processing difficulty in the following order: literal sentences, literal mapping sentences and metaphorical sentences. The authors proposed a blending theory according to which (a) attributes and relational structure from distantly related conceptual domains (source-target) are mapped and imported into a blended mental space, (b) these blended spaces can explain the emergent properties triggered by metaphorical expressions, (c) what makes metaphor "special" is the establishment and retrieval of the mappings motivated by conceptual metaphors, and (d) literal and non-literal language processing may share some processing mechanisms (= continuity claim) considering the existence of non literal mappings. We acknowledge the value of some of the account's components, such as the continuity claim, however it has not been exhaustively tested, and in essence it could stand as a complement to the Conceptual Metaphor Theory.

Furthermore, the more recent Career of Metaphor approach (Bowdle & Gentner, 2005) offered a unified theoretical framework between comparison and categorisation models of metaphor, and shifted attention to other aspects, rather than metaphoricity per se, that may influence metaphor understanding. This approach suggested that metaphorical mappings shift from a comparison to categorisation procedure as metaphors are conventionalised. More specifically, processing of novel metaphors involves comparison between the source and target of metaphors, whereas conventional metaphorical terms are processed essentially as if they are established categories. We believe, that the implication of this approach is mainly methodological (rather than explanatory), such that metaphor conventionality, which is subject to individual differences, must be controlled in metaphor research.

Finally, there are socio-cognitive approaches to metaphor, which highlight the importance of communicative intention (Happé, 1993) and language competence (Norbury, 2005) for metaphor comprehension. In particular, Happé (1993) compared performance of subjects with autism and controls in a metaphor task and suggested that theory of mind and the ability to represent speaker's intention is necessary in order to interpret metaphor. Similarly, Norbury (2005) compared performance of children with autism and controls in metaphor tasks and suggested that theory of mind is necessary, but not sufficient to interpret metaphor. Language competence and in particular semantic knowledge plays also an important role for metaphor comprehension. These approaches are not standing alone, rather complement Conceptual Metaphor Theory, and they can be incorporated in metaphor research focusing on individual differences and specific populations.

2.2.2 Hemispheric involvement for metaphor processing

Hemispheric involvement for metaphorical processing has attracted attention in research the past thirty years. This is because metaphors are fundamental elements of speech and thought. Hence, understanding the underlying neural mechanisms for metaphorical processing is relevant to understanding the mechanisms for linguistic processes, verbal creativity and complex cognition. The current thesis draws upon the weak version of the Right Hemisphere Hypothesis for Metaphor (e.g., Bottini et al., 1994), which suggests the co-ordination and divided labour in the two brain hemispheres for different components of semantic processing. That is, both hemispheres contribute to language processing, but the left hemisphere is particularly important for fine (i.e., links between strong and focused semantic features) semantic processing while the right for the coarse (i.e., large semantic fields and links between distant and unusual semantic features) semantic processing (Jung-Beeman, 2005). This ability of the right hemisphere to bring together coarse semantic associations underlies metaphorical processing. However, we acknowledge that some studies failed to support a particular involvement of the right hemisphere for metaphorical processing (e.g., Rapp, Leube, Erb, Grodd, & Kircher, 2004; Stringaris, Medford, Giampietro, Brammer, & David, 2007), and we believe that this, mainly, highlights task- and methodology-related differences.

Right Hemisphere Hypothesis for Metaphor

The first line of evidence for right-hemispheric involvement during metaphorical processing came from research with brain-damaged patients. In Winner and Gardner (1977), normal controls and patients with either right or left hemisphere lesions performed a pictorial and a verbal metaphorical task. Participants listened to a metaphorical phrase (e.g., “he has a heavy heart”). They had to match the meaning of the sentence to the appropriate picture representing the metaphorical meaning (e.g., a picture of someone crying) vs. a picture representing the literal meaning (e.g., a picture of someone carrying a heart). In addition, they had to verbally explain what the phrase means. The patients with right hemisphere lesions selected the literal version of the pictures, but they were able to accurately explain the phrases. On the other hand, patients with left hemisphere lesions accurately selected the metaphorical version of the pictures, but they sometimes literally explained them. This finding suggests that the left hemisphere is not adequate and responsible for the processing of every linguistic message, and the right hemisphere is involved but not adequate for the processing of metaphorical meaning. In another patient study, Brownell, Simpson, Bihrle, Potter, and Gardner (1990) asked patients with right and left lesions, and controls to perform a similarity judgment between triads of words, which included one target ambiguous word (e.g., “warm”), a word related to the metaphorical meaning of the target (e.g., “affectionate”), and a word related to the prior meaning of the target (e.g., “blanket”). The selection of the two metaphorically related words was considered the correct response. Patients with right hemisphere damage performed worse compared to controls and those with left hemisphere damage, suggesting that the right hemisphere is particularly involved for the evaluation of alternate, metaphorical meaning.

More evidence for the right-hemispheric involvement for metaphor came from brain-imaging studies. Bottini et al. (1994) used plausibility judgment and lexical decision tasks for literal and metaphorical sentences in a PET scan study. Findings showed that comprehension of metaphorical and literal meaning is associated with similar activations in the left hemisphere, but metaphorical comprehension is associated with additional activations in right hemisphere regions (the prefrontal cortex, the middle temporal gyrus, the precuneus and the posterior cingulate). Thus, brain hemispheres are bilaterally activated for language processing, and the right hemisphere is particularly involved for metaphorical processing. In addition, Mashal and colleagues provided evidence for the Right Hemisphere Hypothesis for metaphor in several brain-imaging studies. In Mashal, Faust, and Hendler (2005) and Mashal, Faust, Hendler, and Jung-Beeman (2007) participants read Hebrew word pairs representing four semantic relationships: literal (e.g., "broken vase"), conventional metaphorical (e.g., "bright student), novel metaphorical (e.g., "crystal river"), and unrelated (e.g., "boot laundry"). They performed a silent semantic judgment task while in the fMRI scan (i.e., decide if the word pairs are literally related, metaphorically related or unrelated). Findings showed shared activation of a core bilateral network for all conditions, and a special role of the right homologue of Wernicke's area for the novel metaphorical pairs.

Finally, behavioural studies using the divided visual field technique have provided evidence in favour of the Right Hemisphere Hypothesis. Anaki, Faust, and Kravetz (1998) combined the divided visual field technique with the semantic priming paradigm to investigate hemispheric involvement for metaphorical and literal semantic associations in Hebrew. Participants read a prime (e.g., "stinging") and performed a lexical decision on a target, which would be either literally (e.g., "mosquito") or metaphorically (e.g., "insult") related to the prime. Findings for short stimulus onset asynchronies (200ms) suggested facilitation for metaphorically related targets in both hemispheres while literally related targets were facilitated only in the RVF (= left hemisphere). Findings for long stimulus onset asynchronies (800ms) suggested that metaphorically related targets were facilitated in the right hemisphere, whereas literally related targets were facilitated in the left hemisphere. In addition, Schmidt, DeBuse, and Seger (2007) used the divided visual field technique at sentence level to investigate hemispheric involvement for metaphorical and literal semantic relationships. Participants read sentences with three different endings (e.g., “the camel is a dessert […]” “animal”-literal or “taxi”-metaphorical or “table”-anomalous). They would read the endings presented either in the right-visual field (left hemisphere) or the left-visual field (right hemisphere). They performed a semantic judgment task (i.e., respond whether the ending fits the sentence or not). Findings showed right hemisphere time advantage for metaphorical relationships and left hemisphere advantage for literal relationships. In a second divided visual field experiment, they varied familiarity of stimuli by creating conditions of literal-familiar, literal-unfamiliar and metaphorical sentences for a plausibility judgment task. Findings showed a right hemisphere time advantage for both literal-unfamiliar and metaphorical sentences, but not for literal-familiar. In a third divided visual field experiment, they varied familiarity of metaphorical stimuli only by creating four conditions of “very high, high, low and very low” metaphor familiarity in a sensibility judgment task. Findings showed right hemisphere time advantage for unfamiliar metaphors and left hemisphere advantage for familiar ones.

Some studies failed to provide support for a particular involvement of the right hemisphere during metaphorical processing. For example, in Rapp et al. (2004) participants read short, simply structured German sentences with either a metaphorical (e.g., “the lovers’ words are harp sounds”) or literal (e.g., “the lovers’ words are lies”) meaning. Participants performed an overt connotation judgment task (i.e., they decided if the sentence had a positive or negative connotation) while in the fMRI scanner. Findings showed that metaphors elicited increased BOLD contrasts in the left rather than the right hemisphere. Similarly, in Rapp, Leube, Erb, Grodd, and Kircher (2007) participants read the same stimuli and performed an additional metaphorical judgment task where they decided if the sentence had a metaphorical or literal meaning. Brain activations showed left lateralisation overall, however there were more right hemisphere regions activated for the metaphorical than the connotation judgment (though not significant). In Stringaris et al. (2007), participants read metaphorical (e.g., “some surgeons are butchers”), literal (e.g., “some surgeons are fathers”) or meaningless sentences (e.g., “some surgeons are shelves”). They performed an overt sensibility judgment task while in an fMRI scanner (i.e., they decided if the sentence made sense or not). Contrasts between the literal and metaphorical conditions failed to provide support for a predominant role of right hemispheric structures (e.g., right inferior frontal gyrus). Finally, Coulson and Van Petten (2007) assessed the lateralisation of metaphorical thinking by recording event-related potentials (ERPs). Participants read sentences that ended literally, with either high or low predictability, and metaphorically. The final part of the sentence was presented in either the left or the right visual hemifield. Findings provided no evidence for differential metaphoricity effects between hemifields, and suggested that the integration of metaphoric meanings required similar involvement of the two hemispheres.

To conclude, the empirical evidence about the hemispheric involvement during metaphorical processing reveals a heterogeneous picture. It seems that the right hemisphere has a particular role for metaphorical processing, however its involvement could vary as a function of other factors rather than metaphoricity per se. For example, familiarity of stimuli (novel vs. conventional metaphors), complexity of stimuli (word pairs vs. sentences), task and instructions (overt vs. covert responses; tasks that rely heavily on semantic processing vs. passive reading tasks), and measurements (behavioural vs. neurophysiological) could determine the degree of right hemispheric involvement (see Schmidt, Kranjec, Cardillo, & Chatterjee, 2010 for a review of studies on the neural basis of metaphor). More importantly, whether the semantic, as opposed to syntactic properties of a metaphorically used term drive the involvement of the one or the other hemisphere has received little attention. To our knowledge, only one study directly compared the role of syntactic and semantic processing for the hemispheric involvement in metaphorical comprehension. In Cardillo, Watson, Schmidt, Kranjec, and Chatterjee (2012), participants passively read in the scanner metaphors that had the same base term used metaphorically but differed in their syntactic structure. Half of the metaphors were nominal (e.g., “the shop display was was a gentle tug”) and half were predicate (e.g., “the urgent letter tugged at her sleeve”) metaphors and crucially the nominal metaphors had a nominalised verb as a metaphor base term. All sentences were carefully matched for lexical and sentential properties (e.g., frequency, imageability, and figurativeness). Results showed no differences in the neuronal activations (e.g., the inferior frontal gyrus on the left hemisphere and its right hemisphere homolog) for the two types of metaphors that differed syntactically but were equated semantically. This result suggested that semantic rather than syntactic features are crucial to the hemispheric involvement for metaphorical comprehension. However, this study did not test a non-metaphor condition, hence interpretation is tenuous.

2.2.3 Theoretical explanation of hemispheric involvement for metaphor processing

In this section we review the predominant theories, which explain the hemispheric involvement for metaphorical processing. The theories are not necessarily mutually exclusive. They rather focus on aspects of metaphorical processing from a different angle (saliency/familiarity, semantic distance).

The Graded Salience hypothesis (Giora, 1997; Giora, Zaidel, Soroker, Batori, & Kasher, 2000) characterised the difference between right-hemisphere and left-hemisphere semantic processing without explicitly referring to the literal vs. metaphor distinction. That is, both literal and non-literal language processing are controlled by the principle of salience in such way that salient meanings are processed primarily in the left-hemisphere, where most of our linguistic knowledge is stored. The right-hemisphere has a selective contribution for understanding non-salient meanings. Given that meanings are made salient through familiarity, conventionality and/or prototypicality, the graded salience account predicted that salient, familiar metaphors are processed in the left-hemisphere, and less salient, novel metaphors in the right-hemisphere. In other words, there is a shift in increased activations from the right to the left hemisphere as metaphors become familiar. Cardillo et al. (2012) proposed a slightly different approach, which is also based on the relationship between the level of metaphor familiarity and hemispheric involvement. They found that activations in critical bilateral regions sub-serving metaphorical comprehension negatively correlated with familiarity of metaphors. That is, as metaphor familiarity increases and categorisation processing takes place (following the Career of Metaphor model; Bowdle & Gentner, 2005), activations in both hemispheres decrease, rather than activations increasingly shifting from the right to left hemisphere.

The Fine-Coarse Semantic Coding Model, introduced in Beeman and Chiarello (1998) and Jung-Beeman (2005), is most commonly used to explain the right-hemisphere bias for metaphorical processing. According to this model, the two hemispheres process semantic information in a qualitatively different, yet complementary way based on the notion of "semantic distance". In particular, any meaning depending on distant and coarse semantic relationships (i.e., distant and unusual semantic links) is processed in the right-hemisphere, and any meaning depending on close and fine semantic links (i.e., dominant and strong interpretations) is processed in the left-hemisphere. This is because the right hemisphere is more interconnected than the left hemisphere (i.e., the right hemisphere has more white matter and neuron connections than the left hemisphere) (Jung-Beeman, 2005). So, when encountering a word, the left hemisphere is involved for a dominant interpretation (= fine semantic coding), and the right hemisphere is involved for maintaining larger semantic fields, which include more distant, unconventional semantic associations (= coarse semantic coding). Almost by definition, metaphorical compared to non-metaphorical language includes links between more distantly related meanings (e.g., “animal” as opposed to “taxi” is more closely linked to “desert” in the phrases “a camel is a desert animal” and “a camel is a desert taxi”). Therefore, the right-hemisphere is particularly engaged in processing metaphors.

2.2.4 Metaphor: relevance to the thesis

The literature related to metaphor as reviewed in the above sections has motivated and informed the current thesis in several ways.

Firstly, *why study metaphor*? Metaphors – as conceptualised in cognitive linguistics – are holistic and multifaceted representations of knowledge, because they rely on the whole abstract-to-concrete continuum of semantic knowledge. As a matter of both language and thought, metaphors enable the study of interactions between cognition, speech and non-verbal behaviours. The current thesis focused on metaphor, as it requires complex embodied cognitive processing, yet it is a pervasive component of everyday communication.

More specifically, theories about metaphor and in particular the Conceptual Metaphor Theory informed the selection of tasks and measurements in the empirical studies of the current thesis. In Chapters 3 and 6 we used a metaphorical explanation task, which required the explanation of phrases focusing on the metaphorical mappings between conceptual domains. For example, participants had to explain how the concrete concept of “beans” represents the abstract concept of “secrets” in the phrase “to spill the beans”. In Chapters 3 and 4 we developed coding schemes to measure metaphoricity levels in speech and identify the use of metaphorical language in verbal responses on the basis of conceptual metaphors. For example, the phrase “focus on important aspects” would be identified as metaphorical, because it derives from the conceptual metaphor UNDERSTANDING IS SEEING. Finally, Chapter 5 aimed to provide support for the Conceptual Metaphor Theory by investigating the sensorimotor basis of metaphor comprehension focusing on the role of action gestures for semantic judgment of action sentences. In this way we put the heart of metaphorical processing in the heart of the thesis.

In addition, we drew upon the evidence for the right hemispheric involvement in coarse semantic processing, in particular metaphorical processing, and we aimed to further explore factors determining this involvement. In Chapters 3, 4 and 5 we investigated whether hand choice for gesturing (e.g., left hand gestures) determines different types of metaphorical processing (e.g., metaphorical explanation; spontaneous use of metaphors; metaphorical judgment of sentences). This question is motivated by the account that the right hemisphere is particularly involved for metaphorical processing. Furthermore, in Chapter 6 we explicitly explored the role of semantic processing, which has received little attention, for the particular involvement of the right hemisphere during metaphorical explanations. This way, the thesis informed the discussion of hemispheric involvement for metaphorical processing.

2.3 Gestures: a visible example of embodiment

2.3.1 Types of gestures

The visible hand movements that a speaker produces while speaking can be either gestures or non-gestures. Non-gestures mainly comprise of self-touching movements (e.g., stroking the hair; scratching) or object manipulation. Gestures comprise of imagistic and non-imagistic hand movements that often accompany speech. Based on the imagistic degree of the movement, a number of gesture classification schemes have been proposed. McNeill (1992) introduced four types of gestures: iconic, metaphoric, beat, and deictic. A gesture is iconic when it has a close semantic relationship with the concurrent speech. Iconic gestures depict actions, physical objects (size, shape), and movement, and carry information, which could be present or absent in the concurrent speech. For example, if someone utters the sentence "he grasped the ball", they could produce two different iconic gestures to depict the size of the ball and the way of grasping (e.g., both hands semi-closed, palms facing each other, forming a circular space in front of the body to describe a big ball or one hand with semi-closed palm facing to the front to describe a small ball). Metaphoric gestures are similar to iconic in representing imagery, but they represent an image of an abstract concept. For example, if someone utters the sentence "he revealed a secret", they could produce a metaphoric gesture representing the concept of "secret" as an object on an open palm, and move the arm away from the body representing the action of sharing information. Deictic gestures are pointing movements used to indicate concrete entities present or absent in the environment, or even refer to abstract concepts. Finally, beat gestures are rhythmic hand movements (usually vertical), which do not carry meaning, but they might carry information about the discourse (e.g., emphatic information).

2.3.2 Types of gestures: relevance to the thesis

The current thesis focused on "representational" gestures, which comprise McNeill's iconic and metaphoric gestures. Representational gestures represent units of thoughts and allow the investigation of how non-verbal encoding of meaning can affect the way we think and speak. More specifically, in Chapters 3 and 4 we focused on representational gestures and their role on metaphorical processing when gestures and speech co-occur. In addition, in Chapter 4 we directly compared the effect that representational and meaningless tapping hand movements have on spontaneous production of metaphors. Finally, in Chapter 5, we investigated whether representational gestures when produced alone may prime sentence comprehension.

2.3.3 Generation of gestures

Where do gestures arise? In this section we review the most closely aligned frameworks developed to explain what gestures are and when they emerge.

According to the Interface Model (Kita & Ozyürek, 2003), gestures arise during the conceptualisation stage of speech production. Generators are responsible for planning the form of gesture (action generator) and speech (message generator). Both of them access visuo-spatial images in working memory and most importantly, they communicate bi-directionally. This bi-directional communication between gesture and speech means that gestures can be influenced by linguistic and visuo-spatial properties of information. Evidence for this model comes from cross-linguistic research (Kita & Ozyürek, 2003) suggesting that gestures representing motion events can be influenced by the way each language encodes aspects of motion and the visuo-motoric properties of an event per se. For example, native speakers of English, Turkish and Japanese described an event in which a protagonist swings on a rope like Tarzan. The English speakers encoded the arc-shaped trajectory of the motion, both linguistically and in gestural content. However, this was not the case for Turkish and Japanese, because they do not have such an easily accessible linguistic unit. Therefore, speakers produced a gesture to represent the change of location only, without the arc-shaped trajectory.

The Gesture-as-Simulated-Action account (Hostetter & Alibali, 2008) brings the link between perception and action in the centre of the gesture production system, and suggests that gestures emerge from the perceptual and motor simulations that underlie embodied language and mental imagery. That is, whenever ideas are simulated in the form of perceptual and motor information (both physically and metaphorically spatial), a gesture may emerge. The strength of speakers' perceptuo-motor activations during conceptual processing, and the conceptual content are factors that determine whether simulations will be executed as gestures. For example, the more the speakers evoke visuo-spatial imagery during conceptual processing, the more likely they are to produce gestures. In addition, action related content of speech gives rise to gestures, because it depends on motor-information (Hostetter & Alibali, 2008). The Gesture-as-Simulated-Action account does not explicitly propose a bi-directional communication between gesture and speech, but speakers' perceptual and motor simulations may rely on linguistic constraints of their languages (Hostetter & Alibali, 2008).

2.3.4 Functions of gestures

The first wave of gesture research has considered gestures as communicative tools elicited after cognitive processing (e.g., lexical access, conceptualisation), which constitute a cognitively independent bodily output (Graham & Argyle, 1975; Kendon, 1994). However, cumulative studies on embodied cognition and gestures have made it clear that gesture is more than that, and that gestures can influence cognitive processing of speakers themselves. In the next sections, we review the theories and empirical evidence for different functions of gestures.

2.3.4.1 Communicative Functions of Gestures

Features of communicative contexts modulate gesture production. Speakers produce gestures to enhance listeners' understanding of the message they convey. There is a great deal of evidence for the communicative functions of gestures (see Hostetter, 2011 for a meta-analysis). Alibali, Heath, and Myers (2001) showed that the frequency of gesture production increased when the speaker/gesturer and listener had visual contact compared to when they did not. In addition, Melinger and Levelt (2004) suggested that speakers intend for their gestures to communicate, because when they communicate much information, they utter some of it (e.g., size of a stimulus) and represent other pieces of information (e.g., shape) in gestures only. Holler and Stevens (2007) showed that speakers adjust the information they convey in speech and gestures depending on the listener's previous knowledge. When speakers were aware of the listener's knowledge gap about the content of speech, they used both gestural and verbal information, whereas they only used verbal information for informed listeners. Similarly, speakers changed their gestures before and after addressees' feedback. For example, when feedback was confirmatory, speakers produced less gestures than when feedback encouraged elaboration or specifications. Also, gestures were larger and more precise after than before feedback (Holler & Wilkin, 2011). Finally, listeners' understanding may (Graham & Argyle, 1975; Kendon, 1994) or may not (Kelly & Goldsmith, 2004) benefit from seeing gestures. For example, listeners fail to understand speakers' verbal message when it is accompanied by mismatching gestures or no gestures at all (Goldin-Meadow, Kim, & Singer, 1999). In addition, gestures may help understanding of intentions, which remain unuttered. For example, Kelly et al. (1999) found that when speakers uttered the sentence "it is getting hot in here" and pointed to a window, the listener interpreted it as a request, thus opened the window. However, this was not the case when the sentence was uttered without gesture.

2.3.4.2 Self-oriented Functions of Gestures

Speakers often produce gestures when having a telephone conversation which are not visible to their listener (Bavelas, Gerwing, Sutton, & Prevost, 2008). In addition, congenitally blind children gesture when they speak to blind listeners (Iverson & Goldin-Meadow, 1998). These findings suggested that gestures do not occur only for the listeners, but they must facilitate cognitive processing of the speakers-gesturers themselves. In the following sections, we review the various theoretical accounts proposed to describe the processes facilitated by gestures, which are not necessarily mutually exclusive, rather complementary.

The Lexical Gesture Process Model

The Lexical Gesture Process Model proposed by Krauss and colleagues (Krauss, 1998; Krauss & Hadar, 2001) holds that gestures facilitate the generation of utterances at the surface level. More specifically, gestures that share semantic content with a word can help speakers formulate speech by helping the lexical access at the stage of phonological encoding. Evidence for this "lexical function" of gestures mainly comes from studies using cross-modal priming paradigms and showing that representing a concept in gestures may prime the lexical representation of this concept (R. Krauss, Chen, & Gottesmann, 2000). Also, gesture prohibition studies show that preventing speakers from gesturing may affect qualities of speech (e.g., fluency, speech rate). For example, when speakers are prohibited from gesturing during speech, and in particular speech with spatial content, they are less fluent and have lower speech rates than when gesturing is allowed (Rauscher et al., 1996). Similarly, participants who were allowed to gesture retrieved more lexical items from their definition than those who were prohibited (Beattie & Coughlan, 1999). The reverse link has also been shown and more gestures are produced when lexical access is difficult (e.g., during the tip of the tongue phenomenon where the speaker tries to recall word forms) (Chawla & Krauss, 1994). In addition, gestures are synchronised with speech (e.g., produced either before or simultaneously with the relevant utterance), and the more familiar the word the smaller the gesture-speech asynchrony (Morrel-Samuels & Krauss, 1992). These findings suggested that gesture production is linked to features of lexical access. Finally, the account has been confirmed in developmental studies. Children of 6 and half years old performed better in a naming task when they were allowed to gesture compared to not gesturing (Pine, Bird, & Kirk, 2007).

The Information Packaging Hypothesis

According to the Information Packaging Hypothesis (Kita, 2000), representational gestures help the organisation of spatio-motoric information into packages to enhance the content of speech to be uttered. The key idea is that gestures help cognitive processes by organising and packaging of information into "verbalisable" units. Evidence for this "spatio-motoric organisation function" of gestures mainly comes from studies on the effect of gestures on processing visuo-spatial information. For example, more gestures emerge during a task with high spatial cognitive demand, such as description of a mental rotation problem and difficult-to-conceptualise figures (Hostetter, Alibali, & Kita, 2007), or description of complex geometrical figures (Kita & Davies, 2009). Moreover, encouraging participants to gesture during a mental rotation problem task enhances their performance, by improving the internal computation of spatial transformations (Chu & Kita, 2011). In addition, studies with children showed that gestures help them for what information to attend to and in turn verbally express. When children performed an explanation task (i.e., they explained if two containers include the same or different quantity), they produced many gestures to represent perceptual dimensions of the containers and information, which was not uttered (Alibali, Kita & Young, 2000). Also, when children were prohibited from gesturing in an explanation task, they referred to more perceptually absent objects than when gesturing (Alibali & Kita, 2010). Thus, gestures help the conceptual planning of speech and highlight information, which is perceptually present. Similarly, when adults were asked to divide information (e.g., the manner and the path of a movement) in separate gestures, they also verbally encoded the information in separate clauses (Mol & Kita, 2012). Thus, gestures can influence information packaging in speech. Finally, studies on cross-cultural differences of speech and gesture production (Kita & Ozyürek, 2003; Kita, Ozyürek, et al., 2007) provided evidence that gestures derive from spatio-motoric processes and interact with speech at the conceptual planning level. For example, Turkish and Japanese speakers differ from English speakers in how they organise and package information about the Manner and Path of motion events in gestures and speech (i.e., separation of Manner and Path in Turkish and Japanese gestures is due to difficulty to verbalise the two pieces in a single processing unit for speech production) (Kita & Ozyürek, 2003).

The Gesture-in-Learning-and-Development Framework

According to the Gesture-in-Learning-and-Development framework (Goldin-Meadow, 2003) gestures help cognitive processing by reducing the cognitive load and allowing more effort to be devoted in another task (e.g., speech production). For example, gestures helped speakers to reduce working memory load during a math explanation problem, and freed capacity to perform a secondary letter recall task (Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001; Wagner, Nusbaum, & Goldin-Meadow, 2004). Gesticulation reduced the working memory load imposed by explaining math problems even when the secondary task was visuo-spatial (e.g., remember a visual grid pattern) (Wagner et al., 2004). In addition, speech-gesture matches (i.e., the same information was conveyed in speech and gesture) increased the amount of items participants remembered (Wagner et al., 2004). These findings suggested that gestures aid cognitive processing because of their propositional organisation rather than their visuo-spatial form, and unload working memory by complementing speech.

The Image Maintenance Theory

According to the Image Maintenance Theory, introduced in Wesp et al. (2001), spatial imagery serves a short-term memory function during the lexicon search, and gestures may facilitate the maintenance of the non-lexical imagistic concept during lexical access. Even earlier studies pointed towards this account. For example, Rime, Schiaratura, Hupet, and Ghysselinckx (1984) found that when gesturing is prohibited, the vividness of imagery in spontaneous conversations is decreased compared to when gesture is free, suggesting that gestures are part of the representational process, rather than the lexical one, and maintain a focus on spatial information. In addition, de Ruiter (1998) found that when participants described shapes, which were not visible, they produced more gestures compared to when the shapes were visible to the addressee. This finding suggested that gestures maintain images in mind. Similarly, Wesp et al. (2001) showed that when participants explained pictures to a listener and the pictures were absent – thus the need for image maintenance was higher –, they produced more gestures compared to when the pictures were visible to the listener. Thus, gestures can help the pre-linguistic representation of spatial information by maintaining the spatial images in memory. Finally, prohibiting gestures reduces the amount of spatial metaphors in a free speech production task, confirming the imagistic nature of gestures, which has a special role for the verbalisation of abstract spatial imagery in the form of metaphor (Bos & Cienki, 2011).

2.3.5 Functions of gestures: relevance to the thesis

The literature related to functions of gestures as reviewed in the above sections has motivated and informed the current thesis in several ways.

We followed the Gesture-as-Simulated-Action account (Hostetter & Alibali, 2008) that gestures arise from embodied thinking, and we included gestures, the "visible evidence of embodiment", in the study of embodied abstract thinking in the form of metaphor. In addition, following the bi-directional link between gesture and speech as proposed in the Interface Model (Kita & Ozyürek, 2003), and the role of conceptual knowledge and sensory-motor simulations for metaphor processing as proposed in the Conceptual Metaphor Theory (Lakoff & Johnson, 1980a), we investigated whether gestures may influence metaphorical processing. More specifically, we focused on the self-oriented functions of gestures and aimed to bring the literature a step forward. Gestures may reinforce our mental images and help maintain them in memory, as the image maintenance account (Wesp et al., 2001) suggests. Also, they may help speakers identify which features of a mental image to mention and organise information to be uttered, as the information packaging account (Kita, 2000) suggests. Or they may help speakers identify which lexical features to use, as the lexical processing model suggests (R. M. Krauss, 1998). So, there are many accounts describing which cognitive processes are facilitated by gestures, but the exact mechanism underlying these facilitative effects is underspecified (Pouw, de Nooijer, van Gog, Zwaan, & Paas, 2014). In the current thesis, we aimed to approach this underspecified issue by investigating if facilitative functions of gestures relate to gesture handedness and its mutual involvement with hemispheric involvement for cognitive processing.

More specifically, in Chapters 3, 4 and 5 we measured several components of embodied processing of abstract meaning in the form of metaphor (e.g., explanation of metaphorical mappings; spontaneous use of metaphors; metaphor comprehension) as a function of gesture production. In addition, we did not simply measure if gestures facilitated cognitive processing. We measured if gestures can actually modulate and determine language processing, such that they can change the content of speech. Thus, providing more evidence for gestures' self-oriented functions.

In the following section we outline research, which motivated us to investigate a hemisphere-specific feedback hypothesis for gestures' self-oriented functions, and whether left- and right-hand gestures differ in the degree of impact they have on language processing.

2.3.6 Hemispheric involvement for gesture production

We can investigate the inter-relation between speech and gesture by investigating the role that the cerebral hemispheres may play in speech-gesture production. For example, does the left hemisphere only control speech and gesture production? Several behavioural and patient studies investigating hand choice for gesturing, and brain imaging studies have addressed this issue.

Research on human motor function includes the study of hemispheric dominance and handedness. The traditional approach suggests a left hemispheric advantage for the production of simple hand actions. For example, Kim et al. (1993) in a brain imaging study, found that the right motor cortex was activated in a contra-lateral manner, that is, during the movement of the left hand (movement of fingers). However, the left motor cortex was activated in a contra-lateral and ipsi-lateral manner, that is, during movement in either hand. Similarly, the left-hemisphere is specialised for the bilateral control of repetitive, meaningless hand movements (Kimura & Archibald, 1974; Wyke, 1971). However, more recent studies using near-infrared spectroscopy (NIRS) provide ambiguous evidence. Some studies (Franceschini, Fantini, Thomspon, Culver, & Boas, 2003; Sato et al., 2007) suggested that the hemispheric control of simple hand movements (e.g., finger tapping) is contra-lateral, while other studies (Helmich, Rein, Niermann, & Lausberg, 2013) showed that both hemispheres are equally activated during simple movements (e.g., flexion/extension with the thumb) with the one or the other hand.

Therefore evidence for hemispheric involvement for the production of simple motoric movements is not clear, and the picture becomes more vague when it comes to hemispheric involvement for more complex movements, such as meaningful gestures.

The traditional neuropsychological view is that speech and gesture production systems share a common brain mechanism, which, for most speakers, is the language dominant, left hemisphere (Kimura, 1973a, 1973b). Kimura's research is based on the contra-lateral cortical control for hand movements, that is, the right hemisphere controls hand movements with the left hand and the left hemisphere controls hand movements with the right hand. Kimura (1973a) suggested that healthy right-handed speakers with left hemisphere language dominance (evidenced by a right-ear advantage in a dichotic listening task) presented increased frequency of right hand movements[3] compared to left hand movements in a free speech production task. Similar patterns of results were found in left-handers (Kimura, 1973b), but in a less exclusive unilateral degree (e.g., left handers, regardless of their ear advantage, would use the left hand for gestures more than right handers), because language is also less unilateral in left-handers[4]. This finding suggested that hand preference for movements is influenced by which hemisphere is language dominant, as evidenced by a dichotic listening task. In addition, Lavergne and Kimura (1987) videotaped right-handed subjects as they spontaneously spoke about spatial and neutral topics. Participants gestured more in the spatial than the neutral topics, which suggested that the nature of the speech task might influence the amount of gestures. However, and contrary to an expected asymmetry (i.e., spatial content was associated with right hemisphere processing,

[3] Note, that in Kimura's research free hand movements are defined as "any motion of the limb which did not result in touching of the body or coming to rest" (Kimura, 1973a, p.46).

[4] Some (but not all) left-handers might have right-hemisphere language dominance (Hunter & Brysbaert, 2008) and even strong right-handers might have right hemisphere language dominance (Knecht et al., 2000).

hence left hand preference was predicted), speakers consistently preferred the right hand for gesturing regardless of the topic.

More recent evidence from brain imaging studies also suggests the left hemispheric involvement for gesture production. Regardless of the hand used, transitive (e.g., stirring) and intransitive (e.g., waving) action gestures (Kroliczak & Frey, 2009), and pantomimed and imagined actions (Moll et al., 2000) activate the left hemisphere more strongly than the right. Finally, evidence from the development of language skills showed that infants (10-12 months) who had a strong right hand preference for pointing gestures also had a larger receptive vocabulary (Mumford & Kita, under review). Similarly, Gonzalez, Li, Mills, Rosen, and Gibb (2014) showed that children (4-5 years old) with stronger right hand preference for hand-to-mouth grasping gestures were better at differentiating sounds (e.g., the acoustic distance between "s" and "sh"). These findings suggested that gesture and speech are developed and produced intertwined[5] in the left hemisphere.

However, the role of the language dominant left hemisphere for gesture production may have been "overestimated" and "oversimplified". The right hemisphere may also be involved for gesture production. For example, Kita, de Condappa, and Mohr (2007) showed that right-hand preference for gesturing is reduced when right-handed speakers explained metaphorical phrases (e.g., "to spill the beans" meaning to reveal a secret), which are known to particularly engage the right-hemisphere (see section 2.2.2 "Hemispheric involvement for metaphor processing"), compared to non-metaphorical, concrete phrases (e.g., "to spill the marbles"). Similarly, K. Miller and Franz (2005) found that when right-handed speakers talked about their daily routines and sequential events (e.g., "describe how your daily routine was at the university"), they used more unimanual gestures with the left hand than when they

[5] Fagard, Sirri, and Raemae (2014) highlighted that this relationship between hand preference for gesturing and language development is not causal, but reflects the tendency of language development and right-handedness to recruit the hemispheres in a lateralised manner.

talked about spatial conditions (e.g., "describe the house where you live now"). This finding suggested that hemispheric involvement relative to the content of speech might determine hand choice for gesturing.

Moreover, studies with clinical populations provided evidence that the language dominant left hemisphere is not the only one involved in gesture production. Foundas et al. (1995) showed that aphasic stroke patients with left hemisphere damage produced comparable amount of gestures with their healthy controls. In addition, they produced gestures with either one or both hands, thus the intact right hemisphere may compensate for gesture production. Similarly, Hadar, Wenkert-Olenik, Krauss, and Soroker (1998) showed that aphasic patients with lexical retrieval deficits in the left hemisphere produced iconic gestures. Studies with split-brain patients (patients with callosal disconnection) showed that speech and gesture production systems are closely related, but can be independent. In split-brain patients, the right hemisphere controls the left hand and the left hemisphere the right hand. If Kimura's theory was right, then split-brain patients with left hemispheric language production should produce right-hand gestures only. However, this has not been the case. Lausberg, Zaidel, Cruz, and Ptito (2007) showed that split-brain patients were unable to use the left hand for verbal command (e.g., experimenter would give command to use toothbrush and patients were unable to do so), but they used the left hand for gesturing. Similarly, Kita and Lausberg (2008) showed that split-brain patients (with either left-hemisphere dominant or bilateral language representation) produced gestures with spatial content with both left and right hands. This finding suggested that even the non-language-dominant right hemisphere could generate gestures independently from left hemispheric speech production.

Finally, there are always other aspects that may determine hand choice for gesture production. For example, Lausberg and Kita (2003) showed that semantic aspects of the message determined the choice of the right or left hand for gesturing (e.g., use of left hand to gesturally depict an object moving in the relative left position). In addition, Casasanto and Jasmin (2010) found that speakers used their dominant hand (either left or right) to represent messages with positive connotations in political debates. This finding suggested that emotional valence (positive-negative), and the way right- and left-handers represent valence (e.g., the dominant side, either left or right, is positive) may determine hand choice for gesturing. Furthermore, cultural conventions and type of gestures may also influence hand choice for gesturing. For example, speakers of the Arrernte dialect in central Australia always use their left hand to refer to targets that are on the left (Wilkins & de Ruiter, 1999). Pointing gestures show a right hand preference (McNeill, 1992; Wilkins & de Ruiter, 1999), while self-touching (e.g., shoulder shrugs) and beat gestures, which often co-occur with increased stress levels, show a left hand preference indicating the right hemispheric involvement for emotional expression (Kimura, 1973a; Lausberg et al., 2007).

To sum up, speech and gesture production systems are linked in the brain, but they may also be dissociated. The functional activity in the left or right hemisphere relative to cognitive processing may give rise to gestures with the right or left hand, respectively. This has an important implication for the rehabilitation of patients with unilateral damage. For example, Hanlon, Brown, and Gerstman (1990) found that right hand pointing, compared to left hand pointing or right hand fisting movement, enhanced performance of patients with left-hemisphere damage in a naming task. This finding suggested that gestures with one hand might enhance activations in the contra-lateral hemisphere, and in turn enhance processing involving this hemisphere. However, whether this enhancement occurs for cognitive processing in healthy speakers is unknown. If so, it could reveal an important aspect of the mechanism underlying gestures' self-oriented functions related to the mutual influence between hand choice for gesturing and hemispheric involvement for cognitive processing.

2.3.7 Hemispheric involvement for gesture production: relevance to the thesis

The literature related to the inter-relation between speech and gesture production systems in the brain, and hand choice for gesturing as reviewed in the above section has motivated and informed the current thesis in several ways. We investigated whether gestures with a particular hand may enhance processing in the contra-lateral hemisphere in healthy adults, and how gesture and speech interact in the right hemisphere.

More specifically, we know that hemispheric involvement in a cognitive task may determine hand choice for gesturing (e.g., Kita et al., 2007; Miller & Franz, 2005). In the current thesis, we manipulated the hand choice for gesturing to investigate if the reverse causal chain is also true. In Chapters 3, 4 and 5 we investigated whether gestures with the left hand may enhance several types of metaphorical processing in the right hemisphere (e.g., metaphor explanation; metaphor production and comprehension). If so, a hemisphere-specific feedback hypothesis would explain gestures' self oriented function, which implies that functional activation of the left hand for the production of gestures gives feedback and enhances activation in the right hemisphere areas involved in metaphorical processing.

2.4 Mouth asymmetry and hemispheric involvement during cognitive tasks

Several behavioural paradigms have been used to infer hemispheric involvement during different cognitive processes (e.g., visual hemifield tasks; dichotic monitoring tasks; mouth asymmetry tasks). In the current thesis, we are interested in hemispheric involvement during production tasks, and, as far as we know, mouth asymmetry is the only behavioural measurement for speech production. In this section, we review studies, which reported robust mouth asymmetry effects as evidence for the relative contribution of the two hemispheres during different tasks. The foundation of these studies is the contra-lateral cortical control of the facial musculature (Adams, Victor, & Ropper, 1997; Gardner, 1969). That is, if a process involves the left hemisphere and includes a mouth movement, the right side of the mouth will open wider than the left.

Research measuring mouth movements indicated the left-hemispheric involvement for speech production as evidenced by right-sided dominant mouth openings. Speakers open the right side of their mouth wider than the left during propositional speech production (e.g., spontaneous speech, word list generation) (R. Graves & Landis, 1985; Wolf & Goodale, 1987). The pattern is reversed (i.e., left side opens wider than the right) during automatic speech (e.g., singing, counting), which is considered to involve the right hemisphere (R. Graves & Landis, 1985).

Additionally, research measuring mouth movements indicated hemispheric involvement for emotional expressions (e.g., smiles). For example, Wyler, Graves, and Landis (1987) found a clear left-sided dominance for smiles, and in particular, this is true for spontaneous compared to posed smiles (Wylie & Goodale, 1988). Similarly, Holowka and Petitto (2002) showed that infants (5-12 months old) opened the right side of their mouth wider than the left when they were babbling (considered a precursor to speech) compared to smiling.

Research with clinical populations showed different mouth asymmetry patterns, but confirmed the sensitivity of the technique to capture hemispheric involvement across different populations. For example, Ulrich, Sydathnunez, and Mulleroerlinghausen (1990) found that patients with bipolar depression did not show strongly right-sided dominant mouth openings. Similarly, Choo, Robb, Dalrymple-Alford, Huckabee, and O'Beirne (2010) found that adult stuttering speakers showed left-sided dominant mouth openings, compared to a control non-stuttering group. This finding suggested that the right-hemisphere is also involved for speech production in these groups.

Finally, mouth asymmetry during speech production may affect visual perception. Nicholls, Searle, and Bradshaw (2004) suggested that listeners have an intuitive knowledge of the mouth asymmetry, because they preferentially attended to the right side of a speaker's mouth. This suggests that mouth asymmetry is a valid measurement of the visual expression of speech that could potentially affect speech comprehension.

2.4.1 Mouth asymmetry: relevance to the thesis

The literature reviewed in the above section suggested that the mouth asymmetry is a safe, inexpensive technique, and the only way to infer hemispheric involvement during online speech production rather than perception (such as dichotic listening tasks). In addition, the patterns of mouth asymmetry seem to feature a similar trend to those of gesture lateralisation and handedness (as reviewed in section 2.3.6 "Hemispheric involvement for gesture production"), and the systems of mouth and hand movements are linked for the production of language (Iverson & Thelen, 1999). Thus, mouth asymmetry during speech production provides evidence for hemispheric involvement during speech production at an individual level. More specifically, in Chapter 3 we collected mouth asymmetry measurements in explanation tasks as an index of individual differences for hemispheric involvement during speech production. We assessed the relationship of this index with the gesture handedness effect on metaphorical explanation, in order to further support a hemisphere-specific feedback hypothesis for gestures' self-oriented functions.

In addition, in Chapter 6 we collected mouth asymmetry measurements during different explanation tasks (metaphorical and concrete), and during production of different word types (content and function words) to investigate whether metaphorical as opposed to literal meaning particularly involves the right hemisphere. We also investigated whether semantics, as in metaphorical representation of meaning in content words rather than expression of grammatical relationships in function words, are crucial for this right-hemispheric involvement during metaphorical speech production.

2.5 Summary and research aims

To sum up, the current thesis investigates how language interacts with other cognitive functions, by exploring how language and gesture inter-relate, and how sensory-motor information influences language processing. It particularly focuses on how sensory-motor information expressed in gestures influences semantics during metaphor processing, that is the representation of the semantic link between concrete and abstract meaning whilst speakers explain and comprehend metaphors. It explores the bi-directional relation between language and gestures with a focus on the link ‘from gesture to language’. The thesis draws upon and aims to extend four core theoretical fields:

(a) The Embodied Theories of meaning representation suggest that sensory-motor information systems have a functional role for language processing (see for a review Meteyard et al., 2012). Strong embodied accounts suggest so for processing both abstract and concrete language (Glenberg & Kaschak, 2003). The current thesis investigates whether representing sensory-motor information in gestures (rather than producing meaningless motoric movements or not moving) determines the semantic representation of abstract meaning in the form of metaphor. If so, sensory-motor information and physical experience would be necessary for language processing, and gestures would help cognitive functions due to semantic (i.e., they carry and represent meaning) rather than motoric properties.

(b) The Conceptual Metaphor Theory supports that metaphor comprehension relies on conceptual metaphors and systematic metaphorical mappings between semantically distant concepts (Lakoff, 1993; Lakoff & Johnson, 1980a). If conceptual knowledge and metaphorical mappings from concrete to abstract concepts underlie and motivate the whole range of metaphor processing, then gestural representation of sensory-motor information would affect all different components of metaphorical processing, which may vary in the degree of their dependence on metaphorical mappings (e.g., metaphorical explanation – high dependence on mappings, production of metaphors – low dependence on mappings). The current thesis draws upon the importance of conceptual knowledge for metaphor processing and investigates whether metaphor processing can be facilitated by gestures.

(c) The Right Hemisphere Hypothesis for metaphor proposes a particular involvement of the right hemisphere for metaphor comprehension (Bottini et al., 1994; Jung-Beeman, 2005), but why and whether this holds true for metaphor production is still unclear. The current thesis investigates the relative involvement of the right hemisphere during metaphorical speech production and explores if the production of content words related to metaphor rather than function words, which express grammatical relationships is crucial for this involvement.

(d) The theories for Self-oriented Functions of gestures suggest that gestures facilitate cognitive processing by helping lexical access, image maintenance, working memory and organisation of information (Goldin-Meadow et al., 2001; Kita, 2000; Krauss, 1998; Wesp et al., 2001). The current thesis investigates whether gestures with the one or the other hand, compared to meaningless movements or no movement may modulate conceptualisation of abstract meaning in the form of metaphor and content of speech in different linguistic tasks, which vary in the degree of relative hemispheric involvement. For the first time, it explores whether left and right hand gestures differ in the degree of their facilitative effect. If so, gestures' self-oriented functions would be hemisphere and task specific, and using the one hand to gesture would enhance processing in the one or the other hemisphere.

In order to approach our research aims, we implemented three experiments, in which we manipulated hand movements and measured their effect on metaphorical speech production and comprehension, and one in which we measured relative hemispheric involvement for metaphorical speech production. In each experiment, we addressed the following specific questions:

(1) Do left hand gestures enhance explanations of metaphorical phrases as opposed to right hand gestures or not gesturing at all? Does this left-over-right-hand gesturing advantage relate with the right-hemispheric involvement for speech production? (Chapter 3)

(2) Do left hand gestures trigger the use of metaphor related expressions within abstract context as opposed to meaningless tapping movements (Chapter 4)

(3) Does representation of action meaning through gesturing prime semantic categorisation of metaphorical and literal action sentences? Do priming effects differ among the categorisation of literal and metaphorical sentences? Does representation of action meaning through left hand gestures particularly prime categorisation of metaphorical compared to literal action sentences? (Chapter 5)

(4) Is the right hemisphere particularly involved during production of metaphorical speech? If so, is semantics crucial for this involvement? Does the right-sided mouth asymmetry reduce during metaphorical compared to concrete speech production? If so, is this reduction particularly pronounced for the production of content compared to function words? (Chapter 6).

3 Hand matters: left-hand gestures enhance metaphor explanation

3.1 Motivation and aims

This study investigated whether the underlying mechanism for gestures' self-oriented functions relates to the mutual influence between gesture handedness and language hemispheric dominance, focusing on metaphorical processing. Previous research (Kita, de Condappa, et al., 2007) has shown that the right-over-left hand preference for gesturing is reduced when speakers explain metaphorical compared to non-metaphorical phrases. The current study investigated the reverse directional link: does left hand gesturing improve metaphor explanation? It provided evidence for a "hemisphere-specific feedback hypothesis" for gestures' self-oriented functions.

3.2 Abstract

Research suggests that speech-accompanying gestures influence cognitive processes, but it is not clear whether right- vs. left-hand gestures have differential effects. Two experiments tested the "hemisphere-specific feedback hypothesis" for gestures' self-oriented functions: gestures with a particular hand enhance cognitive processes in the contra-lateral hemisphere. Specifically, we tested whether left-hand gestures enhance metaphorical explanation, which involves processing in the right hemisphere. In Experiment 1, right-handers explained metaphorical mappings in phrases such as "to spill the beans" (e.g., beans represent pieces of information). Participants were instructed to gesture with their left hand or right hand or to not gesture at all. Speech outputs included more elaborate explanations of the metaphorical mappings when participants gestured with their left hand compared to when they gestured with the right hand or did not gesture at all. Furthermore, we measured participants' mouth asymmetry during additional verbal tasks to determine individual differences in right-hemispheric involvement for speech production. The left-side mouth dominance, indicating stronger right-hemispheric involvement, positively correlated with the left-over-right-hand advantage in the gestural facilitation of metaphor explanation. Experiment 2 ruled out an alternative interpretation of Experiment 1 that the observed left-hand advantage was due to right-hand prohibition (e.g., causing distractions). These results supported the hemisphere-specific feedback hypothesis.

Keywords: Metaphor; gesture handedness; brain hemispheric lateralisation; right hemisphere; mouth asymmetry.

3.3 Introduction

Imagine two people talking face-to-face. Now imagine a person talking on the phone. One thing is common: whether seen by others or not, people often spontaneously produce hand gestures to accompany their speech. That is, speech and gesture often co-occur and co-express the speakers' message as a composite signal (Engle, 1998; Kelly, Ozyurek, & Maris, 2010; Kendon, 2004). Speech and gesture are tightly linked behaviours at various levels of language structure such as phonetics, syntax, semantics and pragmatics (Iverson & Thelen, 1999; Kita & Ozyürek, 2003; McNeill, 1992). This close relationship between language, cognition and gesture has drawn scholars' attention in a wide range of research topics such as the embodied nature of language processing (Glenberg & Kaschak, 2002; Hostetter & Alibali, 2008), the role of body in understanding and representing abstract thought (Cienki & Müller, 2008; Lakoff & Johnson, 1980a; Mittelberg & Waugh, 2009), and the gestural origin hypothesis of language evolution (Arbib, 2005; Corballis, 2003). Gestures express information valuable for the listener, and thus play an important role in how people communicate (Hostetter, 2011). Furthermore, gestures not only reflect, but also influence the contents of speakers' thoughts (de Ruiter, 1995; Kita, 2000; Rauscher et al., 1996). The current study investigated the mechanism through which representational gestures influence speakers' thoughts and determine speech output. Representational gestures iconically depict shape, motion and action or deictically indicate locations and directions. Speakers can also use gestures to express abstract content metaphorically (e.g., moving a palm-up open hand away from the body can express the abstract action of "conveying a message", depicted as an object on the palm moving away from the body) (McNeill, 1992).

Various theoretical accounts propose that representational gestures facilitate specific cognitive processes in the gesturer's mind: lexical retrieval (R. Krauss & Hadar, 2001; Pine et al., 2007; Rauscher et al., 1996), imagery maintenance (de Ruiter, 1995; Wesp et al., 2001), conceptualisation for speaking (Alibali & Kita, 2010; Alibali, Kita, & Young, 2000; Hostetter et al., 2007; Kita, 2000; Melinger & Kita, 2007), and working memory (Goldin-Meadow et al., 2001). However, the mechanism for such facilitative effects remains to be explored. In particular, no studies have investigated whether the right- and the left-hand gestures differ in the degree of impact they have on language processing.

Hand choice for gesturing is linked to hemispheric dominance for certain cognitive processes, in particular language processing (but see Lausberg, Zaidel, Cruz, & Ptito, 2007). Kimura's research (1973a) with healthy adults showed that stronger left lateralisation for language (measured with a right-ear advantage in a dichotomous listening task) leads to more frequent right-handed gestures during speaking compared to manual activities during a silent task. Furthermore, infants who spontaneously choose the right hand for gesturing are more advanced in language development. For example, Locke, Bekken, McMinnLarson, and Wein (1995) showed an increase of right-hand shaking in babbling infants as compared to non-babbling infants. Also, 10-12 month-old infants who are more strongly right-handed when pointing have a larger receptive vocabulary (Mumford & Kita, under review).

Hand choice for gesturing also reflects the right-hemisphere contribution for language production. Patients with complete callosal disconnection ("split-brain patients") produced "batons" (repetitive up and down hand movements, equivalent to beats in McNeill, 1992) more with the left hand. Other studies on split-brain patients provided converging results (Lausberg, Davis, & Rothenaüser, 2000; McNeill, 1992; McNeill & Pedelty, 1995). As batons are thought to be linked to speech prosody (Krahmer & Swerts, 2007), this finding indicates that the right hemisphere dominance in prosody production (Lindell, 2006) led to the left-hand preference for this type of gestures.

Metaphorical language processing is another good domain for assessing the link between hand choice for gesturing and hemispheric dominance for cognitive processing.

Firstly, according to the Conceptual Metaphor Theory (Lakoff & Johnson, 1980a), metaphor is a way of talking about an abstract concept such as “love” in terms of a more concrete, yet semantically distant, concept such as “journey”. Hence, understanding the metaphorical phrase “their relationship was a roller-coaster ride” would involve metaphorical mapping from the source (JOURNEY) to the target (LOVE) domain of the metaphor. These mappings are key parts of metaphor interpretation processes. For example, Nayak and Gibbs (1990) presented participants with short scenarios about emotions (e.g., anger), which were structured to include phrases priming a specific conceptual metaphor. An emotional scenario about anger would include phrases such as “Mary was tense […] made her fume […] the pressure was building up” to prime the conceptual metaphor ANGER IS A FLUID IN A HEATED CONTAINER. After reading the texts participants had to select one out of two idioms to appropriately describe the meaning of the scenario. The related idiom was motivated by the primed conceptual metaphor (e.g., “blew her top”), and the unrelated one had the same meaning but different underlying conceptual metaphor (e.g., “bit her head off”; ANGRY BEHAVIOUR IS ANIMAL BEHAVIOUR). Participants selected the related idiom, suggesting that congruent metaphorical mappings can prime each other.

Secondly, according to the Right-Hemisphere Hypothesis for Metaphor, the right-hemisphere is particularly involved for metaphorical processing (Anaki et al., 1998; Bottini et al., 1994; Brownell et al., 1990; Mashal et al., 2005; Mashal et al., 2007; Schmidt et al., 2007; Winner & Gardner, 1977), though some studies failed to provide evidence for such a claim (Rapp et al., 2004, 2007) (see Schmidt, Kranjec, Cardillo, & Chatterjee, 2010 for a review on the neural correlates of metaphor). One plausible explanation for the Right-Hemisphere Hypothesis for Metaphor is that metaphorical mappings can be seen as distant semantic relations between the source and target domains, and the right hemisphere is better tuned to process distant semantic links (Jung-Beeman, 2005).

Hand choice for gesturing is linked to hemispheric dominance for metaphor processing. More specifically metaphorical processing in the right hemisphere triggers left-hand gesturing. Kita, de Condappa, et al. (2007) investigated whether spontaneous hand preference is influenced by metaphorical contents of speech. Participants explained metaphorical mappings in phrases such as "to spill the beans", and in the control conditions, they explained the meaning of concrete and abstract phrases (e.g., "to spill the marbles", "to reveal something confidential"). They produced gestures spontaneously (the instruction did not mention gesture) during explanations and the proportion of left-hand gestures out of all unimanual gestures was higher in the metaphor condition than the concrete and the abstract condition. Similarly, a study on split-brain patients also showed a descriptive[6] trend that the left hand is preferred for gestures depicting abstract concepts ("ideographs") (Lausberg et al., 2007). These results suggest that language processes in the contra-lateral hemisphere triggered gestures with a particular hand. However, it is not clear whether the reverse causal chain is at work, that is, whether left-hand gestures may trigger processing in the contra-lateral hemisphere.

The present study tested whether left-hand gesturing enhances metaphorical explanations compared to right-hand gesturing and not gesturing at all. If the hypothesis were confirmed, gesture handedness would be an important part of the underlying mechanism for gestures' self-oriented functions. More specifically, Experiment 1 tested whether the hand used for gesturing differentially affected participants' performance in a metaphorical explanation task. Participants were asked to explain the metaphorical mapping underlying English phrases, such as "to spill the beans" (meaning "to reveal a secret"): "beans" represent secrets and "spilling" represents dispersion of information. Tasks using these phrases have been previously shown to engage metaphorical thinking, and thus are likely to involve the

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[6] Lausberg et al. (2007) reported only descriptive statistics for the hand choice for each of the gesture types.

right hemisphere (Argyriou, Byfield, & Kita, 2015; Kita, de Condappa, et al., 2007). The explanations were rated for the level of metaphoricity, namely, how well participants described metaphorical mappings.

We manipulated gesture production by encouraging subjects to gesture with their left or right hand only or instructing them not to gesture at all. If gestures facilitate cognitive processes in the contra-lateral hemisphere, then metaphorical explanations should be of higher quality and metaphorical mappings should be explained more elaborately when participants gestured with their left hand compared to the other two conditions.

In order to better link the hand-specificity of the facilitative gesturing effect to the processing in the contra-lateral hemisphere, we measured behavioural indicators for the degree of lateralisation of speech production during explanation tasks from each participant. Behavioural tasks provide valid measurements of cerebral language dominance. Hunter and Brysbaert (2008) showed that language dominance as measured by a visual hemifield advantage in a word naming task positively correlated with cerebral dominance determined in an fMRI silent word generation task. In the current study, we collected mouth asymmetry measurements during speech production in a separate explanation task. Mouth asymmetry is sensitive to relative hemispheric involvement during different cognitive tasks. For example, R. Graves and Landis (1985, 1990) showed that the right side of the mouth opened wider than the left during propositional speech (e.g., spontaneous speech, word list generation), reflecting the left hemisphere cerebral involvement for speech production. In contrast, during automatic speech (e.g., singing, counting) or emotional expressions (e.g., spontaneous smiles) (Wyler et al., 1987), which are both thought to particularly involve the right-hemisphere (see for a review Lindell, 2006), the left side of the mouth opened wider than the right. In addition, Hausmann et al. (1998) showed a right-sided mouth asymmetry during discrete speech production tasks (i.e., utter words only once) for male and female speakers, but a reduced right-sided asymmetry for females only during serial speech production tasks (i.e., utter the same words repeatedly). Thus, this suggests that mouth asymmetry is sensitive enough to reflect the existence of separate, bilateral neural systems for speech production, which are gender dependent. Furthermore, a study from our group (Argyriou et al., 2015) showed that the right-sided mouth openings reduced during explanation of metaphorical phrases compared to non-metaphorical phrases (same tasks as in the present study), and this reduction was larger for content words than for function words. This suggested that mouth opening asymmetry is sensitive to hemispheric differences in semantic processing involved in metaphorical explanation. Finally, stronger lateralisation of cognitive functions measured in behavioural tasks is associated with better performance in these tasks. Hirnstein, Hugdahl, and Hausmann (2014) showed that accuracy in performance in a dichotic listening task (e.g., number of correctly reported syllables) increased as the degree of the (left/right) ear advantage increased. In light of these findings, if the left-hand gesturing facilitates metaphorical processing in the right hemisphere, this facilitation effect should be stronger for those who show a stronger right-hemisphere involvement in speech production during explanation tasks. This is because when the right-hemisphere is strongly involved in speech production, it is easier for left-hand gestures to influence speech production processes.

Finally, even if we obtained the predicted result that the left-hand free condition leads to better metaphor explanations in Experiment 1, there is a possible alternative explanation that prohibition of the right-hand movement, rather than left-hand gesturing, is responsible for the effect. We conducted Experiment 2 to rule out this possibility.

3.4 Experiment 1

3.4.1 Method

Participants

31 right-handed, male, native English speakers and monolinguals (via self-report), at least until the age of 5 years (age: M = 20.35 and SD = 2.86), participated in the experiment for course credit or £4. Handedness was assessed with a 12-items questionnaire based on the Edinburgh Handedness Inventory (Oldfield, 1971). Two bimanual items (from Oldfield's long list) were added to his recommended 10-items questionnaire to equate the number of unimanual and bimanual items (see Text S1 in Appendix Chapter 3 for the questionnaire). Each "left" answer was scored with 0, each "either" answer with 0.5 and each right answer with "1". A total score of 8.5 and above determined right-handedness (M = 10.9 and SD = 1.08). None of the participants had any previous serious injury to the face or jaw. All of them were recruited at the University of Birmingham. The rationale for the size and gender of our sample follows below.

The current thesis did not employ *a priori* power analysis to calculate sample size. We rather followed the paradigm of similar studies in the literature, which found significant results and tested a comparable amount of participants (e.g., Kita, de Condappa et al., 2007 tested 20 subjects; Rauscher et al., 1996 tested 40 subjects, therefore we tested 31 subjects which is the mid-point). When our design had more treatments or more groups we doubled the amount of people tested (e.g., in Chapter 4 we tested 60 subjects). However, results from G*Power 3.1 show that for one group being measured across three observations, alpha of .05, a power of .80, and a large treatment effect of .05, we would need to collect data from 33 participants. Therefore, our decision was justified.

Furthermore, we focused on male speakers because they exhibit bilateral representation of language processing less frequently than women (J. McGlone, 1980). In addition, in females cerebral asymmetries and lateralisation of cognitive functions, such as language processing, can be modulated by hormones, hence are less stable than in men (Hausmann & Güntürkün, 2000). In a small subset of the population, language may be predominantly processed in the right hemisphere. Some left-handers might have right-hemisphere language dominance (Hunter & Brysbaert, 2008), and even strong right-handers might have right-hemisphere language dominance, though the percentage of such cases should be very small (about 5%) (Knecht et al., 2000). However, future experimental studies, including Chapters 4 and 5 to follow in this thesis, should aim to extend findings to female speakers as well.

Stimuli

For the main metaphorical explanation gesture elicitation task, we used 18 English phrases with metaphorical meaning. We added 6 phrases to the list of metaphorical stimuli used in Kita, de Condappa, et al. (2007). We created 3 (plus one reserve item in case one phrase was unknown) additional metaphorical and concrete phrases for the mouth asymmetry task (see Table 3.1).

Table 3.1 The stimuli for the metaphorical explanation gesture elicitation task, and the mouth asymmetry task. The items in parentheses are reserve items used when the participants did not know the main items.

Metaphorical phrases for main explanation task for gesture elicitation	
To burst someone’s bubble	To sit on the fence
To cross that bridge later	To skate on thin ice
To dodge the bullet	To spill the beans
To fall back down to earth with a bump	To stand your ground

To get back in the saddle	To take the bull by the horns
To get hot under the collar	To tie up loose ends
To hold all the cards	To turn a corner
To leave a bad taste in the mouth	To turn the tables
To look on the bright side	Water under the bridge
Metaphorical phrases for the mouth asymmetry task	
To pour oil onto the fire	To spin a yarn
To set your sights higher	(To hit the nail on the head)
Concrete phrases for the mouth asymmetry task	
To pour oil into the pan	To spin a golf ball
To put a shelf higher	(To hit someone on the head)

Procedure

Participants were tested individually. They were seated on a chair, which was located between two tables of the same height (71 cm tall). The experimenter was facing the participant, and the video camera (Sanyo HD camera) was placed next to the experimenter. Stimuli were presented one by one on a white sheet of paper (font size 72, Times New Roman), which was held by the experimenter until the participant started the description.

Participants were instructed to explain the meaning of the 18 metaphorical phrases (see Table 3.1) as if they were explaining it to a non-native English speaker (the task was the same as in the metaphorical condition in Kita, de Condappa et al., 2007). To encourage metaphorical thinking, participants were instructed to include an explanation as to how the literal meaning can be mapped on to the metaphorical meaning of the phrase (e.g., in the phrase "to spill the beans", describe that the "beans" refer to secrets, and the action of "spilling" refers to revealing them to everybody). During the description, participants were told to place one of their hands on the indicated marks (white sticky dots) on the surface of the table(s), and to keep it still for the whole procedure. For the total prohibition condition, participants were asked to place both their hands on the tables (see Figure 3.1). Differently from Kita, de Condappa et al. (2007) where participant were free to gesture or not, in the current study for the gesturing conditions, participants received gesture encouragement instructions (i.e., the experimenter asked them "please use your free hand to gesture while speaking"). Gesture encouragement has been used in a number of recent studies (Broaders, Cook, Mitchell, & Goldin-Meadow, 2007; Chu & Kita, 2011; Cook, Yip, & Goldin-Meadow, 2012), and allowed us to test the link between gestures and speech focusing on the direction "from-gesture-to-speech". Participants were debriefed about the purpose of the hands immobilisation after the experiment and the permission to use the data was allowed. Order of stimuli (forward - reverse), and order of hand(s) prohibition were counterbalanced across participants in a within-subjects blocked design.

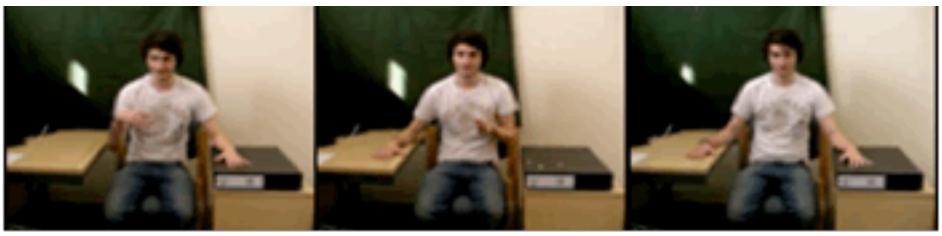

Figure 3.1 Experimental conditions in Experiment 1: Right Hand Free (left panel), Left Hand Free (middle panel), No gesturing (right panel).

The mouth asymmetry task followed the metaphorical explanation gesture elicitation task. In the mouth asymmetry task, participants were instructed to explain the 3 metaphorical phrases (see Table 1) (e.g., explain the mapping of the literal meaning to the metaphorical meaning), just as in the main metaphorical explanation gesture elicitation task. They also explained the meaning of 3 concrete phrases (see Table 1) and were instructed to be as elaborate as possible. During the explanations both hands were prohibited. Hand prohibition was necessary in order to collect a pure measurement of participants' hemispheric involvement for metaphorical processing without any influence from hand movement. The order of the tasks (concrete – metaphorical) was counterbalanced across participants. Video-recording zoomed-in on the face area.

Coding

The verbal responses from the main task were transcribed and coded for level of metaphoricity. The level of metaphoricity was measured based on whether the explanations included an explicit link between the literal and metaphorical meanings, and whether participants explicitly referred to the mapping and correspondences between the source and target domains of the conceptual metaphor underlying each phrase (following the Conceptual Metaphor Theory; Lakoff & Johnson, 1980a; Nayak & Gibbs, 1990). The stimulus phrases were idiomatic, which may not always activate the right-hemisphere. For example, Papagno, Oliveri, and Romero (2002) used repetitive transcranial stimulation while participants matched the meaning of an idiom to a picture. They found no evidence that right, temporal lobe stimulation affected response times and accuracy. However, the task in the current study required participants to actively analyse the literal and metaphorical meaning, and establish a metaphorical mapping between distant semantic relations. Such a process is considered crucial for the right-hemispheric involvement for metaphorical processing (Jung-Beeman, 2005). More specifically, a ‘‘0’’ rating indicated that the explanation did not contain words or phrases referring to the source domain of the relevant conceptual metaphor, therefore there was no metaphorical cross-domain mapping; a rating of ‘‘1’’ indicated that the explanation contained words or phrases that might be construed as references to the source domain, but the references were ambiguous, and the mapping between the two domains implicit; a rating of ‘‘2’’ indicated that the explanation contained words or phrases that clearly referred to the source and target domains, and the mapping was explicit. Text S2 in Appendix Chapter 3 presents examples and the coding manual in detail.

Video recordings from the two gesturing conditions in the main task were analysed using ELAN software (developed by the Max Planck Institute for Psycholinguists, Nijmegen, the Netherlands). They were coded on a trial-by-trial basis to locate the existence of at least one gesture type, using the coding scheme by Chu, Meyer, Foulkes, and Kita (2014). That is representational gestures (e.g., hand movements depicting shape, motion and action or deictically indicate location), palm-revealing gestures (e.g., palm rotates to show uncertainty or that speaker has nothing to say or), conduit gestures (e.g., hand moves towards listener as if speaker is conveying a clear message), and other (e.g., small biphasic movements/ beats). See the supplementary material in Chu et al. (2014) for more details. The rationale for this ‘rough’ coding (instead, for example, of coding all gestures for their type) is twofold. Firstly, full coding would be useful if gesture rate was part of the research hypothesis and analysis, which is not the case in the current study. Secondly, participants in the current study were encouraged to gesture, hence the amount of gestures produced would not reflect the spontaneous gesture rate usually calculated in gesture studies. Therefore, we believe that the current gesture coding (i.e., presence of at least one gesture type per trial) is sufficient to ensure that participants produced meaningful representational gestures and validate the success of the gesture encouragement instruction.

Video recordings from the mouth asymmetry task were analysed on a frame-by-frame basis using ELAN software to identify the maximum mouth openings in each phrase explanation. One maximum opening was defined as the widest point the mouth opens, from the lips opening to the lips resting or the lips meeting completely. We coded the laterality at each maximum mouth opening. The options for laterality classification were right-side dominant (the right side of the mouth opens wider than the left), left-side dominant (the left side of the mouth opens wider than the right) or sides equally open (see Figure 3.2 for examples). Maximum openings for filled-pauses were coded, but not the ones for non-speaking purposes (e.g., smile) or the ones whilst participants were repeating the phrase to be explained. We coded the first 30 mouth openings per condition (metaphorical – concrete), per participant (the first ten mouth openings from each explanation) (following Graves, Goodglass & Landis, 1982 who also coded the first ten successive lip openings with word production). In total, we coded 930 mouth openings in the metaphorical task and 915 in the concrete task (few participants gave short explanations in the concrete task and thus we could only obtain less than 30 mouth openings per condition). Text S3 in Appendix Chapter 3 presents the coding manual in detail.

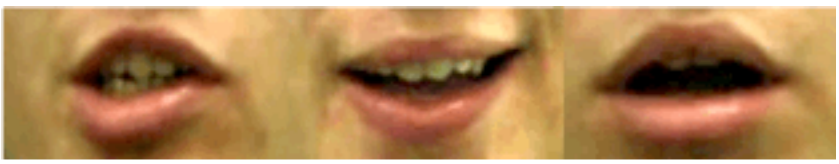

Figure 3.2 Examples of maximum mouth opening asymmetry in Experiment 1. Right-sided asymmetry (left panel), Left-sided asymmetry (middle panel), Both sides equally open (right panel) (“Left-sided” and “right-sided” refer to participants’ left and right).

Inter-coder reliability for coding

An additional coder, "blind" to the hypothesis under test and conditions, independently coded 32% of the total verbal responses in terms of metaphoricity. All answers from 10 randomly selected participants were coded (in total 180 trials were double coded). Coding of metaphoricity matched between the two coders 76% of the time (Cohen's weighted kappa $\kappa_w = .68$, $p < .001$, kappa maximum $\kappa_{max} = .91$).

An additional coder, "blind" to the hypothesis under test and conditions, independently coded 24% of the video recordings from the two gesturing conditions in terms of the existence (or absence) of at least one gesture type. All answers from 7 randomly selected participants were coded (in total 84 trials were double coded). Coding matched between the two coders 98% of the time for the coding of trials with at least one representational gesture; 85% of the time for palm-revealing gesture; 96% of the time for conduit gesture; 81% of the time for other gesture. Note that measurement of agreement (kappa statistics) was not calculated because the random selection of cases for second coding led to a constant value (= either absence or existence of particular gesture type for all 84 trials) for a variable upon which kappa is calculated.

An additional coder independently coded 22% of the data in terms of right, left or equal dominance of mouth openings. All mouth openings from 7 randomly selected participants were coded (in total 414 maximum mouth openings were double coded). Coding of mouth opening dominance matched between the two coders 91% of the time (Cohen's kappa $\kappa = .854$, $p < .001$).

Note, that partial double coding of gesture and speech is used in other studies (e.g., in Kita, de Condappa, et al. 2007, 8.3% of all responses was double coded). In addition, we double coded all verbal responses and mouth openings from random participants instead of coding some random verbal responses and mouth openings from all participants. For the verbal responses, the latter option would mean that the second coder reads no more than 5 examples of the same phrase explanation, while with our strategy the second coder read and coded 10 examples of the same phrase explanation. This way the second coder had more chances to see the variability of responses and made good use of the whole range of the scale more than once or twice. Similarly, for the mouth openings double coding all mouth openings from a specific amount of participants ensured an adequate probability of all types of openings (left, right, equal) to be double coded (instead of selecting more equals for example). Finally, for all analyses, the first coder's original coding was used, because the partial coding does not allow calculation of means, however the substantial agreement (kappa above .61) between the coders proves the validity of the first coding.

3.4.2 Design and measurements

The dependent variable from the main metaphorical explanation gesture elicitation task was the level of metaphoricity in participants' explanations. The independent variable (within-subjects manipulation) "hand free" had three levels (left, right, no hand).

Next, we calculated a left-over-right-hand gesturing advantage index from the main metaphorical explanation gesture elicitation task: the average level of metaphoricity when gesturing with the left hand minus the average level of metaphoricity when gesturing with the right hand. Thus, a high and positive mean score indicated that participants were more metaphoric when gesturing with their left hand compared to the right (= left-over-right-hand gesturing advantage on metaphoricity). We argue that the difference score is a better measurement to test our hypothesis compared to the metaphoricity scores in the single gesturing conditions. This is because single condition scores may be influenced by many other factors (e.g., general intelligence of participants, their linguistic knowledge or how focused they were at the time of the experiment), which all add noise to the analysis of interest, while the difference score is not influenced by these factors. In addition, the differences are not the same for all participants (e.g., some participants were better in the left hand free condition, some in the right hand free), hence the difference score makes sense (for a review on difference scores see Edwards, 2001).

Finally, we measured the mouth asymmetry during speaking in a task additional to the main metaphorical explanation gesture elicitation task, in which participants explained concrete and metaphorical phrases. We computed a left-sided dominance in mouth openings using the following formula: (L-R)/(L+R+E), where L, R and E are the numbers of left-side-dominant, right-side dominant, and equal mouth openings, respectively (Argyriou et al., 2015; Holowka & Petitto, 2002). Thus, a positive mean score indicated more instances of left-side dominant mouth openings (right-hemispheric involvement) and a negative mean score indicated more instances of right-side dominant mouth openings (left-hemispheric involvement).

3.4.3 Note for mixed effect models

We used linear mixed effects models (LME) with subject and item as random factors, and the packages *lme4* and *multcomp* in the R Project for Statistical Computing environment, version 3.1.1 (Bates & Sarkar, 2012; Hothorn, Bretz, & Westfall, 2012; R Development Core Team, 2011). All mixed effects regressions were carried out with "lmer()" function specifying that Maximum Likelihood (rather than Restricted Maximum Likelihood) is used (needed to get a more valid likelihood ratio test of the full against the null model). Random effects structure was kept maximal as long as model convergence was reached (for a discussion about random effects structure and simplification see Barr, Levy, Scheepers, & Tily, 2013). We obtained p-values for fixed effects following the likelihood ratio test approach for model comparison and we always reported the maximal model following a design-driven approach for confirmatory analyses. Tests of further contrasts of our interests were carried out based on a priori predictions using the generalised linear hypothesis test with correction for multiple comparisons of means, (Tukey Contrasts) using the "glht()" function.

3.4.4 Results

Out of the 558 trials in the main task, 4% were excluded as failed trials; that is when the participants did not follow the instruction (e.g., no gesture production when encouraged to gesture with the right or left hand) or when they did not know the phrases.

Out of the 354 gesturing trials, 99% included at least one representational gesture; 23% included at least one palm-revealing gesture; 7% included at least one conduit gesture; 18% included at least one "other" gesture – comprising mainly beat and metacognitive gestures. Thus, the instruction to produce gestures was effective and gestures were predominantly representational gestures.

On average, participants produced explanations with higher levels of metaphoricity (measured on a 3-points scale from 0-2) in the following order: when gesturing with the left hand (M = 1.44, SEM = .06), the right hand (M = 1.30, SEM = .06) and not gesturing at all (M = 1.16, SEM = .06) (see Figure 3.3).

We fit LME[7] model to the measurement of the level of the metaphoricity (see Figure 3.3 for the means). The model included one fixed effect factor: hand free (left, right, no hand; "no hand" was the reference category). We selected "no hand" as the reference category so that the model produces the comparisons between the experimental conditions and the

[7] We ran the analysis treating the dependent variable as ordinal and results remained the same. See Text S4 in Appendix Chapter 3 for the results in detail.

baseline of no movement. We included random intercepts and slopes by subjects and items (phrases) for the fixed effect factor.

Model estimates are reported in Table 3.2. We compared the model with the null model with no fixed effect factors (same random effect structure). Adding the effect of hand free for gesturing (left, right, none) improved the model fit: χ^2 (2) = 16.36, $p < .001$ (see Figure 3.3). Simultaneous tests for general linear hypotheses (Tukey Contrasts) (see Table 3.3) revealed that gestures with the left hand increased the level of metaphoricity in metaphorical explanations as compared to the right hand and not gesturing at all.

Table 3.2 Parameters estimates for the model with the effect of hand free on levels of metaphoricity. "No hand" condition was the reference category.

	Estimate	SE	t-value
(Intercept)	1.159	.078	14.700
Left Hand	.277	.061	4.509
Right Hand	.133	.062	2.126

Table 3.3 Tukey contrasts for the model with the effect of Hand Free on levels of metaphoricity.

	Estimate	SE	z-value	p-value
No – Left Hand	-.277	.061	-4.509	< .001
Right – Left Hand	-.143	.061	-2.345	.049
No – Right Hand	-.133	.062	-2.126	.084

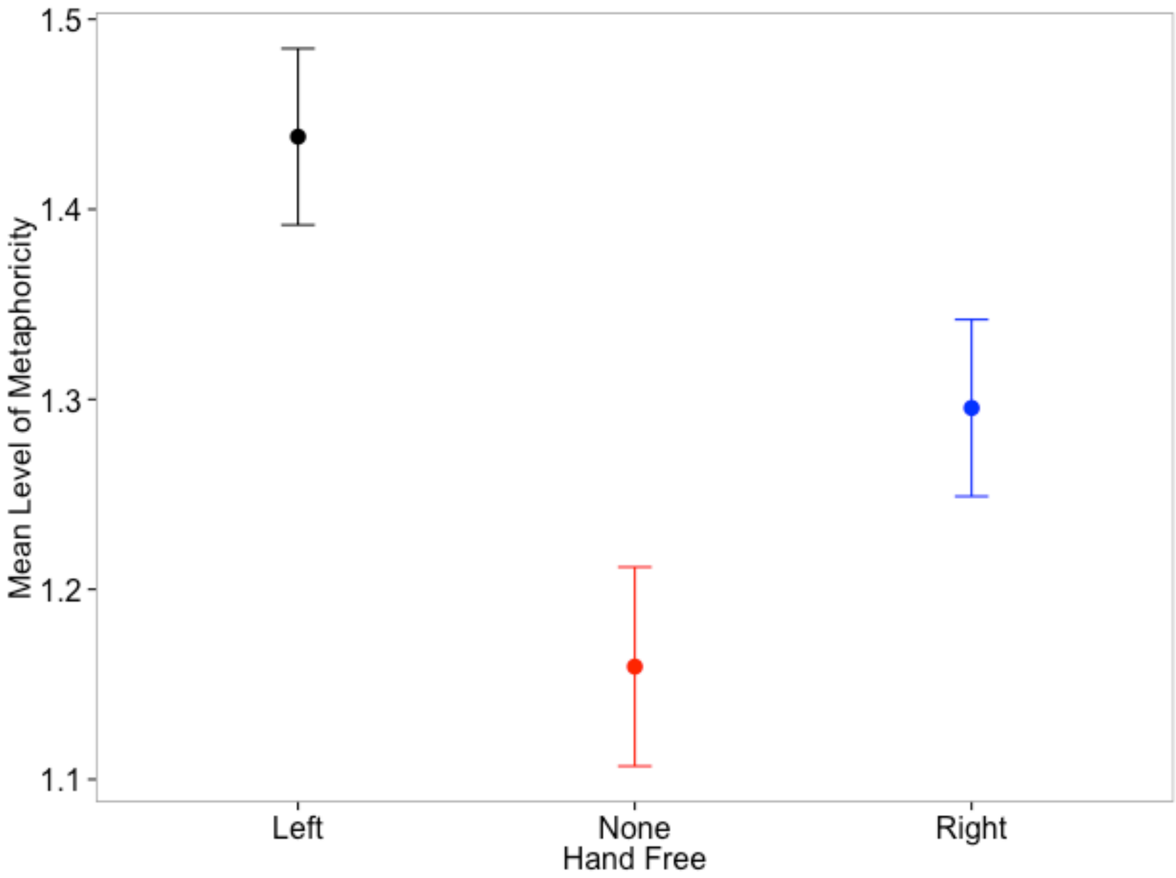

Figure 3.3 Mean levels of metaphoricity (measured on a 3-points scale from 0-2) in speech in the three gesturing conditions (Experiment 1). Error bars represent 1 standard error of the means.

One may argue that the observed effects of hand gestures may relate to the verbosity of speakers (i.e., how many words they produced to explain the phrases; length of explanation). To our knowledge, there is no theory suggesting that 'the more you speak the more metaphorical explanations you may produce', and such an effect is not predicted by our hypothesis. However, we ran the analysis of the gesturing effect on length of explanations (i.e., word count) and we found no effect (see Text S5 in Appendix Chapter 3 for details).

Next, we investigated how mouth asymmetry during speaking (as described in section 3.3.2 "Design and measurements") related to the left-over-right-hand gesturing advantage.

Though the left-side dominance in mouth opening was stronger for metaphorical phrases than concrete phrases (see Text S6 in Appendix Chapter 3), the degrees of the left-side dominance in the two types of phrases were highly correlated (r (29) = .829, p < .001, 95% CI [.672, .914]) indicating the overall right-side dominance. Thus, we used the average of the left-side dominance scores in the two types of phrases as a general indicator of right-hemispheric involvement in speech production (due to the high correlation, using the left-side dominance score from the metaphorical or the concrete phrases only yielded the same results). Crucially, the averaged left-side dominance in mouth openings for speech production (range = -.95 to .67) positively correlated with the left-over-right-hand gesturing advantage in metaphoricity (range = -.30 to .83) (r (29) = .365, p = .043, 95% CI [.013, .637]) (see Figure 3.4). Thus, the participants who had a stronger right-hemispheric involvement for speech production tended to have a larger left-hand gesturing advantage in metaphoricity.

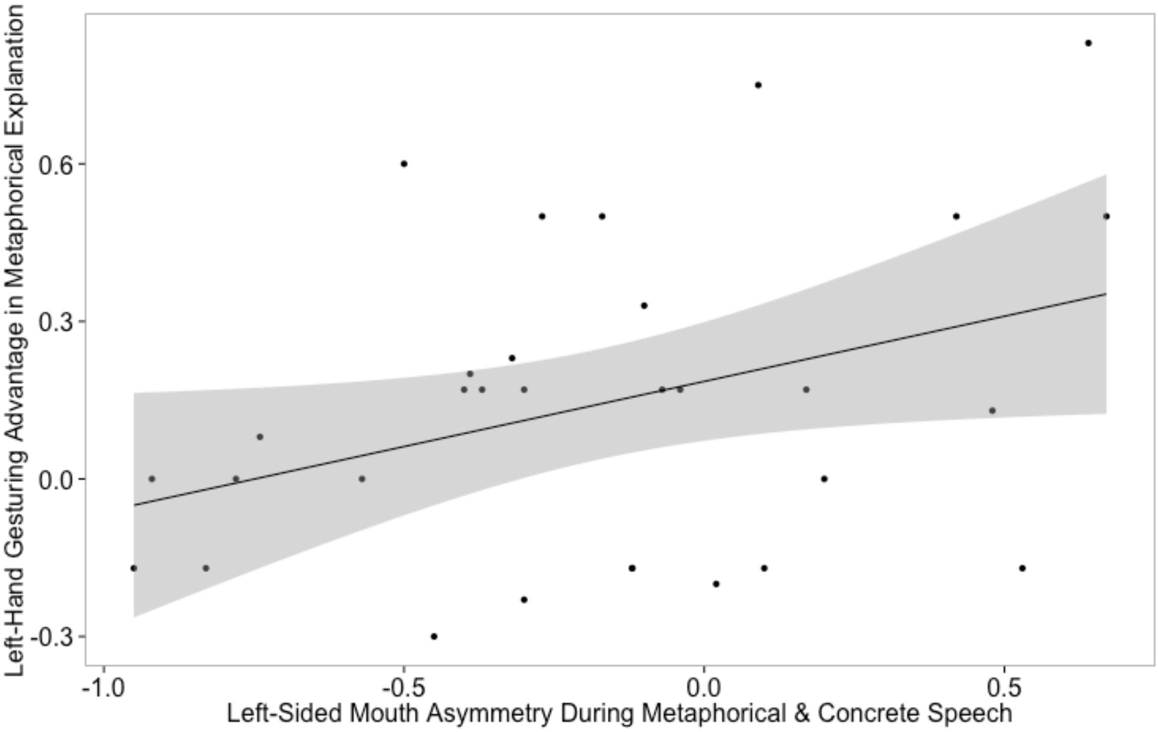

Figure 3.4 Scatterplot for the positive correlation between the averaged index of left-sided mouth asymmetry during speech and the left-hand gesturing advantage in metaphorical explanation (Experiment 1). The grey area represents 95% confidence intervals.

3.4.5 Discussion

We examined whether gesturing with a particular hand affected cognitive processing involving the hemisphere contra-lateral to the gesturing hand. We found that gesturing with the left hand increased the level of metaphoricity in explanations compared to gesturing with the right hand or not gesturing at all. We also found that this left-over-right hand advantage on metaphorical explanations was higher for those people who also had a stronger right-hemisphere involvement during speech production as measured through the mouth asymmetry technique. These findings indicate that representing meaning through left-hand gestures enhances the mapping from concrete, conceptual domains on to more abstract ones, that is, the processing of distant semantic links that strongly involves the right hemisphere (Jung-Beeman, 2005).

While our results supported our hypothesis, one open question is whether the observed effects were due to gesturing with one hand or inhibiting the impact of the other hand. That is, did participants perform well in the left-hand free condition because they produced gestures with the left hand or because their right hand was immobilised? There are two reasons for which the current results are likely to be due to gesturing advantage, rather than prohibition disadvantage. Firstly, the participants were all right handed; thus, the right-hand prohibition (left-hand gesturing) should have led to greater distraction or discomfort than left-hand prohibition. Secondly, the correlation with the mouth asymmetry is difficult to explain based on the distraction or discomfort due to prohibition of movement with the dominant hand. However, to further support our hypothesis, we conducted a control study (Experiment 2) to show that prohibition of right hand movements is not sufficient to explain the results of Experiment 1.

3.5 Experiment 2

We examined (a) whether spontaneous left-hand gestures increased levels of metaphoricity compared to spontaneous absence of left-hand gestures, and (b) whether absence of gestures with a particular hand by choice vs. by instruction had comparable effects on the level of metaphoricity in speech. A different group of participants completed the same metaphorical explanation task as in Experiment 1. They were asked not to move one hand (right or left), but they were not instructed to produce gestures with the free hand. They nevertheless *spontaneously* produced gestures with their free hand in some trials but not in others. We predicted levels of metaphoricity would be higher when participants produced left-hand gestures by choice than when they did not produce left-hand gestures by choice. Furthermore, as participants sometimes spontaneously chose not to produce a gesture when a given hand was free, we investigated the difference between not gesturing by choice vs. by instruction. We predicted that levels of metaphoricity would not differ between situations in which participants did not produce gestures by choice vs. by instruction. If the predicted results were obtained, then we could conclude that left-hand gesturing (rather than right-hand prohibition) was responsible for the increase in metaphoricity.

3.5.1 Method

Participants

32 right-handed, male (age: *M* = 22.35 and *SD* = 4.82), native English speakers and monolinguals at least until the age of 5 years (via self-report), participated in the experiment for course credit. Handedness was assessed as in Experiment 1 (*M* = 11.12 and *SD* = 1.16) (see Text S1 in Appendix Chapter 3 for the questionnaire). All of them were recruited and tested at the University of Bristol[8].

Stimuli

We used 12 English phrases with metaphorical meaning similar to the list of stimuli used in Experiment 1 (see Table 3.4). The phrases were identical to the ones used in Kita, de Condappa, et al. (2007) for the metaphorical condition.

[8] We would like to thank Prof Christine Mohr for agreeing to let us use video data collected by her and Prof Sotaro Kita for a project in the University of Bristol. This was a different project from the current study, which compared gesture rates with the left and right hand in three conditions (i.e., abstract, concrete, metaphorical explanation). We coded speech data (while the Bristol project did not) and analysed them for different hypothesis testing, which tests the effect of gestures to language (and not the other way around).

Table 3.4 The stimuli for the gesture elicitation task.

Metaphorical phrases for explanation task for gesture elicitation	
To dodge the bullet	To spill the beans
To fall back down to earth with a bump	To spin a yarn
To get back in the saddle	To swim against the tide
To lead someone up to the garden path	To tie up loose ends
To set your sights higher	To turn a corner
To sit on the fence	To turn the tables

Procedure

The procedure was essentially the same as in Experiment 1 with few alterations. There was no total hand prohibition condition. Participants had their left or right hand free, but the instruction did not mention gesture; that is, they were not explicitly encouraged to gesture (see Figure 3.5). When they produced gestures with their free hand, these were spontaneous gestures. The metaphorical explanation task was exactly the same as in Experiment 1. The order of the stimuli and the order of which hand was free first were counterbalanced across participants in a within-subjects blocked design. There were two practice trials preceding the main trials.

Figure 3.5 Experimental conditions in Experiment 2: Right Hand Free (left panel), Left Hand Free (right panel).

Coding

The verbal responses from the task were transcribed and coded for level of metaphoricity exactly as in Experiment 1.

Video recordings from the two gesturing conditions were analysed using ELAN software (developed by the Max Planck Institute for Psycholinguists, Nijmegen, the Netherlands). Each trial was classified into two types: spontaneous gesture present vs. absent. For the purposes of the current study, we did not include self-adaptors and beat gestures, because they do not represent semantic information related to speech (Lavergne & Kimura, 1987). That is, trials including at least one representational or conduit or palm-revealing gesture were coded as “spontaneous gesture present”.

Inter-coder reliability for coding

An additional coder independently coded 32% of the total verbal responses for metaphoricity. All answers from 10 randomly selected participants were coded (in total 120 trials were double coded). Coding of metaphoricity matched between the two coders 75% of the time (Cohen's weighted kappa $\kappa_w = .77$, $p < .001$, kappa maximum $\kappa_{max} = .82$). For all analyses, the first coder's original coding was used. We made the same decisions regarding inter-coding as in Experiment 1 (see Section 3.4.1).

3.5.2 Design

The dependent variable was the level of metaphoricity in participants' explanations. The experiment had a 2 x 2 factorial design with two independent variables (within-subjects manipulation): hand free (left, right) and presence/absence of spontaneous gesture.

3.5.3 Results

Out of the 384 trials in total in the task, 8% were excluded as failed trials; that is when the participants did not follow the instruction (e.g., they moved the prohibited hand) or when they did not know the phrases.

On average, participants produced explanations with the levels of metaphoricity (measured on a 3-points scale from 0-2) descending in the following order: when their left hand was free and they spontaneously produced gestures (M = 1.22, SEM = .08), when their right hand was free and they spontaneously produced gestures (M = 1.08, SEM = .10), when their right hand was free and did not produce gestures with it (M = .91, SEM = .13) and when their left hand was free and did not produce gestures with it (M = .78, SEM = .10) (see Figure 3.6).

We ran linear mixed effect models following the same specifications as in Experiment 1 (see section 3.3.3). We fit LME[9] model to the measurement of the level of the metaphoricity (see Figure 6 for the means). The model included two fixed effect factors and

[9] We ran the analysis treating the dependent variable as ordinal and results remained the same. See Text S7 in Appendix Chapter 3 for the results in detail.

the interaction between the two. The one fixed factor was the hand free (left, right; dummy coded; “right” was the reference category). The model automatically selected “right” as the reference category against which the comparisons are made. The second fixed factor was presence/absence of spontaneous gestures (dummy coded; “absence” was the reference category). We included random intercepts and slopes by subjects and items (phrases) for the main effects and interaction of the fixed effect factors.

Model estimates are reported in Table 3.5. We compared the maximal model with the reduced model including the main effects only (same random effect structure). Adding the interaction did not significantly improve the model fit: $\chi^2(1) = 1.506$, $p = .219$ (see Figure 3.6). Though the interaction was not significant we further explored the contrasts for two reasons. Firstly, we had a priori predictions for the comparison of the spontaneous presence/absence of gestures within each hand condition. Secondly, a large number of missing values in the data made the test of interaction less powerful. Only 12 out of 32 participants had cells in all four conditions and fully contributed data for estimating the interaction effect. This was, mainly, because many participants did not have any trials without right-hand gestures (e.g., they spontaneously gestured in all right-hand free trials) and some participants did not have any trials with spontaneous left-hand gesture. In contrast, more participants could be included if we analysed the effect of presence/absence of spontaneous gestures for the left hand and for the right hand separately (e.g., 19 participants for the left hand and 18 participants for the right hand), which would lead to more reliable results. Simultaneous tests for general linear hypotheses (Tukey Contrasts) revealed that the contrast between presence and absence of spontaneous gestures was significant for the left hand, but not for the right hand (the rest of the contrasts were not significant) (see Table 3.6). Thus, spontaneously gesturing with the left hand increased the level of metaphoricity in metaphorical explanation compared to not gesturing with it by choice.

Table 3.5 Parameters estimates for the model with the main effects and interaction between Hand Free and Presence/Absence of Spontaneous Gesture on metaphoricity in Experiment 2. “Right hand” and “Gesture Absent” were the reference categories.

	Estimate	SE	t-value
(Intercept)	.924	.165	5.519
Left Hand	-.136	.206	-.663
Gesture Present	.156	.161	.966
Left Hand : Gesture Present	.280	.176	1.596

Table 3.6 Tukey contrasts for the model with the main effects and interaction between Hand Free and Presence/Absence of Spontaneous Gesture on metaphoricity for the left hand and the right hand (Experiment 2).

	Estimate	SE	z-value	p-value
Left Hand Gesture Present vs. Absent	.417	.129	3.224	.006
Right Hand Gesture Present vs. Absent	.156	.161	.966	.753

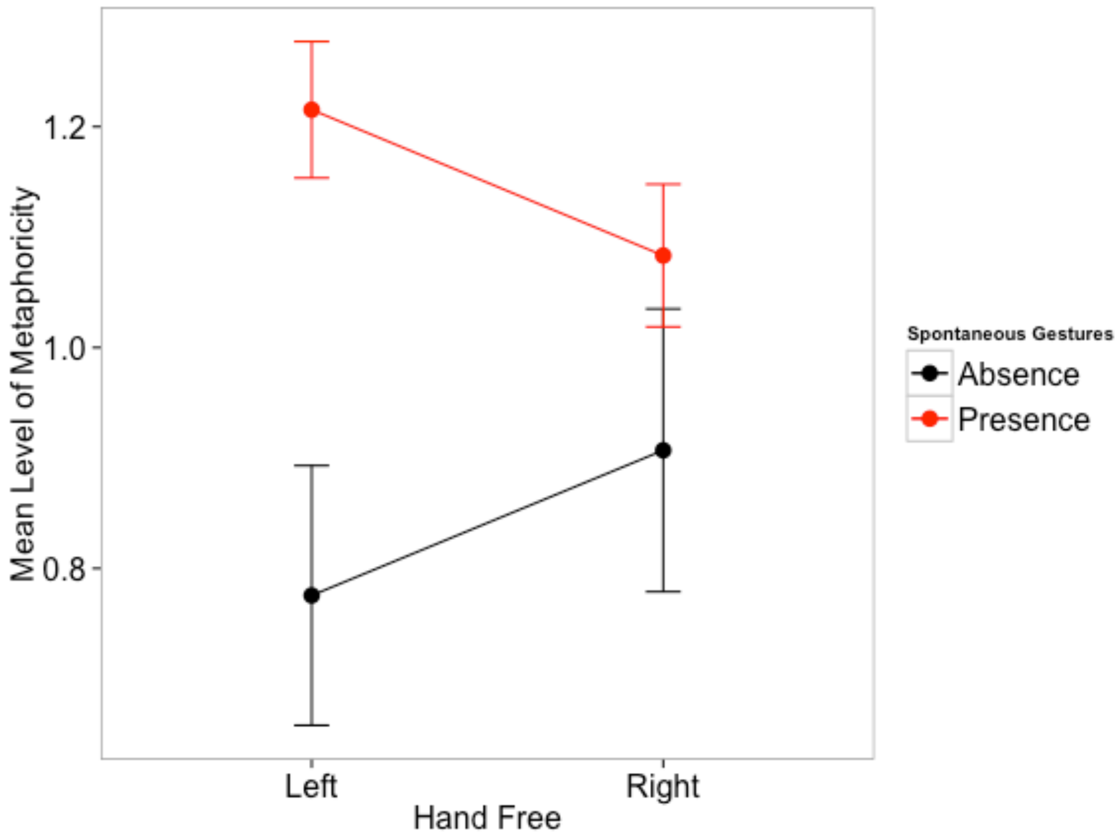

Figure 3.6 Mean levels of metaphoricity in speech (measured on a 3-points scale from 0-2) in the four gesturing conditions (Experiment 2). Error bars represent 1 standard error of the means.

Finally, we investigated whether metaphoricity differed when gestures were absent by choice vs. by instruction. More specifically, did gesture prohibition by instruction have a negative impact on metaphoricity in the responses? To this end, we conducted two analyses, each focusing on a subset of data from Experiment 2. In the first analysis, we focused on the trials where the left-hand was immobilised (e.g., the right hand was free), and thus left-hand gestures were absent by instruction vs. the trials where the left hand was free but the participants chose not to gesture, and thus left-hand gestures were absent by choice. In other words, we collapsed data from the conditions "Right Hand Free and Gesture Present" and

"Right Hand Free and Gesture Absent" into the new condition "Left Hand Gesture Absent by Instruction" (a total of 175 trials from 32 participants). We compared it with the condition "Left Hand Gesture Absent by Choice" (a total of 49 trials from 21 participants). In the second analysis, by the same token, we collapsed data from the conditions "Left Hand Free – Gesture Present" and "Left Hand Free – Gesture Absent" into the new condition "Right Hand Gesture Absent by Instruction" (a total of 179 trials from 32 participants). We compared it with the condition "Right Hand Gesture Absent by Choice" (a total of 43 trials from 18 participants). For both analyses, we fit LME models to the measurement level of the metaphoricity. The models included one fixed effect factor: the type of gesture absence (by choice, by instruction; dummy coded; "by instruction" was the reference category). We included random intercepts and slopes by subjects and items (phrases) for the main effect of the fixed factor.

The mean metaphoricity is reported in Figure 3.7. Error bars in the by-choice conditions are larger than in the by-instruction due to smaller number of trials (SDs are comparable in by-choice and by-instruction conditions). The model estimates are reported in Table 3.7. We compared the models with the null models with no fixed effect (same random effect structure). Adding the effect of the type of gesture absence did not significantly improve the models fit: (a) for left hand gesture absence $\chi^2(1) = 2.420$, $p = .119$, and (b) for right hand gesture absence $\chi^2(1) = .902$, $p = .342$. Simultaneous tests for general linear hypotheses (Tukey Contrasts) revealed non-significant contrasts (see Table 3.8). Therefore, we have no evidence that levels of metaphoricity in the metaphorical explanation task differed when participants did not gesture (regardless of the hand) by instruction or by choice.

Table 3.7 Parameters estimates for the model of the effect of type of gesture absence on metaphoricity for the left hand and the right hand. "Absent by Instruction" was the reference category (Experiment 2).

	Estimate	SE	t-value
Left Hand, Gesture Absent by Choice	-.219	.133	-1.637
Right Hand, Gesture Absent by Choice	-.173	.168	-1.027

Table 3.8 Tukey contrasts for the model with the main effect of type of gesture absence on metaphoricity for the left hand and the right hand (Experiment 2).

	Estimate	SE	t-value	p-value
Left Hand Gesture Absent by Choice vs. by Instruction	-.219	.133	-1.637	.102
Right Hand Gesture Absent by Choice vs. by Instruction	-.173	.168	-1.027	.305

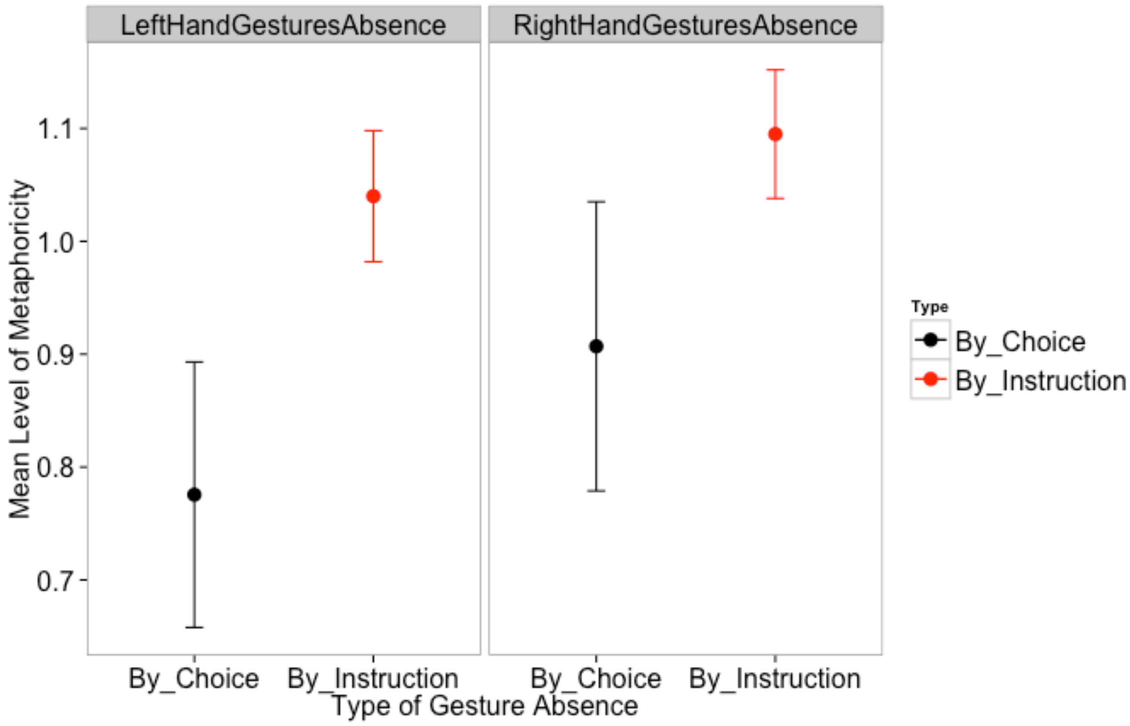

Figure 3.7 Mean levels of metaphoricity in speech (measured on a 3-points scale from 0-2) when left- and right-hand gestures were absent by choice or by instruction. Error bars represent 1 standard error of the means.

3.5.4 Discussion

In the left-hand free condition, metaphoricity was higher in trials with spontaneous left-hand gestures than in trials without left-hand gestures (by choice). This difference cannot be attributed to the right-hand gesture prohibition as the right-hand gesture was prohibited in both types of trials. We also found that, for both right hand and left hand gesture production, metaphoricity was comparable when not gesturing by choice vs. by instruction. These two findings combined support that left-hand gestures (and not prohibition of right-hand movements) facilitated metaphorical explanation in Experiment 1.

3.6 General discussion

The present study investigated a "hemisphere-specific feedback hypothesis" for gestures' self-oriented functions. We hypothesised that gestures enhance cognitive processes in the hemisphere contra-lateral to the gesturing hand. The first and most important finding (Experiment 1) is that when encouraged to gesture with one hand, while the other hand is prohibited from gesturing, speakers produced explanations with higher levels of metaphoricity when they gestured with the left hand, compared to the right hand or not gesturing at all. This indicates that left-hand gestures led to higher metaphoricity in the explanation task because they activated metaphorical processing in the contra-lateral right hemisphere. Experiment 2 ruled out the possible alternative explanation that the left-hand gesturing advantage is solely due to distraction or discomfort due to prohibition of right-hand gesturing. In Experiment 2, participants were asked not to move one of the hands during metaphorical explanation, just like in Experiment 1, but were not told anything about gestures in the instruction (they sometimes spontaneously produced gestures). Spontaneous hand gestures increased levels of metaphoricity compared to not gesturing with it by choice within the left-hand free condition. In addition, not gesturing by choice vs. by instruction did not influence the level of metaphoricity (in line with Goldin-Meadow et al., 2001 and Goldin-Meadow & Wagner, 2005).

The second finding (from Experiment 1) strengthened our argument about gestures enhancing cognitive processes in the hemisphere contra-lateral to the gesturing hand. The left-over-right-hand gesturing advantage on metaphorical explanation positively correlated with the left-side mouth dominance during speaking. When the right-hemisphere is more strongly involved in speech production, left-hand gestures can more readily influence processes in the right hemisphere, such as metaphorical mappings and explanation. Although a control, non-metaphoric task would provide more direct evidence about the specificity of the left-hand gestures' effect, we believe this correlational result cannot be explained alternatively and further supports that the left-over-right-hand gesturing advantage is metaphor specific. Taken together, producing left-hand representational gestures enhances the metaphorical mapping from concrete conceptual domains on to more abstract ones, which depends on processes in the right-hemisphere.

This study goes beyond the previous literature in an important way. Several studies manipulated gesturing in order to assess gestures' effect on speaking (Alibali & Kita, 2010; Goldin-Meadow et al., 2001; Rauscher et al., 1996). However, they did not investigate differential effects of right- vs. left-hand gestures. Several studies showed that cognitive processes in a particular hemisphere trigger gestures in the contra-lateral hemisphere (Kimura, 1973a; Kita, de Condappa, et al., 2007; Lausberg et al., 2007; Mumford & Kita, under review). However, these studies did not investigate the reverse causality. Thus, the present study demonstrated, for the first time, that gestures by a particular hand facilitate cognitive processes in the contra-lateral hemisphere.

In addition, the present findings are in line with the Information Packaging Hypothesis for self-oriented functions of co-speech gestures (Alibali et al., 2000; Hostetter et al., 2007; Kita, 2000; Melinger & Kita, 2007), which states that gestures help conceptual planning of the speech. We showed that left hand gestures help the conceptual mapping from the source domain to the target domain of metaphor, thereby influencing the course of thinking (Alibali, Spencer, Knox, & Kita, 2011) and the content of verbal output (Alibali & Kita, 2010; Rime et al., 1984).

How exactly does this mechanism work? Metaphor requires speakers to map two semantically distant concepts: a concrete concept from the "source domain" on to a more abstract one in the "target domain" (Lakoff & Johnson, 1980a). In the phrase, "to spill the beans", participants had to represent the abstract concept of IDEAS (target) in terms of the distant concrete concept of OBJECTS (source). The right hemisphere is crucially involved in processing of coarse-grained semantic information and thus more distant semantic relationships (Jung-Beeman, 2005). Producing gestures activates spatio-motoric information (Alibali & Kita, 2010; Alibali et al., 2011; de Ruiter, 1995; Hostetter & Alibali, 2008; Wing Chee So, Ching, Lim, Cheng, & Ip, 2014; Wesp et al., 2001), and producing left-hand gestures should do so in the right hemisphere. This helps generating a distant semantic relationship between target and source domains of the metaphor. This allows speakers to represent the metaphorical mapping in speech more easily. That is, gestures with a particular hand can modulate content of speech when the linguistic task particularly involves the hemisphere contra-lateral to the gesturing hand (= "hemisphere-specific feedback hypothesis" for self-oriented functions of gestures).

3.7 Conclusions

The present study has, for the first time, provided evidence for a hemisphere-specific feedback hypothesis for gestures' self-oriented functions. Left-hand gestures enhanced metaphorical explanations compared to right-hand gestures or not gesturing at all. This left-hand gesturing advantage was stronger for people with strong right-hemispheric involvement for speaking as inferred from mouth opening asymmetry during speaking. In addition, spontaneous left-hand gestures enhanced metaphorical thinking in comparison to not gesturing with the left hand by choice. We propose that gestures enhance cognitive process in the contra-lateral hemisphere. Thus, gestures are not merely hand waving. They rather shape our thoughts and can modulate the content of what we say: speech-accompanying gestures help speakers understand abstract concepts in the form of metaphor by mapping concrete physical events on to abstract concepts.

However, the current study raised two new questions: (a) whether gestures enhance cognitive processing because of their motoric properties or their depictive nature, and (b) whether gesturing with the left hand might determine the use of metaphorical language even when not needed (e.g., within abstract context). We will explore both prospects in the next study.

4 Gesturing vs. Tapping: do all types of hand movement enhance metaphorical processing?

4.1 Motivation and aims

This study investigated whether gestures facilitate cognitive processes because of their motoric properties or their depictive nature (i.e., their ability to convey meaning). We compared the effect that meaningless tapping hand movements and meaningful gestures might have on spontaneous use of metaphorical language. In addition, we examined whether the proposed “hemisphere-specific feedback hypothesis” for gestures’ self-oriented functions can be reflected in an explanation task other than metaphorical explanation, such that left hand gestures (as opposed to left hand taps) trigger metaphorical language use even when not needed.

4.2 Abstract

Research suggests that speech-accompanying gestures with a particular hand may influence cognitive processes involving the hemisphere contra-lateral to the gesturing hand, such that gesturing with the left compared to the right hand enhances metaphorical explanation, which involves the right hemisphere. Additionally, gestures are thought to facilitate cognitive processing because of their depictive nature rather than their motoric properties. In the current study, we tested the "hemisphere-specific feedback hypothesis" for gestures' self-oriented functions in a task that does not particularly involve the right hemisphere. We also investigated whether gestures can trigger metaphorical language use because of their depictive or motoric nature. Right-handers explained abstract phrases (e.g., "to disclose something confidential"). Half of the participants were instructed to gesture with the left or right hand or to not gesture at all. The other half were instructed to tap their left or right hand or to not tap at all. We measured the likelihood for use of metaphorical language. We hypothesised that meaningful gestures compared to meaningless tapping movements, and in particular gestures with the left hand, would increase the use of metaphorical language while explaining the meaning of abstract phrases. We found no evidence that type of hand movement and hand choice for gesturing affects spontaneous use of metaphorical language.

Keywords: Spontaneous metaphorical language use; abstract meaning; representational gestures; tapping.

4.3 Introduction

Gestures have self-oriented functions facilitating cognitive processes (Alibali & Kita, 2010; Goldin-Meadow et al., 2001; Kita, 2000; R. Krauss & Hadar, 2001). In Chapter 3 we showed that left hand gestures modulated content of speech leading to enhanced metaphorical explanations compared to right hand gestures or not gesturing. We proposed that the mechanism underlying this effect relates to the mutual influence between hand choice for gesturing and hemispheric involvement during linguistic processing. In particular, gestures may enhance processing in the hemisphere contra-lateral to the hand used. However, it is unclear why gestures have this effect: is it the motoric (i.e., hand movement *per se*) or the depictive nature (i.e., gestural representation of meaning) of the hand movement that enhances cognitive processes? In addition, would left hand gestures have this effect when the right hemisphere is not necessarily involved, and metaphorical language processing is not encouraged? The current study investigated these questions by directly comparing meaningful gestures with meaningless hand movements in an abstract phrase explanation task: do gestures with the left hand, rather than tapping movements, increase the likelihood of metaphorical language use within abstract context?

To our knowledge, there are few studies, which suggested that non-iconic movements might have an effect on working memory. Firstly, Ravizza (2003) investigated whether production of non-iconic movements facilitates the retrieval of words in two different tasks varying the level of activation of the words to be retrieved. Findings from two experiments on tip-of-the-tongue states during lexical retrieval suggested that participants who tapped their index fingers of both hands retrieved more words from their definition compared to those who kept still. However, in a letter fluency task (i.e., generate words starting with the letter Q), participants who tapped performed worse compared to the ones kept still. These findings suggested that non-iconic movements may facilitate lexical retrieval when items have already been selected and are weakly activated, but not when strategic search in the lexicon is required. Secondly, W. C. So, Chen-Hui, and Wei-Shan (2012) compared the effect that perception of (a) meaningful, (b) meaningless beat gestures and (c) no movement might have on memory recall in adults and children. Participants listened to audio input of verbs while watching a video of an actor representing the verb with a meaningful iconic gesture or producing a beat gesture or did not gesture at all. They had to remember as many verbs as they could. Proportion of verbs recalled was at a comparable level for iconic and beat gestures, and higher than the absence of gesture. Thus, even meaningless, beat gestures had a mnemonic effect on adults (however this effect was not found in children). Findings indicated that beat gestures have meta-cognitive functions to emphasise speech or modulate auditory activity during speech processing.

In contrast, Cook et al. (2012) did not provide evidence for a facilitative effect of meaningless hand movement on working memory. The authors directly compared the effect that (a) meaningful, (b) meaningless (e.g., rhythmic circular movement) and (c) no movement might have on working memory in a math explanation task. Participants explained a math problem in the three conditions and had to recall a string of six letters appeared in each trial. Findings suggested that meaningful gestures as opposed to meaningless movements or no movements at all lightened up working memory load and improved recall of the letters. Thus, gestures' facilitative role on working memory is due to their depictive nature and their ability to convey meaning rather than their motoric properties.

The studies reviewed above provide somewhat contradicting evidence. The use of different types of meaningless hand movements (e.g., index tapping vs. beat gestures vs. rhythmic rotation of hand) might account for inconsistent results of whether non-iconic, meaningless hand movements might aid or hinder performance in memory tasks. More importantly, none of the studies has measured the differential effect that meaningless and meaningful hand movements might have on modulating speech content. Therefore, it is still unknown whether gestural representation of meaning, rather than hand movement per se, may modulate content of speech. If so, gestures would not only facilitate cognitive processes, but also change the way we speak.

Several studies investigated the effect of gestures on properties of verbal outcomes by comparing gesture allowance with gesture prohibition conditions. For example, Rime et al. (1984) showed that the level of vivid imagery in conversations, measured with content analysis, decreased when gestures were not allowed. In addition, Alibali and Kita (2010) found that gesture prohibition affected the nature of information children (6 years old) verbally expressed in a Piagetian conversation task (i.e., children judges and explain their judgment of whether two transformed objects contain the same quantities before and after transformation). More specifically, when prohibited from gesturing, children focused more on information that was not perceptually present compared to present. Furthermore, Bos and Cienki (2011) showed that inhibition of gesture also inhibited the use of metaphorical spatial language in a free speech production task. Finally, in Chapter 3 we showed that left hand gestures particularly facilitated the explanation of metaphorical mappings in a metaphor explanation task indicating that left-hand gestures have a special role for the representation and verbalisation of abstract concepts in the form of metaphor. This may be because gestures highlight visual-spatial information (Alibali & Kita, 2010; Alibali et al., 2011), and metaphors use visual-spatial source domains (Lakoff & Johnson, 1980a). Hence, gestures represent the concrete visual-spatial properties of the source domain of the metaphor and aid the mapping to the abstract target domain. However, all of these studies compared gesturing to not moving at all, rather than meaningless movement. In addition, the study in Chapter 3 encouraged metaphorical thinking. Therefore, it is still unknown whether gestural representation of meaning with a particular hand, rather than hand movement per se, can trigger spontaneous use of metaphorical language.

The present study investigated whether speech-accompanying, meaningful gestures with a particular hand (the left hand), as opposed to meaningless movements, may activate metaphorical thinking and increase the likelihood of metaphorical language use within abstract context. Unlike previous studies we used an abstract explanation task (instead of memory tasks or metaphor specific task). This was critical to assess the modulating effect of gestures on content of speech, and to measure spontaneous use of metaphorical language when not needed[10] or instructed. In addition, we investigated the role of hand choice for gesturing. This was critical to provide evidence for the generality of the proposed "hemisphere-specific feedback hypothesis" for gestures' self-oriented functions across different tasks.

To this end, we manipulated type of hand movement, hand choice, and assessed speakers' performance in an abstract phrase explanation task. More specifically, participants were asked to explain the meaning of English phrases with abstract meaning (e.g., "to disclose something confidential"). Type of hand movement was manipulated between-participants by asking half of the subjects to gesture and half of them to tap their whole arm. Hand choice was manipulated within-participants by asking subjects to gesture or tap with their left hand only or right only or to not move their hands at all. The explanations were coded for the presence or absence of at least one metaphor related expression. If meaningful gestures rather than meaningless tapping movements help participants to strategically search between semantic fields, represent visual-spatial information, and map concrete concepts on

[10] There have been arguments (Giora, 1997; Keysar & Bly, 1999) suggesting that it would be useful to show "under which circumstances a literal meaning may have a metaphorical interpretation". Even more, under which circumstances metaphorical language is used when not instructed as in Chapter 3.

more abstract ones in the form of metaphor, then the gesturing group should be more likely to produce explanations including metaphor related expressions than the tapping group. In addition, if left hand gestures activate cognitive processes in the contra-lateral hemisphere, then gesturing, rather than tapping, with the left hand should increase the likelihood of metaphorical language use. In contrast, we should expect no differences between the hands used for the tapping movement. This is because the left hemisphere is specialised for the bilateral control of repetitive movements of the hands, such as tapping (Kimura & Archibald, 1974; Wyke, 1971). Hence a tapping movement, regardless of the hand used, should not affect processes involving the right hemisphere.

4.4 Method

Participants

60 (age: *M* = 21.03, *SD* = 2.84), native English speakers (46 females[11]) and monolinguals before the age of 5 years (via self-report) participated in the experiment for course credit or £4. Handedness was assessed with a 12-items questionnaire based on the Edinburgh Handedness Inventory (Oldfield, 1971). Two bimanual items (from Oldfield's long list) were added to this recommended 10-items questionnaire to equate the number of unimanual and bimanual items (see Text S1 in Appendix Chapter 3 for the questionnaire). Each "left" answer was scored with 0, each "either" answer with 0.5, and each "right" answer with 1. A total score of 8.5 and above determined right-handedness (handedness: *M* = 11.33, *SD* = .79). All of them were recruited at the University of Birmingham.

[11] In the current study, we included females, because we wanted to extend findings from the study in Chapter 3, which used males only. However, due to recruiting limitations we could not test a proportionate sample of males and females. This limitation is further discussed in Discussion, Section 7.3.

Stimuli

For the explanation task, we used eighteen English phrases with abstract meaning (see Table 4.1). Twelve of the phrases were identical to the ones used in Kita, de Condappa et al. (2007) for the abstract condition and have been proved effective for producing elaborate explanations, free of 'metaphor bias' (i.e., participants were free to spontaneously produce metaphors whilst explaining them). We created six more on the same vein, and made them semantically paired with the metaphorical phrases used in Chapter 3 (e.g., "to spill the beans" – metaphorical, "to disclose something confidential" – abstract).

Table 4.1 The stimuli for the explanation task.

Abstract phrases for explanation task	
To conform	To disclose something confidential
To intervene	To discuss
A catastrophe	To be angry
To tell a fairy tale	To control
To purposely mislead someone	To forgive
To be persistent	To announce
To finalise details	To be liberated
A change of circumstances	To be moody
To be indecisive	To plan for the future

Procedure

Participants were tested individually. They were seated on a chair, which was located between two tables of the same height (71 cm tall). The experimenter was facing the participant, and the video camera (Sanyo HD camera) was placed next to the experimenter. Stimuli were presented one by one on a white sheet of paper (font size 72, Times New Roman), which was held by the experimenter until the participant started the description.

Participants were instructed to explain the meaning of stimuli as if they were explaining it to a non-native English speaker, and they were asked to elaborate as much as possible. During the task, participants were told to place one of their hands on the indicated marks (white sticky dots) on the surface of the table(s), and to keep it still for the whole procedure. For the total prohibition condition, participants were asked to place both their hands on the tables (see Figure 4.1). The gesturing group received gesture encouragement instructions (e.g., the experimenter asked them "please use your free hand to gesture while speaking"). Gesture encouragement instruction has been used in a number of recent studies (Broaders et al., 2007; Chu & Kita, 2011; Cook et al., 2012). The tapping group was instructed to tap their arm from their thigh and up to mid-torso, at a comfortable pace, and to use the same pace for left and right hand. Participants were debriefed about the purpose of the hands immobilisation and manipulation of hand movement after the experiment and the permission to use the data was allowed. Order of stimuli (forward - reverse) and order of hand(s) prohibition was counterbalanced across participants in a within-participants blocked design. 29 participants produced gesturing hand movements and 31 participants produced tapping hand movements in a between-participants design.

Figure 4.1 Experimental conditions (from top left and clockwise): Right Hand Gesturing, Left Hand Gesturing, No Gesturing, No Tapping, Right Hand Tapping, Left Hand Tapping.

Coding

The verbal responses from the abstract task were transcribed and coded for the absence or presence of at least one metaphor related expression. The responses were coded with a "1" (presence of at least one metaphor related expression) or a "0" (absence of metaphor related expression). A unit of speech was identified as metaphor related (and thus was given a code of "1") in the following cases: (a) if it was an idiomatic metaphorical expression (e.g., "to forgive means *to let someone off the hook*"; "to finalise details is *to tie up loose ends*"), (b) if the coder could detect an underlying conceptual metaphor (e.g., "to finalise details means *to focus on* all important aspects" [UNDERSTANDING/CONCENTRATING IS SEEING]), and (c) if there was a physically or spatially related concrete equivalent expression that could act as the source domain of a metaphor (e.g., "to forgive is *to let a memory go*", where memories are seen as objects

[MEMORIES ARE OBJECTS] that are usually let go). Text S1 in Appendix Chapter 4 presents examples and the coding manual in detail.

An additional coder independently coded all the verbal responses in terms of the absence or presence of at least one metaphor related expression. Coding matched between the coders 81% of the times (Cohen's kappa $\kappa = .623$, $N = 1080$, $p < .001$). For all analyses, the first coder's original coding was used (see Section 3.4.1 for informed decisions regarding inter-coding reliability).

In addition, verbal responses with at least one metaphor related expression were coded for the familiarity of each metaphor related expression by an independent coder. A 7-point scale was used where "1" indicated that the metaphorical expression was totally novel to the coder, that is they had never heard, read or used the metaphorical expression, and "7" indicated that the metaphorical expression was very familiar to them and they often hear, read and use it. For each trial and explanation, the average familiarity was calculated (overall $M = 5.71$, $SD = 1.14$). For example, the explanation "to disclose something confidential might be *going against* what you are supposed to do […] you are *giving the information* of something that is secret […]" was initially coded with "1" as including at least one metaphor related expression. "Going against" and "giving information" were highlighted as metaphor related expressions because they are motivated by underlying conceptual metaphors: [DISTRUST IS A WAR] and [INFORMATION IS AN OBJECT] respectively. In turn, each of the two expressions were given a familiarity rating of "6" and "7" respectively because the coder felt they are highly familiar with these metaphorical expressions. The whole trial was given a familiarity rating of "6.5". Note that we recoded all trials rated with average familiarity of 7 (= highly familiar), that is 1 SD above the mean, as trials without metaphor related expressions. That led to the recoding of 111 trials (10% of the total of trials) from trials with presence of metaphors to trials with absence of metaphors. We initially included highly conventional metaphors in order to develop a valid coding scheme between two coders. However, there are studies (Mashal et al., 2005; Schmidt & Seger, 2009; Stringaris et al., 2006) highlighting the role of novelty rather than figurativeness *per se* on metaphorical processing. Therefore, the recoded dataset did not include highly conventional metaphors.

Video recordings from the two gesturing conditions (left hand gesture, right hand gesture) were analysed using ELAN software (developed by the Max Planck Institute for Psycholinguists, Nijmegen, the Netherlands). They were coded on a trial-by-trial basis for gesture classification (following the typology in Chu & Kita, 2011); that is representational gestures (e.g., hand movements depicting shape, motion and action or deictically indicate location), representational unclear (e.g., hand movements which could not clearly be classified as representational including ones that were abandoned because the gesturer interrupted a gesture before the stroke was completed or moved to the next gesture and those resembling emblems which conveyed some known meaning such as “maybe” with the hand flat, palm down and wavering), palm-revealing gestures (e.g., palm rotates to show uncertainty or that speaker has nothing to say or), conduit gestures (e.g., hand moves towards listener as if speaker is conveying a clear message), and other (e.g., small biphasic movements/ beats, metacognitive gestures). We then calculated the gesture rate (= number of gestures per minute). Note that gesture data were not double coded.

Video recordings from the two tapping conditions (left hand tapping, right hand tapping) were coded on a trial-by-trial basis to calculate the tapping rate (= number of tapping movements per minute). One tapping movement was defined at the moment the hand touched the thigh.

4.5 Design

The dependent variable was the presence or absence of metaphor related expressions in participants' explanations. The experiment had a 2 x 3 factorial design with two independent variables: type of hand movement (gesture, tap; between-subjects manipulation) and hand free (left, right, no hand; within-subjects manipulation).

4.6 Results

Exclusion of trials and gesture/tap rate

Out of the 1080 verbal responses in total, 3% was excluded as failed trials; that is, when the participants did not follow the instruction (e.g., participant in tapping group produced meaningful gesture during a trial) or if expression was unknown. Out of 4137 gestures that participants produced in total, 62.68% of gestures were representational, 13.32% representational unclear, 19.72% of gestures were classified as "other" (comprising mainly of beat and metacognitive gestures), 0.89% were palm revealing gestures, 0.12% were conduit gestures and finally 3.26% of gestures were classified as "unclear". Thus, the instruction to produce gesture given to the gesturing group was effective and gestures were predominantly representational gestures.

We compared the gesture rate between left and right hand and the tapping rate between left and right hand. Participants in the gesturing group produced comparable amount of gestures with the left and the right hand, and participants in the tapping group kept the same tapping pace with both hands. A Paired Samples t-test showed that there was no significant difference in the gesture rate (i.e., the number of gestures per minute) between the left hand (M = 26.85, SE = 2.18) and the right hand (M = 25.68, SE = 1.66); t (28) = .889, 95% CI [-1.51, 3.84], p = .381. A Paired Samples t-test showed that there was no significant difference in the tapping rate (= the number of taps per minute) between the left hand (M =

56.26, *SE* = 17.53) and the right hand (*M* = 56.59, *SE* = 16.42); *t* (30) = -.221, 95% CI [-3.43, 2.76], *p* = .826. Therefore, we have no evidence for a specific pattern for the gesturing and tapping rate depending on the hand used (left or right).

Note for mixed effect models

The dependent variable was binary (i.e., presence or absence of at least one metaphor related expression), and the data were analysed using generalised linear mixed effects (GLME) models. We used the packages *lme4* and *multcomp* in the R Project for Statistical Computing environment, version 3.1.1 (Bates & Sarkar, 2012; Hothorn et al., 2012; R Development Core Team, 2011). All mixed effect logistic regressions were carried out with "glmer()" function, using the "Laplace" approximation and the "binomial" family. Random effects structure was kept maximal as long as model convergence was reached (for a discussion about random effects structure and simplification see Barr et al., 2013). We obtained p-values for fixed effects and interactions following the likelihood ratio test approach for model comparison, and we always reported the maximal model following a design-driven approach for confirmatory analyses. Tests of further contrasts of our interests were carried out based on a priori predictions using the generalised linear hypothesis test (correction for multiple comparisons of means, Tukey Contrasts) and the "glht()" function.

Spontaneous use of metaphorical language (= presence/absence of at least one metaphor related expression)

On average, participants' likelihood of using metaphors (i.e., proportion of trials which included at least one metaphor related expression per total amount of trials) decreased in the following order for each group: for the tapping group, right hand (*M* = .35, *SEM* = .04), no hand ($M = .33$, $SEM = .04$) and left hand ($M = .29$, $SEM = .04$). For the gesturing group, right hand ($M = .45$, $SEM = .04$), left hand ($M = .40$, $SEM = .04$), and no hand ($M = .39$, $SEM = .04$) (see Figure 4.2 top panel).

We fit GLME model to the measurement presence or absence of at least one metaphor related expression (see Figure 4.2 for means and means accounting for the covariate). The model included two fixed effect factors and the interaction between the two. The one fixed factor was the type of hand movement (tap, gesture; dummy coded; "tapping group" was the reference category against which the comparison with the gesturing group was made). The second fixed factor was the hand free (left, right, no hand; "no hand" was the reference, baseline category against which the comparisons with the two experimental conditions were made). Note, we found a significant positive correlation between the length of the explanations (i.e., number of words produced) and the use of metaphorical language, r (58) = .444, 95% CI [.213, .626], $p < .001$. Thus, it seems that the more the participants spoke (long explanations), the more likely they were to produce metaphor related expressions within abstract context. We accounted for the effect of the length of explanations (i.e., number of words produced) on the likelihood to use metaphors by including it as a covariate in all models (for a detailed analysis on the length of explanations see Text S2 in Appendix Chapter 4). Note, that the assumption of homogeneous regression slopes is satisfied (G. A. Miller & Chapman, 2001), and the interaction between hand free, hand movement and word count was not significant ($F < 1$, $p > .05$). For the random effects structure we had to use a data-driven approach and simplify the model to reach convergence. The maximal model to include (a) random intercept and slope by subjects for hand free (type of hand movement is between-subjects hence a random slope by subjects is not necessary), and (b) random intercept and slope by items for the interaction between hand free and type of hand movement did not converge. Similarly, the model to include (a) random intercepts and slopes by subjects for hand free, and (b) random intercepts and slopes by items for the interaction between hand free and type of movement but not the correlations between random slopes and intercepts did not converge. Thus, we included (a) random intercepts only by subjects assuming that the effect of hand free was invariant across subjects, (b) random intercepts only by items for hand free and its interaction with hand movement assuming that their effects were invariant across items, and (c) random intercept and slope by items for type of hand movement.

Model estimates are reported in Table 4.2. We compared the maximal model with the reduced model with the main effects only (same random effect structure and covariate included). Adding the interaction between the type of hand movement (gesture, tap) and hand free (left, right, none) did not significantly improve the model fit: $\chi^2(2) = .807$, $p = .667$ (see Figure 4.2). Though the interaction was not significant, we had a priori predictions for the main effect contrasts. Simultaneous tests for general linear hypotheses (Tukey Contrasts) revealed most of the contrasts non-significant. Only, participants who gestured with the right hand were more likely to use metaphor related expression compared to participants who tapped with the left hand (see Table 4.3). Thus, we have no evidence that the interaction between type of hand movement and hand free affected the spontaneous use of metaphors.

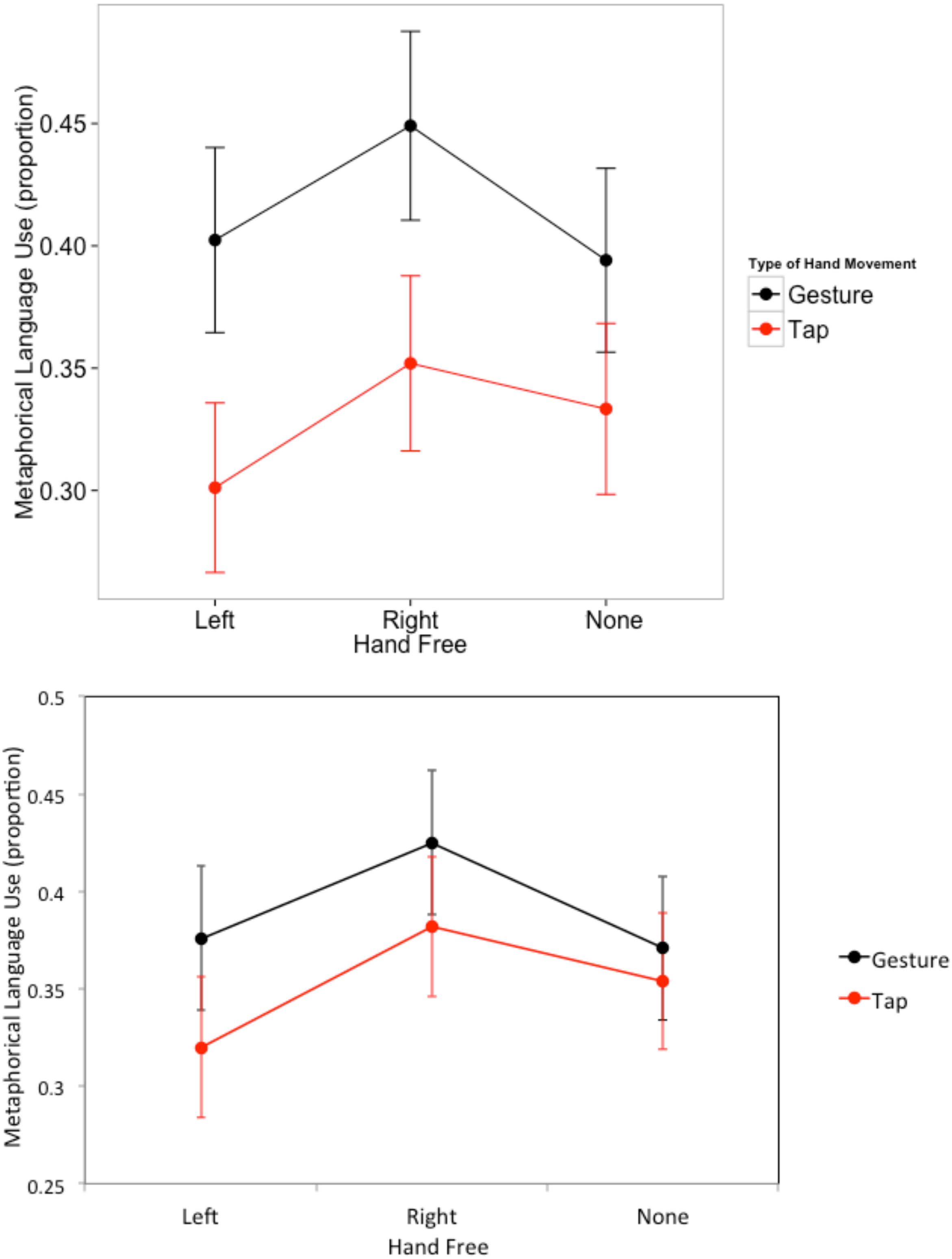

Figure 4.2 Likelihood of metaphorical language use (i.e., trials with metaphor presence per total amount of trials) for the gesturing and tapping groups in the three hand conditions (left, right, no hand). Bottom panel accounts for the covariate length of explanations.

Table 4.2 Parameters estimates for the model with the main effects and interaction between type of hand movement and hand free on metaphorical language use. "No hand" and "Tap" were the reference categories. Length of explanations (i.e., number of words produced) was a covariate.

	Estimate	SE	z-value	p-value
(Intercept)	-1.766	.380	-4.642	< .001
Left Hand	-.246	.257	-.957	.338
Right Hand	.135	.248	.543	.587
Gesture	.137	.295	.464	.643
Left Hand:Gesture	.321	.357	.899	.369
Right Hand:Gesture	.188	.351	.537	.592
Explanations' Length	.017	.003	4.287	< .001

Table 4.3 Significant Tukey contrasts for the model with the main effects and interaction between type of movement and hand free on metaphorical language use.

	Estimate	SE	z-value	p-value
Left Tap – Right Gesture	-.870	.305	-2.848	.048

Next, we proceeded to model reduction and comparisons to investigate the main effect of type of hand movement. We compared the model with the main effects of type of hand movement and hands free with the model with the main effect of hands free only. Adding the effect of the type of hand movement (gesture, tap) did not significantly improve model fit: χ^2 (1) = 2.025, p = .154. Thus, we have no evidence that the type of hand movement affected the spontaneous use of metaphorical language in abstract context.

4.7 Supplementary results

Block order effect

In this section, we investigated whether the block-order in which participants performed the experimental conditions might have affected metaphorical language use. Some participants experienced the no movement condition in the first block (16 participants; 277 trials) and others in the second/third blocks (44 participants; 767 trials). The nature of the dependent variable, which captures the way speakers spontaneously choose to express meaning by using metaphors, can be influenced by gestures and in turn this influence can continue into parts of the experiments that do not involve gesturing. For example, once the gestures with one hand enhance activations in the contra-lateral hemisphere and affect metaphorical language use, it is possible that this effect and activations extend to, and are "carried-over" to the no gesturing condition. To this end, we fit exactly the same models as in the main analysis (see section "Note for mixed effect models") investigating the 2 x 3 interaction between type of hand movement and hand free for the two sub-groups. Any potential difference between the two sub-groups might have affected the critical comparisons between the baseline and experimental conditions. Our research questions did not predict such an effect. However, this exploration may explain absence of expected findings.

No movement in the first block

Model estimates are reported in Table 4.4. We compared the maximal model with the reduced model including the main fixed effects only (same random effect structure; covariate included). Adding the interaction between the type of hand movement (gesture, tap) and hand free (left, right, none) did not significantly improve the model fit: χ^2 (2) = 2.063, p = .356 (see Figure 4.3). Though the interaction was not significant, we had a priori predictions for the main effect contrasts. Simultaneous tests for general linear hypotheses (Tukey Contrasts) revealed non-significant contrasts (p > .05). Thus, we have no evidence that the interaction between type of hand movement and hand free affected the spontaneous use of metaphors for the participants who were immobilised in the first block. However, descriptively (Figure 4.3) gesturing (in particular with the left hand) seems to increase likelihood of language use while tapping to decrease it.

Table 4.4 Parameters estimates for the model with the main effects and interaction between type of hand movement and hand free on metaphorical language use for the group who did the immobilisation condition in the first block. "No hand" and "tap" were the reference categories. Length of explanations (i.e., number of words produced) was a covariate.

	Estimate	SE	z-value	p-value
(Intercept)	-1.880	.610	-3.083	< .001
Left Hand	-.772	.563	-1.371	.170
Right Hand	-.239	.522	-.459	.646
Gesture	-.093	.559	-.168	.866
Left Hand:Gesture	1.027	.719	1.428	.153
Right Hand:Gesture	.392	.692	.567	.570
Explanations' Length	.020	.008	2.397	.016

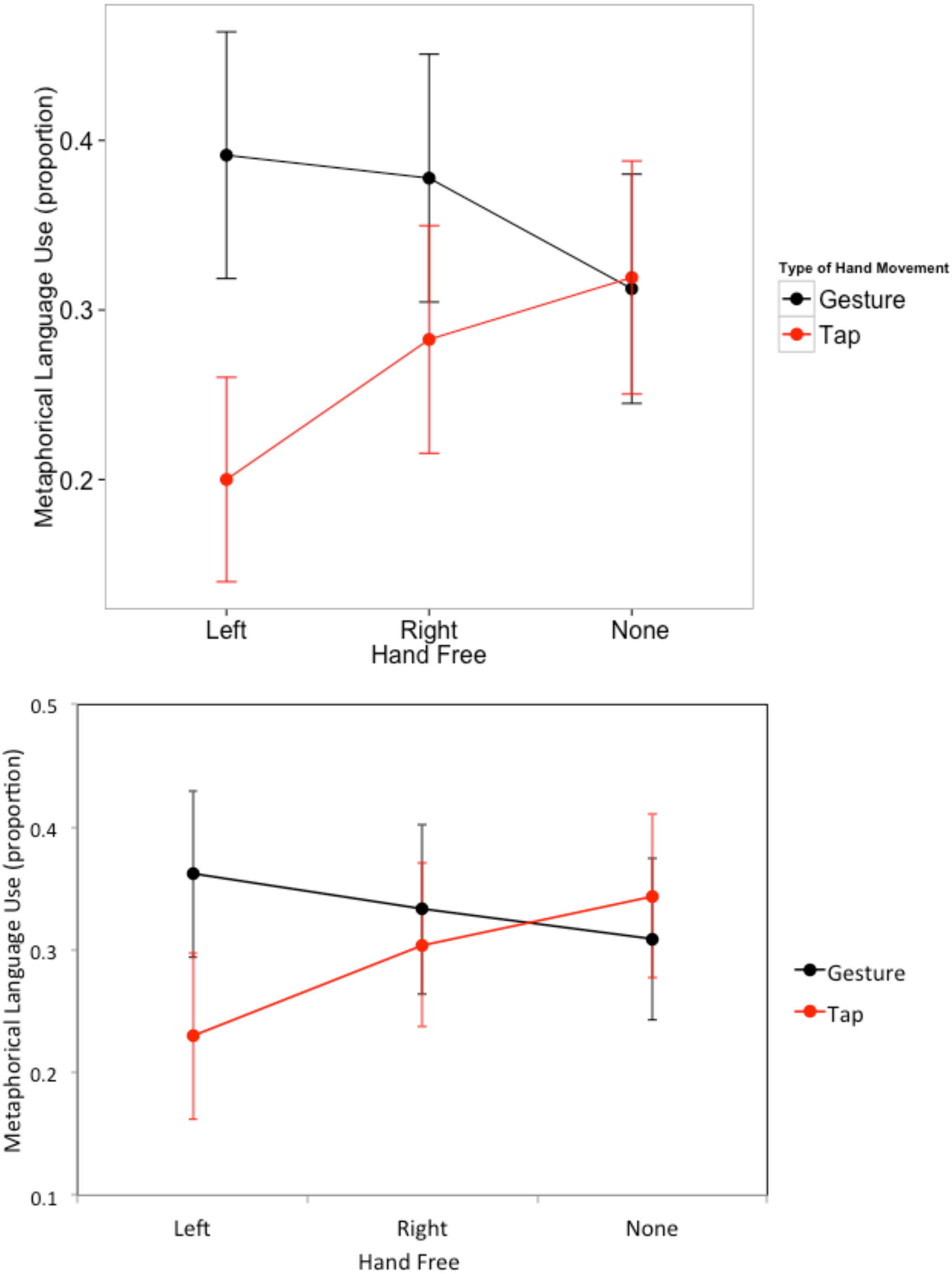

Figure 4.3 Likelihood of metaphorical language use (i.e., trials with metaphor presence per total amount of trials) for the gesturing and tapping groups in the three hand conditions (left, right, no hand) for participants who experienced the no movement condition in the first block. The bottom panel accounts for the covariate length of explanations.

Next, we proceeded to model reduction and comparisons to investigate the main effect of type of hand movement. We compared the model with the main effects of the type of hand movement and hand free with the model with the main effect of hand free only. Adding the effect of the type of hand movement (gesture, tap) did not significantly improve model fit: χ^2 (1) = .767, p = .381. Thus, we have no evidence that the type of hand movement affected the spontaneous use of metaphorical language for the participants who were immobilised in the first block.

No movement in the second/third blocks

Model estimates are reported in Table 4.5. We compared the maximal model with the reduced model including the main fixed effects only (same random effect structure; covariate included). Adding the interaction between the type of hand movement (gesture, tap) and hand free (left, right, none) did not significantly improve the model fit: χ^2 (2) = .116, p = .943 (see Figure 4.4). Though the interaction was not significant, we had a priori predictions for the main effect contrasts. Simultaneous tests for general linear hypotheses (Tukey Contrasts) revealed non-significant contrasts (p > .05). Thus, we have no evidence that the interaction between the type of hand movement and hand free affected the spontaneous use of metaphorical language for the participants who were immobilised in the second/third blocks.

Table 4.5 Parameters estimates for the model with the main effects and interaction between the type of hand movement and hand free on metaphorical language use for the group who did the immobilisation condition in the second/third blocks. “No hand” and “Tapping” were the reference categories. Length of explanations (i.e., number of words produced) was a covariate.

	Estimate	SE	z-value	p-value
(Intercept)	-1.666	.421	-3.950	< .001
Left Hand	-.132	.295	-.450	.652
Right Hand	.196	.286	.687	.492
Gesture	.205	.348	.590	.555
Left Hand:Gesture	.076	.417	.184	.854
Right Hand:Gesture	.140	.409	.344	.730
Explanations’ Length	.015	.004	3.455	< .001

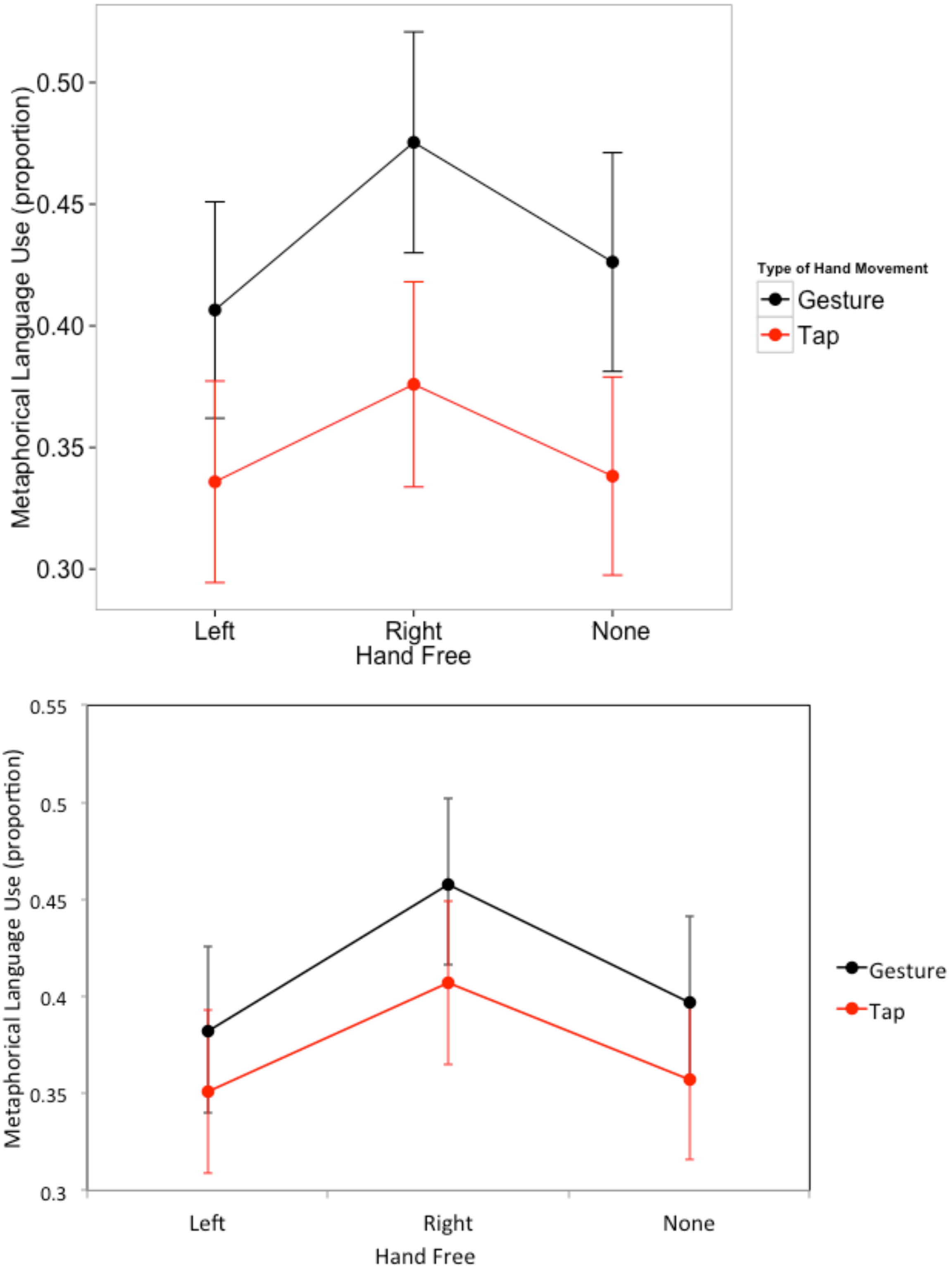

Figure 4.4 Likelihood of metaphorical language use (i.e., trials with metaphor presence per total amount of trials) for the gesturing and tapping groups in the three hand conditions (left, right, no hand) for participants who experienced the no movement condition in the second/third blocks. The bottom panel accounts for the covariate length of explanations.

Next, we proceeded to model reduction and comparisons to investigate the main effect of type of hand movement. We compared the model with the main effects of the type of hand movement and hand free with the model with the main effect of hand free only. Adding the effect of the type of hand movement (gesture, tap) did not significantly improve model fit: χ^2 (1) = 1.164, p = .280. Thus, we have no evidence that the type of hand movement affected the spontaneous use of metaphorical language for the participants who were immobilised in the second/third blocks.

To sum up, the "no movement" condition did not differ from the conditions of left and the right hand movement (regardless of tapping or gesturing) for both sub-groups, but the pattern was different. For participants who performed the immobilisation condition in the first block: gesturing (regardless of the hand) increased the likelihood for metaphorical language use compared to no gesturing. However, tapping (regardless of the hand) reduced metaphorical language use compared to no tapping. Descriptively the difference between gesturing and tapping seems more apparent within the left hand free condition, as expected. Importantly, the "no movement" conditions for the gesturing and tapping groups largely overlapped; that is, the baseline conditions yielded the expected result. For participants who performed the immobilisation condition in the second/third blocks: the right hand movement (regardless of tapping or gesturing) increased the likelihood for metaphorical language use. However, the "no movement" conditions for the gesturing and tapping groups did not largely overlap, hence they might not be comparable (i.e., possibly contaminated baseline conditions). Descriptively and when focusing on the baseline trials only (i.e., no movement) for both gesturing and tapping groups, an order effect for gestures was revealed (see Figure 4.5). It seems that gesture production increased the likelihood for metaphorical language use and this effect lingered on to the subsequent baseline condition. This does not seem to be the case for the tapping group, hence indicating a "sustained beneficial" effect of gestures on metaphorical language use.

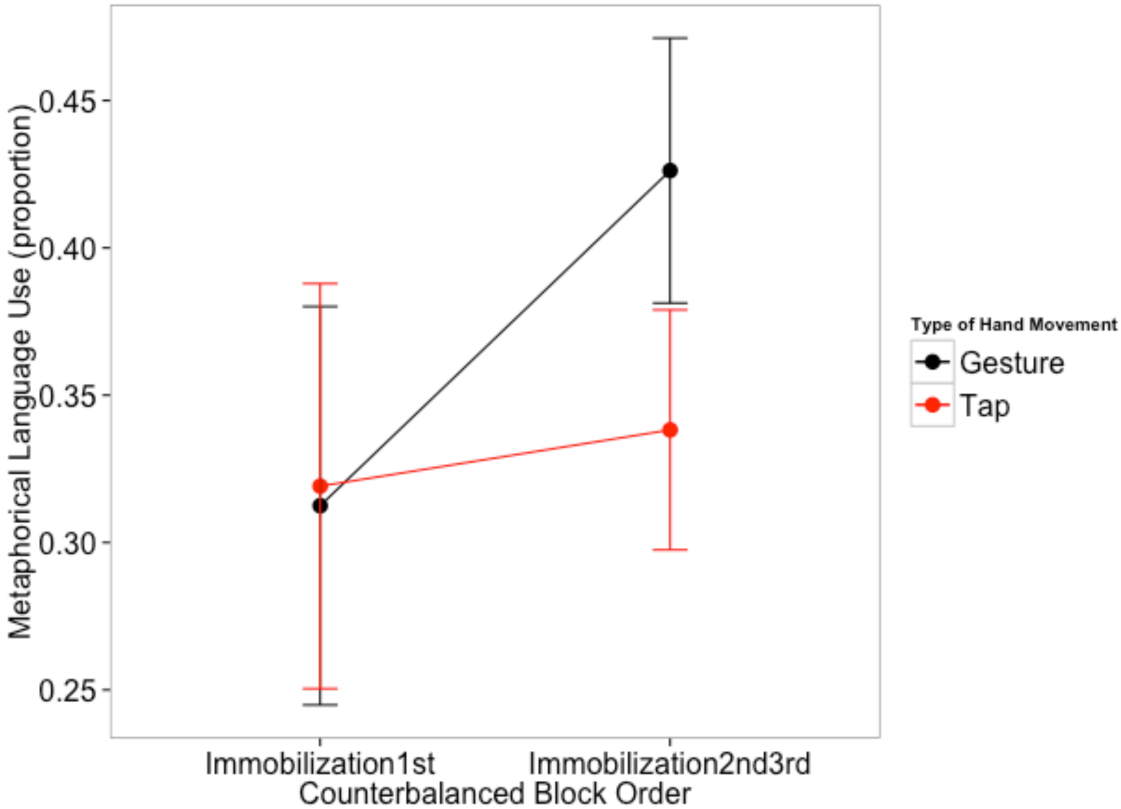

Figure 4.5 Likelihood of metaphorical language use (i.e., trials with metaphor presence per total amount of trials) in baseline blocks (no movement) when performed first and second/third.

4.8 Discussion

The present study investigated the effect that meaningful gestures and meaningless tapping movements might have on the spontaneous use of metaphorical language within abstract context. We hypothesised that producing meaningful gestures (as opposed to meaningless tapping movements), and in particular gestures with the left hand, would activate metaphorical thinking in the contra-lateral right hemisphere, and lead to metaphor related speech production during the explanations of abstract phrases. We found no evidence that the type of hand movement and the hand choice for gesturing may determine the use of metaphor related expressions during abstract explanations.

The present findings provided no evidence that the type of hand movement affects the spontaneous use of metaphorical language. We were expecting that gestures as opposed to tapping movements would increase the likelihood for metaphorical language use, because they activate visuo-spatial information (Alibali & Kita, 2010; Alibali et al., 2011), which is crucial to metaphorical processing (Lakoff & Johnson, 1980a). Our study was the first one to directly compare the effect that meaningless movements and meaningful gestures might have on spontaneous metaphorical language use. However, it did not extend previous findings suggesting that gesture production as opposed to not gesturing leads to metaphorical speech production (Bos & Cienki, 2011). Given the null result, we cannot suggest that gestures compared to tapping help the conceptualisation and verbalisation of metaphors. In addition, the present findings provided no evidence to support our proposed "hemisphere-specific feedback hypothesis" that gesturing with the left hand activates metaphorical thinking in the contra-lateral right hemisphere, thus increases metaphorical language use compared to left-hand tapping. Chapter 3 showed that left-hand gestures enhanced participants' metaphorical explanations compared to right-hand gestures or not gesturing at all. In the current study, we further explored this effect by extending our investigation to explanations of abstract phrases when metaphorical language is not needed or encouraged. The observed discrepancy may relate to different levels of hemispheric involvement during different tasks. Maybe left-hand gestures enhance metaphorical thinking when the right hemisphere is already activated and particularly engaged (i.e., when speakers explain metaphorical mappings), but not when metaphorical thinking should be activated (i.e., when speakers spontaneously use metaphors). However, given the null result we do not strongly suggest that this is the case.

One possible explanation for the null result relates to the open-endedness of the task. The specific explanation task was an informed choice to capture the spontaneous use of metaphorical language when speakers explain abstract phrases. However, we found that the length of explanations predicted metaphorical language use and it was affected by the experimental manipulations (see Text S2 in Appendix Chapter 4 for results). In particular, the more words participants produced, the more likely they were to produce metaphor related expressions. In addition, the gesturing group seems to produce more wordy explanations as opposed to the tapping group. Further research is needed to directly investigate the relationship between "verbosity" and metaphorical language use, and the effect of gestures on quantitative and qualitative properties of speech outcomes (e.g., how does gesturing as opposed to tapping affect the amount of new information and different words uttered). In addition, future research could experimentally control for the amount of information uttered (e.g., instruct participants to explain the phrases in specific number of words).

Furthermore, we may speculate why we did not observe the expected hand choice differences based on the observed block-order effect. Chu and Kita (2011) showed that the beneficial effect of co-thought gestures in a mental rotation task could be extended even in trials when gesturing is prohibited. Our data showed a similar descriptive pattern. The baseline (no gesture condition) elicited more trials with metaphorical expressions when it was in the second or third block than when it was in the first block. This pattern suggests that gesturing in the beginning of the experiment may activate metaphorical thinking and lead to metaphorical language use. This effect may linger on to next parts of the experiment when gestures are not produced. Therefore, it is possible that the baseline condition was contaminated, not statistically distinguishable from the other conditions, and hence not sensitive enough to reveal a particular facilitative effect of left-hand gesturing.

Finally, an important note is the number of female and male participants in the sample. The studies in Chapter 3, which successfully showed the facilitative effect of left-hand gestures on metaphorical thinking, tested male participants only. In contrast, the present study tested 46 females (N = 60). Maybe it is harder to observe the expected left-hand gesturing advantage in our female participants, but the effect it is more prominent in male participants, because language is more bilaterally represented in females than in males (J. McGlone, 1980). Future research should control for gender by testing proportionate samples and/or directly accounting for gender effects.

4.9 Conclusions

In conclusion, the current study provided no evidence that the depictive nature of gestures, rather than the hand movement per se, increases the likelihood for using metaphorical language within abstract context. In addition, there was no evidence that left-hand gestures may activate metaphorical thinking in the right hemisphere, such that left-hand gestures compared to left-hand taps increase metaphorical language use. Unexpectedly, it was found that lengthy explanations increase the likelihood of metaphorical language use. Future research could further explore the effect of gestures and meaningless hand movements on linguistic properties of verbal outcomes (such as speech rate, production of new information), and/or experimentally control for these effects in order to directly assess gestures' effect on the content of speech.

5 Priming effect of gestures on the comprehension of action sentences

5.1 Motivation and aims

This study investigated whether action gestures when produced alone, without concurrent speech, may prime comprehension of metaphorical and literal action sentences at a similar degree. Building upon the previous studies, it also investigated the role of the link between hand choice for gesturing and hemispheric involvement during a linguistic task on the potential priming effect. It aimed to provide evidence for the embodied accounts of meaning, the relationship between higher order conceptual processing and sensory-motor representations through gesturing, and the proposed “hemisphere-specific feedback hypothesis” for gestures’ self-oriented functions, when gestures do not accompany speech.

5.2 Abstract

Action: first do it and then understand it? If so, do it right or do it left? If so, do we "grasp" abstract and concrete action the same way? Visually presented iconic gestures prime comprehension of semantically related words. In addition, according to strong embodied theories, concrete and abstract meaning is understood through simulation of our physical experience with the world. The current study investigated whether production of action gestures with a particular hand primes comprehension of metaphorical and literal action in the same way. Right-handers produced a gesture representing an action verb (e.g., grasp). Next, they read a target sentence representing an action (e.g., "the student grasped the concept"; "the student grasped the flower"). They had to semantically categorise if the sentence had a metaphorical or literal meaning. We manipulated within-subjects the type of action sentences (metaphorical, literal), the relationship between prime and target (congruent, incongruent), and the hand used for gesturing (left, right). All participants performed a baseline no-prime condition as well. We measured response time and accuracy of the semantic categorisation. We hypothesised that congruent gestures compared to incongruent and no gesture condition, and in particular gestures with the left hand would facilitate performance in the semantic categorisation of metaphorical compared to literal action sentences. We found no evidence for such effects.

Keywords: Action sentence comprehension; metaphor; gesture; cross-modal priming; semantic categorisation

5.3 Introduction

The interaction between speech-accompanying gestures and language in shaping thought is well documented. Within gesture research and embodied cognition research, several empirical studies have investigated the facilitative effect of speech-accompanying gestures on cognitive processing. For example, we know that speech-accompanying gestures facilitate lexical retrieval (R. Krauss & Hadar, 2001), working memory (Goldin-Meadow et al., 2001) and the conceptual planning of the speech to be uttered (Kita, 2000). In previous chapters of the thesis, we investigated a “hemisphere-specific feedback hypothesis” for these facilitative effects, and we showed that left hand gestures enhanced metaphorical explanation, which involves the right hemisphere. Thus, when speech-accompanying gestures represent meaning, they facilitate several aspects of high order cognitive processing. However, little is known about the facilitative effect that gestures when produced alone might have on high order cognitive processing. The current study investigated these effects and the proposed “hemisphere-specific feedback hypothesis” for gestures when produced alone by using cross-modal priming in a semantic categorisation task: does action meaning representation through gesturing with the left hand prime the categorisation of matching metaphorical action sentences?

The semantic priming paradigm is one way to investigate the facilitation in cognitive processing as a function of other factors. Semantic priming refers to the facilitation of processing of information after recent exposure to related information (Neely, 1991). The robust semantic priming effect means that words preceded by semantically related primes are responded to faster than words preceded by semantically unrelated primes. Cross-modal semantic priming is a version of semantic priming where gestures act as primes to test the hypothesis that gesturing primes semantically related words (see Tabossi, 1996 for an evaluation of cross-modal priming). The theoretical basis for this lies in McNeill (1985) arguments that language and gestures are tightly interlinked, and the assumption that encoding meaning in gestures activates semantically related words. In the next paragraphs, we review studies, which have used cross-modal priming to investigate the effects that gestures when presented alone might have on linguistic processing.

Firstly, watching videos of iconic gestures alone may facilitate a subsequent lexical decision task, when gestures and words match. Yap, So, Yap, Tan, and Teoh (2011) reported two cross-modal semantic priming experiments where participants performed a lexical decision task. Word targets (e.g., bird) were preceded by video recorded iconic gestures either semantically related (e.g., pair of hands flapping) or unrelated (e.g., drawing a square). They manipulated the video duration from 3,500ms in Experiment 1 to 1,000ms in Experiment 2. They reported significant priming effects in both experiments: participants were faster for related pairs of video gestures and words than unrelated. Importantly, the priming effect was stronger when exposure to iconic gestures was longer than shorter suggesting that the observed effect could have been because of some type of verbal recoding. The study has three limitations. It is possible that the mismatching pairs of gesture videos and words interfered rather than the matching ones facilitated the lexical decision. There was no baseline condition to rule out this interpretation. In addition, it focused on priming through gesture perception rather than real gesture production. Finally, the lexical decision task does not heavily rely on semantic processing and its focus is on word processing rather than higher order cognitive processing. More specifically, in the lexical decision task, participants discriminate real words from similar strings of letters. While semantic features of the words (e.g., valence, concreteness) may affect responses, the focus is placed more on the form rather than the meaning of the word. Similarly, W. C. So, Yi-Feng, Yap, Kheng, and Yap (2013) investigated whether clips with iconic gestures presented alone and with concurrent speech prime lexical decision at a comparable level. They showed an overall priming effect (i.e., related combinations faster than unrelated), but when gestures and speech were concurrent the effect was weaker than gestures-only and comparable to the speech-only condition. They suggested that the facilitative effect of iconic gestures when presented alone might be stronger for tasks that do not rely heavily on semantic processing (e.g., lexical decision).

Secondly, watching videos of iconic gestures alone may interfere with a subsequent reading time task, when gestures and words do not match in meaning, but not necessarily facilitate when gestures and words match. In Bernardis, Salillas, and Caramelli (2008) participants watched a gesture clip with a pantomime referring to an object or action. Next, they saw a word, which would match or mismatch with the preceding video, and they performed a speeded naming task (i.e., read the word as soon as possible). They recorded reading times. Participants had slower reading times in the mismatching conditions compared to baseline, but did not differ in the matching and baseline conditions. The authors suggested an inhibition rather than a facilitation effect. In particular, they stated, "[…] the meaning of iconic gestures did not prime the same-meaning words" (p.1125). The study raises some issues. Firstly, they collected data for the baseline condition (i.e., plain reading times of words) from different participants from the ones participated in the priming conditions. In addition, the study focused on priming through gesture perception rather than real gesture production, and it did not control for the duration of exposure to the iconic gestures (e.g., the clips lasted up to 4,680ms, hence verbal recoding is possible). Finally, statistics were not always consistent with the authors' claims. For example, they suggested absence of priming effect, while on p.1118 they reported, "[…] targets preceded by a related gesture, compared with targets preceded by an unrelated gesture, were named 39ms faster, $p < .001$".

Finally, watching videos of iconic gestures alone may enhance performance in semantic relatedness and reading times tasks, when gestures and words match in meaning.

Wu and Coulson (2007) investigated the cross-modal priming effect while speakers watched soundless videos of iconic gestures clips followed by related or unrelated words. ERPs were recorded for a semantic relatedness task (i.e., classify word targets as related or unrelated to the prime) and a passive task (i.e., silently attend stimuli; surprise memory task to recognise words from the experiment followed). The N400 component showed larger negative deflection for unrelated than related combinations in both tasks, thus suggesting that, even without an explicit task, the visuo-spatial cues provided by gestures facilitate the comprehension of related words. This study focused on priming through the visuo-semantic properties of gesture rather than real gesture production, and it did not include a baseline condition to rule out that unrelated gestures may hinder word processing.

The studies reviewed above indicate that gestures when presented alone may activate meaning-based representations and affect linguistic processing such as reading times, lexical decision or relatedness judgment. The current study builds on these interpretations with the aim to extend them by adding a baseline condition. In addition, none of the studies used real gesture execution as a prime or a task focusing on sentence meaning. More importantly, all of the studies used concrete target stimuli (e.g., concrete nouns such as "bird"). Therefore, it is still unknown whether encoding sensory-motor information in gestures may affect the processing of abstract meaning. If so, the whole "abstract-to-concrete" continuum of knowledge would be grounded in sensory-motor representations (following the strong embodied accounts of meaning; for a review see Meteyard et al., 2012).

To our knowledge only one[12] study has investigated whether *producing* gestures alone, outside linguistic context, may modulate processing of abstract meaning. Wilson and

[12] Santana and de Vega (2011) investigated the meaning-to-action directional link. They found that reading an upward metaphor (e.g., "rise to victory") compared to a downward (e.g., "fall to depression") reduced the time for eliciting a concurrent upward hand movement, thus suggesting that metaphorical action meaning is grounded to bodily experiences.

Gibbs (2007) suggested that people ordinarily understand abstract concepts in terms of physical entities in the form of metaphors, and that bodily action may modulate the comprehension of verbal expressions that represent action in an embodied manner (i.e., strong embodiment). Their study showed that real and imagined hand movements congruent to metaphorical phrases facilitate people's immediate processing of these phrases in a reading time task. For example, when participants executed or imagined the execution of a "grasping" hand movement, they read the action metaphor "to grasp a concept" faster than when they executed or imagined a mismatching movement or when they did not move. However, this study had a limited set of stimuli (9 sentences), it lacked a control set (e.g., literal action sentences), thus could not establish whether the effect was specific for metaphorical meaning or for both abstract and concrete action meaning, and it used a passive task (reading times).

In the current study, we re-examined the cross-modal priming effect from gesture to meaning comprehension addressing some of the limitations of previous research as discussed above. Additionally, we examined the proposed "hemisphere-specific feedback hypothesis" for gestures' self-oriented functions using a different task, which focused on comprehension, and a different experimental setting, which focused on gestures when produced alone. Unlike previous studies, we used sentences (instead of words) and a semantic categorisation task (instead of passive reading times or lexical decision), which weighs semantic information heavily. This was critical to account for the role of semantics in metaphorical processing, and provide evidence for the generality of the priming effect and the "hemisphere-specific feedback hypothesis" across different tasks. In addition, we used a literal, matched set of sentences as a control to the metaphorical ones (unlike Wilson & Gibbs, 2007). This was critical to compare the influence of gestures on comprehension of concrete and abstract action sentences. Finally, we used real gesture production as prime (instead of visual presentation of gesture videos). This was critical to disentangle the potential priming effect from other visuo-semantic activations prompted by perceiving video recorded gesture primes.

To this end, we manipulated sentence type, prime type and hand used for gesturing in a semantic categorisation task using the cross-modal priming paradigm. More specifically, participants were asked to categorise if an action sentence (e.g., "the employee bashed the proposal") had a metaphorical or literal meaning after producing a matching or mismatching action gesture with their left or the right hand or after not gesturing at all. Sentence type (literal, metaphorical), prime type (congruent, incongruent, no prime) and hand used for gesturing (left, right) were manipulated within-participants. Response times and accuracy of semantic categorisation were recorded. If action meaning activated by gesturing facilitates comprehension of action sentences, there should be a main effect of prime type. Participants should be faster and more accurate when categorising the congruent sentences than the incongruent and the sentences with no prime (i.e., matching action gestures would facilitate the comprehension of action sentences rather than mismatching gestures interfere). In addition, if strong embodied accounts are true, and comprehension of the whole concrete-to-abstract meaning continuum is tied to bodily experience, there would be no interaction between prime type and sentence type. Participants would categorise congruent metaphorical and literal action sentences at a comparable level. Alternatively, if weak embodied accounts are true, and comprehension of abstract action does not necessarily rely on sensory-motor information encoded in gestures, there would be an interaction between prime and sentence type. Priming effects would be stronger for literal than metaphorical action sentences. Finally, if the "hemisphere-specific feedback hypothesis" for gestures' self-oriented functions is true for gestures when produced alone, and gestures with one hand enhance cognitive processes involving the hemisphere contra-lateral to the gesturing hand, there should be a significant three-way interaction between sentence type, prime type and hand used for gesturing. Participants should categorise metaphorical sentences faster and more accurately than literal after producing congruent gestures with the left than the right hand.

5.4 Method

Participants

38 subjects (all females[13]; age: M = 19 years, SD = .70) took part in the experiment for credits upon completion of the tasks. All participants were right-handed, English native speakers and students at the University of Birmingham. Handedness was assessed with a 12-items questionnaire based on the Edinburgh Handedness Inventory (Oldfield, 1971). Two bimanual items (from Oldfield's long list) were added to his recommended 10-items questionnaire to equate the number of uni-manual and bimanual items. Each "left" answer was scored with 0, each "either" answer with 0.5, and each "right" answer with 1. A total score of 8.5 and above determined right-handedness (M = 11.58, SD = .65). Text S1 in Appendix Chapter 3 includes the questionnaire.

Stimuli

Stimuli pre-test

A pre-test was conducted to ensure (a) matching of the target sentences in terms of familiarity and predictability of the verb phrase, and (b) clear differentiation of the target sentences in terms of figurativeness. It also informed the design of the mismatching

[13] In the current study, we included females, because we wanted to extend findings from the study in Chapter 3, which used males only. However, due to recruiting limitations we could not test a proportionate sample of males and females. This limitation is further discussed in Discussion, Section 7.3.

combinations between the meaning of the prime gesture and that of the target sentence. See Text S1 in Appendix Chapter 5 for details of pre-test.

Prime gestures

We used 11 abstract symbols, which were visually presented to prompt participants to recall and produce the respective action gesture or do not move (see Table 5.1). Text S2 in Appendix Chapter 5 includes detailed description of the hand movements' motoric properties.

Table 5.1 Symbols corresponding to action gestures.

Gesture	Symbol	Gesture	Symbol
bash	^	raise	:
bend	§	shake	@
grasp	/	spin	√
pull	≠	stir	≈
push	∞	twist	#
no action		*	

Target sentences

We used the 20 metaphorical and 20 literal sentences (see Table 5.2). The properties of two types of sentences were examined by information from CELEX database and by pre-tests (participants who did not take part in the main experiment completed the pre-test; Text S1 in Appendix Chapter 5 includes details about the matching and pre-testing of stimuli. The pairs of metaphorical and literal sentences were matched for (a) frequency of the object noun phrase (O-NP hereafter) (using the CELEX database) (t (19) = .272, p = .788), (b) familiarity of the verb phrase, t (19) = -1.056 p = .304, and they were clearly differentiated in terms of figurativeness (t (19) = 27.075, p < .001). The literal sentences (M = -1.07, SD = .622) had a more surprising verb phrase following the subject noun phrase (S-NP hereafter) than the metaphorical sentences (M = -.56, SD = .634) (t (19) = 2.284, p = .034). However, the difference was small (.51) given that the degree of surprise was judged on a scale of -3 to +3. Moreover, both types of sentences were rated as "moderately unsurprising". Hence, we think this difference would not have substantial influence on processing.

The sentences were in a congruent, incongruent or no prime relation with the preceding symbol and gesture (e.g., for a congruent condition, participants would see the symbol "/", perform a grasping gesture, and then read the sentence "The boy grasped the meaning" or "The boy grasped the bottle"). See Text S1 in Appendix Chapter 5 for details about the matching and pre-testing of stimuli.

Table 5.2 Sentences used in the main semantic categorisation task.

Metaphorical Action Sentences	Literal Action Sentences
The employee bashed the idea	The employee bashed the door
The reporter bashed the decision	The reporter bashed the window
The worker bent the rule	The worker bent the wire
The technician bent the facts	The technician bent the stick
The boy grasped the meaning	The boy grasped the bottle
The daughter grasped the concept	The daughter grasped the handle

The leader pulled the financing	The leader pulled the lever
The performer pulled the audience	The performer pulled the handle
The leader pushed the reforms	The leader pushed the button
The workers pushed the scheme	The workers pushed the handle
The mother raised the income	The mother raised the bottle
The decorator raised the price	The decorator raised the box
The terrorist shook the authority	The terrorist shook the weapons
The thief shook the borough	The thief shook the matchbox
The lady spun the tale	The lady spun the thread
The presenter spun the news	The presenter spun the wheel
The artist stirred the emotions	The artist stirred the paint
The magician stirred the crowd	The magician stirred the liquid
The man twisted the plot	The man twisted the wire
The designer twisted the truth	The designer twisted the hair

Procedure

The whole session had three parts: (a) training for gesture execution, (b) computer-based semantic categorisation task, and (c) computer-based rating of the stimuli.

For part (a) the experimenter trained the participants for gesture execution. Participants were seated in front of a laptop screen (MacBook Pro, 13 inches). They watched the 10 gesture videos, each of them paired with their corresponding symbol (see Table 5.1). Participants watched each gesture and its corresponding icon four and more times according to their request. The verbal label of the gestures was not given to them to avoid verbal recoding that would act as lexical instead of action prime in the main task. Participants had to closely produce the gestures as shown in the videos and recall the symbols linked to them. The procedure went on until they demonstrated perfect performance.

Following the training session, participants completed the computer-based semantic categorisation task (see Figure 5.1). Each trial began with a fixation point in the middle of the screen (a red dot). Then the cue icon appeared on the screen. Participants had to enact the gesture corresponding to the icon with one hand. The hand to be used for the gesturing trials was indicated on the screen with the letter L for left hand and R for right hand presented on top of the cue icon in a blocked design. Participants had both hands on the keyboard pressing keys according to each block and following instructions from the experimenter. For the gesturing blocks, they were pressing the control key with the index finger of one hand (right or left) and the space bar with the other (left or right). When they were ready for gesture execution they released the hand (left or right) from the space bar, produced the gesture indicated by the cue and returned it on the space bar. For the no prime blocks, they were pressing the two control keys on the right and left bottom of the keyboard with their right and left index finger respectively. In the gesturing blocks, participants had 2.5 sec interval to produce action, and in the no prime blocks, they would stay still for 2.5 sec. Note, in the gesturing blocks, participants had unlimited time to recall and execute the gesture after presentation of the cue symbol. In addition, the no prime condition was “a no movement at all” condition instead of an automatic or meaningless gesture for example. The rationale for this decision was that we could not create totally meaningless movement (e.g., there was a risk that participants would attribute some meaning in the production of meaningless movements). Furthermore, in this experiment the meaningless condition could be considered having the same effect as the incongruent condition. We needed a clear-cut baseline condition when there would be no priming from meaning through gesture production.

Next, a sentence appeared on the screen. It was either a metaphorical or a literal action sentence, and congruent or incongruent to the preceding gesture. They were told to attend the meaning of each sentence and complete a semantic categorisation task. That is, they said the word “metaphor” if they thought the sentence had a metaphorical meaning or the word “concrete” if they thought the sentence had a concrete meaning. Also, they responded to test questions probing their comprehension of the sentences. They orally answered “yes” or “no” to simple “yes/no” questions, randomly interspersed between trials (after 15% of the critical trials; in total they answered 36 questions). For example, for the probe sentence “The employee bashed the idea”, the questions were either “Did the employee criticise the idea?” (“yes” was the correct answer) or “Did the employee praise the idea?” (“no” was the correct answer). Note that participants did not know which sentences would be followed by a question. All responses were given through a vocal response key, which recorded the response time. The experimenter recorded accuracy.

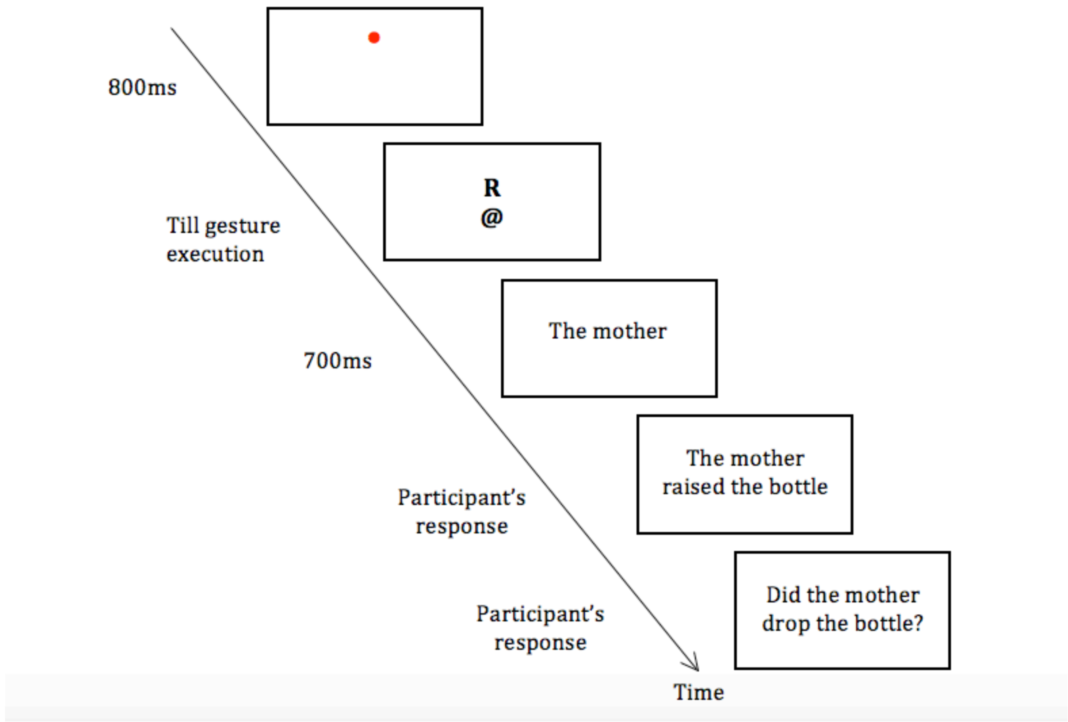

Figure 5.1 The time sequence of a trial with a question probing comprehension.

Presentation of sentence stimuli was as follows: first the subject noun phrase (S-NP hereafter) (e.g., "The artist") appeared on the centre of the screen for 700 msec. It stayed on the screen and then the verb and the O-NP (e.g., "bashed the proposal") was displayed a bit lower on the screen but still on the centre until a response was given. The rationale behind this presentation was twofold: (a) some of the sentences were too long and might need smaller font to be presented in one line, and (b) we avoided a division of the visual field into left side (for S-NP) and right (for rest of the sentence); thus we decreased eye movements (see Figure 5.1).

Each of the 20 literal sentences and 20 metaphorical sentences was repeated six times (see Text S4 in Appendix Chapter 5 for example): (1) congruent condition with the left hand, (2) congruent condition with the right hand, (3) incongruent condition with the left hand, (4) incongruent condition with the left hand, (5) no prime condition, (6) no prime condition. In total each participant experienced 240 trials. Order of stimuli and prime-target relationship (congruent/incongruent) was random. Order of hands used (left, right, no hand) was blocked and counterbalanced across participants.

After the semantic categorisation participants took a break and next they completed computer-based rating tasks for the target sentences in terms of: (a) predictability of the verb phrase, (b) figurativeness, and (c) familiarity of the verb phrase. For task (a) participants rated on a scale from -3 to +3 "how surprising was the second part of the sentence you read" ("-3" being "extremely unsurprising", "-2" being "very unsurprising", "-1" being "moderately unsurprising", "0" being "difficult to say if unsurprising or surprising", "+1" being "moderately surprising", "+2" being "very surprising", "+3" being "extremely surprising"). For task (b) participants rated on a scale from -3 to +3 "how metaphorical was the sentence you read" ("-3" being "extremely literal", "-2" being "very literal", "-1" being "moderately literal", "0" being "difficult to say if literal or metaphorical", "+1" being "moderately metaphorical", "+2" being "very metaphorical", "+3" being "extremely metaphorical"). For tasks (a) and (b) stimuli presentation was the same as in the main task. For task (c) participants saw the verb phrases in one part (e.g., "bash the proposal"; "bash the painting") and rated on a scale from -3 to +3 "how familiar to you was the phrase you read" ("-3" being "extremely unfamiliar", "-2" being "very unfamiliar", "-1" being "moderately unfamiliar", "0" being "difficult to say if unfamiliar or familiar", "+1" being "moderately familiar", "+2" being "very familiar", "+3" being "extremely familiar"). Order of trials (literal – metaphorical) was random. They also rated the similarity between the meanings in the gestures in the videos and the sentences. Participants were presented with the gesture videos and then the written sentences. The combinations were exactly the same as in the main task, but they were not repeated more than once. They rated on a scale from -3 to +3 "how well did the meaning of the gesture you watched match the meaning of the sentence you read" ("-3" being "extremely bad match", "-2" being very bad match", "-1" being "moderately bad match", "0" being "neither bad nor good match/ difficult to say if bad or good match", "+1" being "moderately good match", "+2" being "very good match", "+3" being "extremely good match"). Response was given through keyboard by pressing the respective key from 1 to 7 with their right hand. Note these tasks were identical to the pre-test tasks.

Finally, they rated the ease of recalling the gestures from their respective symbols in a pen and paper task. They used a scale from -3 to +3 to rate "how easy it was for you to recall which gesture was linked to which symbol" ("-3" being "extremely difficult", "-2" being very difficult", "-1" being "moderately difficult", "0" being "neither difficult nor easy", "+1" being "moderately easy", "+2" being "very easy", "+3" being "extremely easy").

5.5 Design

The dependent variables[14] were time for response (for accurate responses only) and accuracy of categorisation The experiment had a 2 x 3 x 2 within-subjects factorial design with three independent variables: sentence type (metaphorical, literal), prime type (congruent, incongruent, no prime), and hand used for gesturing (left, right). Firstly, we assessed the effect of the prime type (congruent, incongruent, no prime) and the interaction between the sentence and prime type. Next, we excluded the baseline, no prime trials and examined the three-way interaction between sentence type (metaphorical, literal), prime type (congruent, incongruent), and hand used for gesturing (left, right).

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[14] Unlike Chapter 4, here we did not report block-order effect analysis. It is not possible for carry-over effects from gesturing to manifest at response time and accuracy level in this design. For example, why would prime-gestures with the left hand influence response times and this influence be carried over to next blocks that do not involve gesture? If anything, and as usual in experiments measuring response times, participants would become faster towards the final parts of the experiment.

Paired mean comparisons from the rating tasks were performed, to confirm the matching of the stimuli.

5.6 Results

5.6.1 Rating tasks

We compared the ratings between the literal and metaphorical sentences to ensure that the target stimuli were carefully controlled (see Text S5 in Appendix Chapter 5 for the results in detail).

Participants rated the metaphorical (M = 1.08, SE = .11) and literal (M = .99, SE = .14) sentences as "moderately familiar" at a comparable level. Participants clearly differentiated the metaphorical (M = 2.01, SE = .08) and literal (M = -2.08, SE = .08) sentences for figurativeness levels. Participants rated the literal sentences as having a more surprising verb phrase (M = -.44, SE = .12) than the metaphorical sentences (M = -.77, SE = .09). However, overall they rated both of them as "moderately unsurprising", and the difference was small (.33) given that the degree of surprise was judged on a scale of -3 to +3, therefore we do not think this difference could modulate participants' performance in the main task. In the video-sentence similarity task, participants rated the congruent combinations as "very good matches" (M = 1.99, SE = .075) and the incongruent ones as "very bad matches" (M = -1.98, SE = .101). However, they were less confident when rating the congruent metaphorical (M = 1.84, SE = .085) than the literal congruent combinations (M = 2.14, SE = .075) (see Figure 5.2). We believe this difference could not account for any observed differences in the main task, where the videos were not used. Finally, participants rated the symbols as "moderately easy" (M = .83, SE = .37) to remind them of each gesture after the training session. The gestures "bend" and "twist" were the most difficult to recall from their respective symbols, but still "moderately difficult" (see Figure 5.3).

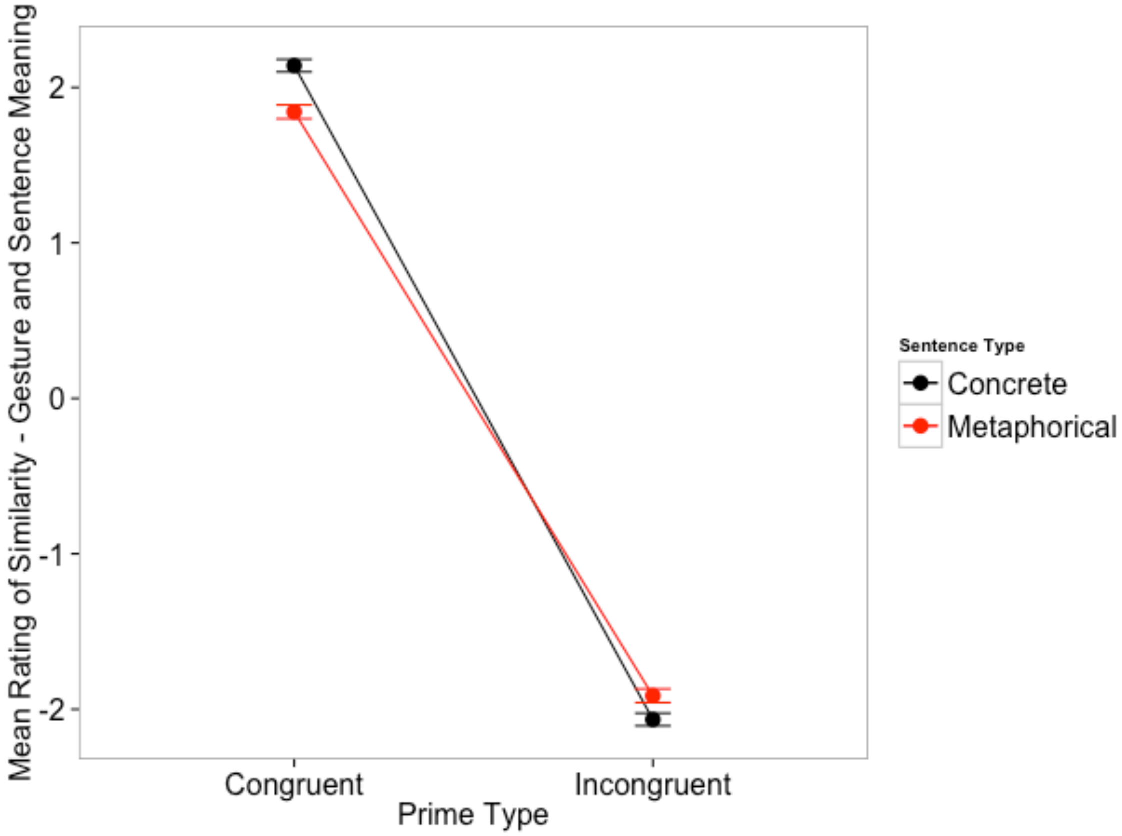

Figure 5.2 Rating for the similarity between the meaning of the gestures and the meaning of sentences. Error bars represent 1 standard error of the means.

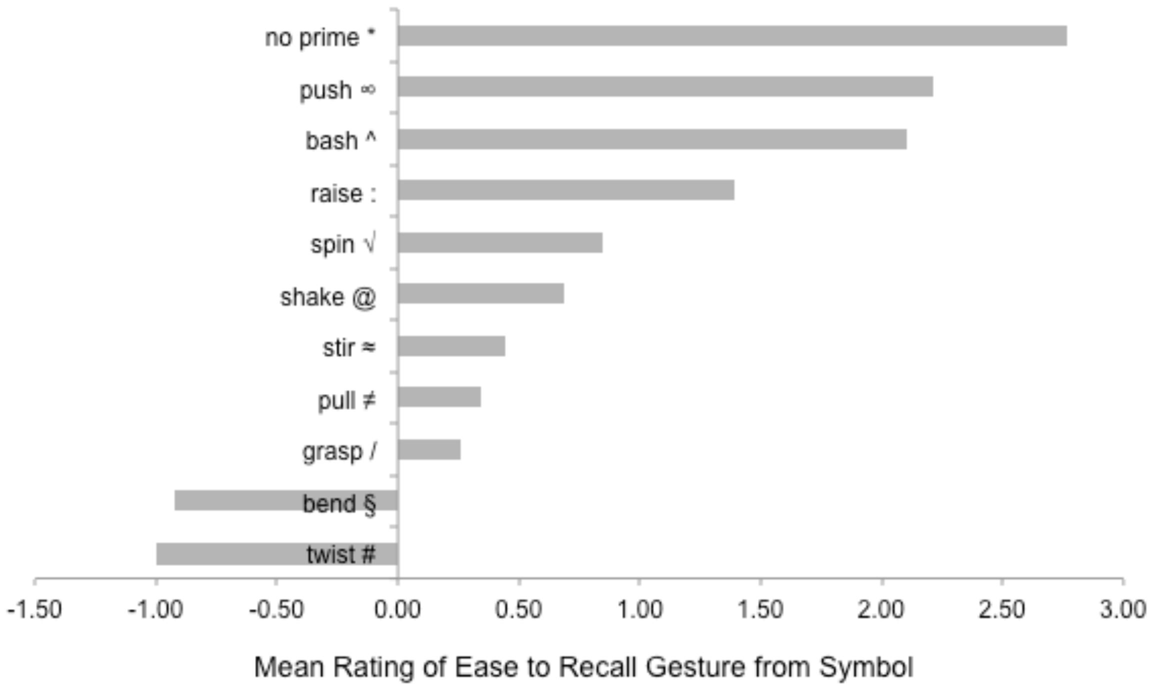

Figure 5.3 Rating of the ease to recall gesture from cue symbol. Negative numbers represent difficulty to recall.

5.6.2 Response time for gesture initiation

We compared the response time for gesture initiation in the three critical experimental conditions, to ensure they are all comparable.

Paired Samples t-test revealed that there was no significant difference between the gesture initiation time for the left (M = 1501.70ms, SD = 928.81) and the right (M = 1494.58ms, SD = 988.70) hand (t (37) = .230 p = .818), for literal (M = 1511.88ms, SD = 912.43) and metaphorical (M = 1484.22ms, SD = 1004.29) sentences (t (37) = .736 p = .466), and for congruent (M = 1500.62ms, SD = 944.20) and incongruent (M = 1495.65ms, SD = 974.07) condition (t (37) = -.893 p = .378). Therefore, there is no evidence that the time for gesture initiation (which could have affected the relation between the prime and the target) could account for any observed differences.

5.6.3 Semantic categorisation task

Exclusion of trials

In total, we collected responses from 9120 trials. Out of this, 6% was excluded from all analyses for the following reasons: (a) inaccurate gesture production as prime; participants produced the wrong gesture (1% of total), (b) inaccurate recording of vocal response through voice key; voice key recorded filled pause, breath, other noise instead of response or did not record the response and participants had to respond again (= delayed response) (1% of total), and (c) delayed response time for gesture initiation; values more than 3SDs from an individual subject's mean in each condition were excluded (2% of total). For the response time analysis, trials of inaccurate semantic categorisation were excluded (= participants categorised a metaphorical sentence as literal and vice-versa) (3% of total). Note, that accuracy of responses to probe questions was high (94%), thus we did not exclude any trials based on this criterion.

Notes for mixed effect models

For the continuous dependent variable (= response time) data were analysed using linear mixed effects models (LME). For the binary dependent variable (= accuracy) data were analysed using generalised linear mixed effects (GLME) models. We used the packages *lme4* and *multcomp* in the R Project for Statistical Computing environment, version 3.1.1 (Bates & Sarkar, 2012; Hothorn et al., 2012; R Development Core Team, 2011). All mixed effects regressions were carried out with "lmer()" function specifying that Maximum Likelihood (rather than Restricted Maximum Likelihood) is used (needed to get a more valid likelihood ratio test of the full against the null model). All mixed effect logistic regressions were carried out with "glmer()" function, using the "Laplace" approximation and the "binomial" family. Random effects structure was kept maximal as long as model convergence was reached (for a discussion about random effects structure and simplification see Barr et al., 2013). We obtained p-values for fixed effects and interactions following the likelihood ratio test approach for model comparison and we always report the maximal model following a design-driven approach for confirmatory analyses. Tests of further contrasts of our interests were carried out based on a priori predictions using the generalized linear hypothesis test (correction for multiple comparisons of means, Tukey Contrasts) and the "glht()" function.

Response time

On average, participants' response times for the semantic categorisation task in the increased in the following order of conditions (i.e., from fastest to slowest): no prime before metaphorical sentence (*M* = 1684.45ms, *SEM* = 71.11), incongruent left hand gesture before metaphorical sentence (*M* = 1716.16, *SEM* = 72.45), congruent left hand gesture before metaphorical sentence (*M* = 1726.48, *SEM* = 74.03), no prime before literal sentence (*M* = 1749.41ms, *SEM* = 75.98), incongruent right hand gesture before metaphorical sentence (*M* = 1767.03ms, *SEM* = 91.05), incongruent left hand gesture before literal sentence (*M* = 1767.85ms, *SEM* = 70.34), congruent right hand gesture before metaphorical sentence (*M* = 1810.09ms, *SEM* = 85.06), congruent left hand gesture before literal sentence (*M* = 1812.82ms, *SEM* = 75.51), congruent right hand gesture before literal sentence (*M* = 1819.93ms, *SEM* = 86.62), incongruent right hand gesture before literal sentence (*M* = 1821.75ms, *SEM* = 82.51).

Firstly, we assessed the 2 x 3 interaction between sentence type and prime type. The factor, hand used for gesturing was not included in this analysis because the no prime condition had no "left" and "right" levels. We fit LME model to the measurement of vocal response time. The model included two fixed effect factors and the interaction between the two. The one fixed factor was the sentence type (metaphorical, literal; dummy coded; “literal” was the reference category against which comparison was made). The second fixed factor was the prime type (congruent incongruent, no prime; “no prime” was the baseline, reference category against which critical comparisons with the experimental conditions were made). The model with maximal random effects structure (as recommended by Barr et al., 2013) did not converge, so we had to use a data-driven approach and simplify the model to reach convergence. The maximal model to include (a) random intercepts and slopes by subjects for the interaction of the fixed effect factors, and (b) random intercept and slope by items (phrases) for the factor prime type (sentence type was a between-items manipulation) did not converge. Thus we included (a) random intercept and slope by subjects for the main effect of sentence type, and thus we had to assume that the main effect of prime type and the interaction between sentence and prime type were invariant across subjects, and (b) random intercept and slope by items (phrases) for the main effect of prime type.

Model estimates are reported in Table 5.3. We compared the maximal model with the reduced model including the main fixed effects only (same random effect structure). Adding the interaction between sentence and prime type did not significantly improve the model fit: $\chi^2(2) = .695$, $p = .706$ (see Figure 5.4). Thus, there is no evidence that the interaction between type of action sentences (metaphorical or literal) and prime type (congruent, incongruent, no prime) modulated participants’ response time in the semantic categorisation task.

Table 5.3 Parameters estimates for the model with the main effects and interaction between sentence and prime type on response times. "Literal" sentences and "No prime" were the reference categories.

	Estimate	SE	t-value
(Intercept)	1754.49	65.23	26.898
Metaphorical	-70.06	40.26	-1.740
Congruent	62.22	27.28	2.281
Incongruent	40.96	29.12	1.407
Metaphorical:Congruent	32.13	38.65	.831
Metaphorical:Incongruent	15.19	41.12	.369

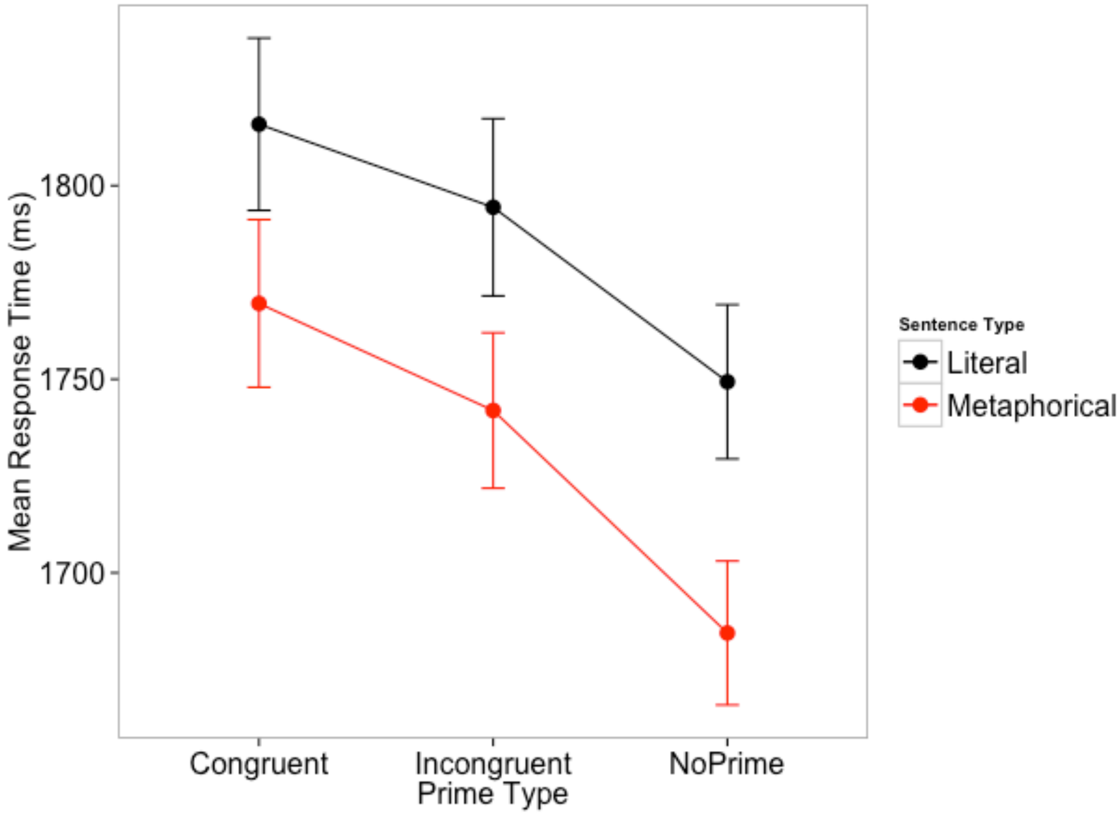

Figure 5.4 Mean response times for the semantic categorisation of literal and metaphorical sentences in each priming condition. Error bars represent 1 standard error of the means.

Next, we proceeded to model reduction and comparisons to investigate the main effect of prime type. We compared the model including the main effects of sentence and prime type with the model including the main effect of sentence type only. Adding the effect of prime type (congruent, incongruent, no prime) improved model fit: χ^2 (2) = 16.01, p < .001. Estimates of the model with the main effect of prime type are reported in Table 5.4. Simultaneous tests for general linear hypotheses (Tukey Contrasts) revealed some significant contrasts (see Table 5.5). In particular, participants categorised the sentences faster in the baseline condition where no gesture primes were produced than the congruent and incongruent conditions. However, there was no significant difference between the congruent and incongruent conditions.

Table 5.4 Parameters estimates for the model with the main effect of prime type on response times. “No prime” was the reference category.

	Estimate	SE	t-value
(Intercept)	1726.56	63.25	27.296
Congruent	78.33	19.30	4.060
Incongruent	408.64	20.48	2.375

Table 5.5 Tukey contrasts for the model with the main effect of prime type on response times.

	Estimate	SE	z-value	p-value
Incongruent – Congruent	-29.70	22.79	-1.303	.391
No Prime – Congruent	-78.33	19.30	-4.060	< .001
No Prime – Incongruent	-48.64	20.48	-2.375	.045

Secondly, we assessed the 2 x 2 x 2 interaction between sentence type (metaphorical, literal), prime type (congruent, incongruent) and hand (left, right). We excluded “no prime” trials (trials reduced to 5555). We fit LME model to the measurement of vocal response time. The model included three fixed effect factors and the interaction between the three. The one fixed factor was the sentence type (metaphorical, literal; dummy coded; “literal” was the reference category). The second fixed factor was the prime type (congruent incongruent; “incongruent” was the reference category). The third fixed factor was the hand used for gesturing (left, right; “right” was the reference category). The model with the maximal random effects structure did not converge, so we had to use a data-driven approach and simplify the model to reach convergence. The maximal model to include (a) random intercept and slope by subjects for the interaction of the three factors, and (b) random intercept and slope by items for the interaction between prime type and hand used for gesturing did not converge. Thus we included (a) random intercept and slope by subjects for the main effect of sentence type, and we had to assume that the main effects of prime type and hand used for gesturing and the interaction between sentence, prime type and hand were invariant across subjects, and (b) random intercept and slope by items (phrases) for the main effect of prime type assuming that the main effect of hand used for gesturing and the interaction between prime type and hand were invariant across items.

Model estimates are reported in Table 5.6. We compared the maximal model with the reduced model including the main fixed effects only (same random effect structure). Adding the three way interaction between sentence, prime type and hand did not significantly improve the model fit: χ^2 (4) = .991, p = .911 (see Figure 5.5). Thus, there is no evidence that the interaction between the type of action sentences (metaphorical or literal), prime type (congruent, incongruent) and hand used for gesturing (left, right) modulated participants' response time in the semantic categorisation task.

Table 5.6 Parameters estimates for the model with the main effects and three-way interaction between sentence type, prime type and hand used for gesturing on response times. "Literal" sentences, "Incongruent" condition and "Right Hand" were the reference categories.

	Estimate	SE	t-value
(Intercept)	1825.50	74.43	24.523
Metaphorical	-50.86	54.96	-.925
Congruent	4.90	40.91	.120
Left Hand	-60.43	36.92	-1.637

Metaphorical:Congruent	31.72	57.52	.552
Metaphorical:Left Hand	-5.61	52.19	-.108
Congruent:Left Hand	37.44	52.01	.720
Metaphorical:Congruent:Left Hand	-30.21	73.83	-.409

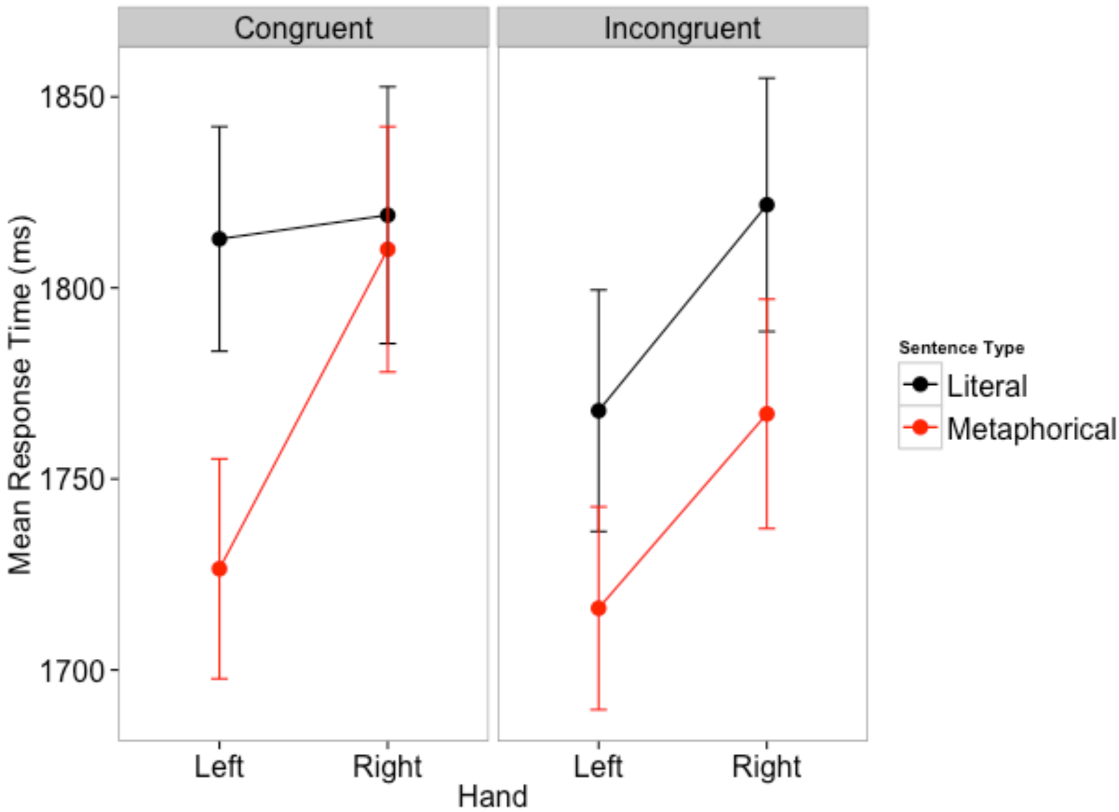

Figure 5.5 Mean response times for the semantic categorisation of literal and metaphorical sentences, in congruent and incongruent priming conditions with left and right hand. Error bars represent 1 standard error of the means.

Next, we proceeded to model reduction and comparisons to investigate the two-way interaction between sentence and prime type. We compared the model including the two-way interaction with the reduced model including the main fixed effects only (same random effect structure). Adding the interaction did not significantly improve model fit: χ^2 (1) = .153, p =

.695. Thus, there is no evidence that the interaction between type of action sentences (metaphorical or literal) and prime type (congruent, incongruent) modulated participants' response time in the semantic categorisation task

Finally, we proceeded to model reduction and comparisons to investigate the main effect of prime type. We compared the model including the main effects of sentence and prime type with the model including the main effect of sentence type only. Adding the effect of prime type did not improve model fit: $\chi^2(1) = 2.116$, $p = .145$. Thus, there is no evidence that the prime type (congruent, incongruent) affected participants' response time in the semantic categorisation task.

Accuracy

Overall, participants showed highly accurate performance and accuracy levels were at ceiling (97%). In addition, there was no indication of speed-accuracy trade-off (i.e., descriptively faster response times and more accurate responses for metaphorical than literal sentences) (see Text S6 in Appendix Chapter 5 for results).

5.7 Discussion

The present study investigated whether production of action gestures primes comprehension of action sentences. More specifically, we hypothesised that (a) producing an action gesture matching with the meaning of a proceeding action sentence would facilitate the semantic categorisation of the sentences compared to producing a mismatching gesture or not gesturing at all, (b) producing an action gesture matching with the meaning of a proceeding action sentence could facilitate the semantic categorisation of the sentences at a similar or different degree for metaphorical and literal sentences (depending on strong or week embodied accounts, respectively), and (c) producing an action gesture with the left (rather than the right) hand and matching with the meaning of the proceeding action sentence would facilitate the semantic categorisation of metaphorical than literal action sentences. We measured response time and accuracy of the semantic categorisation as a function of the type of action meaning (metaphorical, literal), the relation between gesture prime and target sentence (congruent, incongruent, no prime), and the hand used for gesturing (left, right). There were no significant findings related to our research questions. However, we found that participants categorised the sentences faster after the baseline, no gesture prime condition, than after experiencing incongruent and congruent gesture prime-sentence combinations. Note, that the congruent and incongruent conditions did not differ from the each other. Hence, there is no evidence that action gestures facilitate or hinder the semantic categorisation of proceeding sentences when the action meaning in gesture and sentence matches or mismatches, respectively. In addition, we found no evidence that (a) priming effects were stronger or weaker for metaphorical than literal sentences, and (b) congruent gestures with the left rather than the right hand lead to faster categorisation of the metaphorical than literal sentences. Note, that because of the null results there is no evidence in favour or against (a) the embodied accounts of meaning, and (b) the "hemisphere-specific feedback hypothesis" for gestures when presented alone. In the next paragraphs we discuss the results, possible interpretations, which are tenuous, and possible limitations in more detail.

Participants semantically categorised the sentences faster after experiencing the baseline condition compared to the congruent and incongruent conditions. This finding is not in line with Wilson and Gibbs (2007) where comprehension times were slower in the baseline than the matching condition, and did not differ from the mismatching condition. However, it is in line with Bernardis et al. (2008) where reading times in the baseline condition were descriptively faster than both matching and mismatching conditions. This result may relate to the inherently low difficulty of a "neutral" baseline condition in priming paradigms (Jonides & Mack, 1984; Yap et al., 2011). The processing demands associated with semantically categorising isolated sentences versus sentences preceded by a gesture (matching or mismatching to the sentence) are not identical. It seems that the gesture primes are not fully processed by the time the sentence target appears, and this increases the processing time. Future research could use more comparable baseline and priming conditions in terms of the cognitive load they add and their processing demands.

We found no evidence for facilitation or inhibition of semantic categorisation by matching or mismatching gestures, and no differences between the type of action sentences and the hand used for gesturing. Absence of expected results may relate to properties of the task. The purpose of the study was to investigate semantic priming effects from gesture production to sentence comprehension. Semantic priming occurs only when semantic processing is required, and the semantic categorisation tasks guarantee that the participants process semantically the target to be classified (Bowers & Turner, 2003). In addition, Schmidt et al. (2007) and Faust and Lavidor (2003) have suggested that semantic categorisation tasks may require a complex bipolar response, however they do not distort reaction times. Therefore, selection of the specific task was justified. However, absence of expected results may relate to task's properties, and we discuss them in the following paragraph.

Firstly, a possible reason for no priming effects could be that the category labels (metaphorical vs. literal) were very specific. This could have led to the development and use of explicit strategies (e.g., if abstract O-NP, then the sentence is metaphorical) or maybe participants could anticipate sentences from the target list. Other studies, which have also failed to observe an effect of semantic similarity between prime and target on behavioural responses (Light, Prull, & Kennison, 2000; Vaidya & Gabrieli, 2000), have also used a semantic classification task with narrow categories (e.g., is a word a fruit or not). Bowers and Turner (2003) suggested that, in semantic priming studies, it might be useful to reduce potential strategic effects by including semantic categorisation tasks that refer to general categories (e.g., does a sentence make sense or not). Secondly, the categorisation task is a multifaceted task, which requires more than one level of processing: conceptual representation of the sentence meaning, comprehension and then categorisation as a response. It is possible that strong priming effects and interaction with the sentence type would appear during the stage of meaning representation of the sentence rather than when categorising the sentences. Activating meaning by gesturing and the relation of this meaning (congruent-incongruent) with the target might be irrelevant at the stage of categorising the sentence as metaphorical or literal. Hence, the response time for categorisation might have not been the most sensitive measurement.

In addition, absence of effects may have been an artefact of statistical power. It is possible that an increased sample size could reveal significant differences between the congruent and incongruent conditions, and a significant three-way interaction between prime, sentence type and hand used for gesturing.

Finally, the use of alternative designs and/or methods could reveal the expected significant effects. In future studies, the prime type could be blocked (no prime, congruent, incongruent) and the order of left and right hand could be randomised within the congruent and incongruent blocks. However, a pilot study using this design showed that participants were confused with the random switch from left to right gesture, and there were many failed trials (i.e., participants would use the right hand when they should use the left). Hence, although the current design may have made the results prone to artefacts, its selection was informed. In addition, there are cross-modal priming studies suggesting that behavioural paradigms are not sensitive enough to capture priming effects. For example, in Wu and Coulson (2007), priming effects (from iconic gesture video to word) were indexed by the N400, but not by the response times in a relatedness judgment task. In addition, in an fMRI study, Mashal et al. (2005) used an explicit semantic judgment task (e.g., silently decide if a word pair is metaphorically or literally related) and showed right hemispheric involvement for metaphorical sentences. Our study is the first one to use a similar task in a behavioural paradigm. Therefore, it is possible that using the current design and task in a brain imaging study would reveal expected results, when measuring BOLD activations. Future research is essential to further explore this possibility.

5.8 Conclusions

In conclusion, the current study provided no evidence for priming effects of gestures when produced alone on sentence comprehension. It was only found that producing gestures (matching or mismatching) slows down the categorisation of proceeding sentences compared to producing no gestures. There is no evidence for different priming effects between metaphorical and literal action sentences, and no evidence that matching left hand gestures facilitate the semantic categorisation of metaphorical rather than literal sentences. However, findings were based on null results, therefore, future research is essential to investigate the effect that gestures when produced alone might have on semantic processing, and the underlying mechanism for this effect.

6 Reduced right-sided mouth asymmetry during metaphorical explanations: semantics is crucial

6.1 Motivation and aims

This study investigated the role of metaphorical representation of meaning in content words (as opposed to expression of grammatical relationships in function words) for the right-hemispheric involvement during metaphorical speech production using the mouth asymmetry technique. Mouth asymmetry can give an indirect measurement of which hemisphere is predominantly involved for speech production during different linguistic tasks. For example, right-sided mouth asymmetry is associated with left-hemispheric dominance for speech production (e.g., Graves & Landis, 1990). In addition, studies on the hemispheric involvement during metaphorical processing have identified the crucial role of the right hemisphere (e.g., Bottini et al., 1994). However, it is still unclear what aspect of metaphor processing is crucial for this right-hemispheric involvement during production of metaphorical speech.

The current study aimed to extend previous research by investigating the role of semantics for the particular involvement of the right hemisphere for metaphor processing focusing on metaphorical speech production. In addition, it validated the use of the mouth asymmetry technique as a measurement of the differential hemispheric involvement during different linguistic tasks.

6.2 Abstract

Research on the neural basis of metaphor provides contradicting evidence about the role of right and left hemispheres. We used the mouth opening asymmetry technique to investigate the relative involvement of the two hemispheres whilst twenty-eight right-handed healthy male participants explained the meaning of English phrases. This technique is based on the contra-lateral cortical control of the facial musculature and reflects the relative hemispheric involvement during different cognitive tasks. In particular, right-handers show a right-sided mouth asymmetry (right side of the mouth opens wider than the left) during linguistic tasks, thus reflecting the left hemisphere specialisation for language (R. Graves, & Landis, T, 1990). In the current study, we compared the right-sided mouth asymmetry during metaphor explanation (e.g., explain the meaning of the phrase "to spin a yarn") and concrete explanation (e.g., explain the meaning of the phrase "to spin a golf ball"), and during the production of content and function words. The expected right-sided mouth asymmetry reduced during metaphorical compared to concrete explanations suggesting the relative right-hemispheric involvement for metaphorical processing. Crucially, this right-sided mouth asymmetry reduction was particularly pronounced for the production of content words. Thus, we concluded that semantics is crucial to the right-hemispheric involvement for metaphorical speech production.

Keywords: Metaphorical speech production; word-class; mouth asymmetry; right-hemisphere

6.3 Introduction

There are many studies investigating what determines the neural recruitment of metaphorical language processing, and several theoretical accounts have been proposed about the hemispheric lateralisation of metaphor (for a review see Schmidt et al., 2010). However, there is contradicting evidence for the involvement of the right hemisphere in metaphorical processing (e.g., Right Hemisphere Hypothesis, Brownell et al., 1990; for alternative views see Rapp et al., 2007). Furthermore, most of the studies have been focusing on metaphorical processing in comprehension tasks rather than metaphorical speech production. In this study, we used the mouth asymmetry technique during speech production, which reflects relative hemispheric involvement during verbal tasks (for a review see Graves and Landis, 1990). We provided evidence that the right hemisphere is involved during metaphorical speech production and in particular during production of content words related to metaphor.

According to the Right Hemisphere Hypothesis for Metaphor (Brownell et al., 1990) the right hemisphere has a privileged role in lexical-semantic processes related to metaphor comprehension. There are several empirical studies providing evidence in favour of this hypothesis. However, the overall conclusion remains somewhat vague mainly because the studies used different populations (e.g., patients vs. healthy participants), tasks (e.g., metaphor judgment vs. plausibility judgment vs. lexical decision) and stimuli (e.g., sentences vs. single words; novel vs. familiar metaphors).

The first evidence for the right hemispheric involvement for metaphorical processing came mainly from studies of patients with brain damage. For example, Winner and Gardner (1977) have shown a deficit in appreciation of metaphorical meanings in patients with right hemisphere lesions compared to those with left hemisphere lesions in a sentence-picture matching task. However, the pattern was reversed when patients were asked to verbally explain the meanings of the metaphorical phrases in the sentences; that is patients with right hemisphere lesions offered appropriate metaphorical explanations of the phrases while patients with left hemisphere lesions produced literal verbal explanations. They proposed that both hemispheres contribute to metaphorical competence, but the right hemisphere is crucially engaged in the conceptualisation and "visualisation" of metaphors.

In addition, studies with healthy participants have found stronger right-hemispheric engagement whilst processing metaphorical compared to literal stimuli. For example, Anaki et al. (1998) used the divided visual field technique and the word-priming paradigm, and showed that initial activation for metaphorical meanings involves both right and left hemispheres and maintenance particularly involves the right hemisphere only. Initial activation and maintenance of literal meanings involved the left hemisphere only. The findings, though limited to single words, highlight the importance of time course of each hemisphere's involvement in processing semantic links between words. Moreover, a positron emission tomography neuroimaging study (Bottini et al., 1994) found right-hemispheric activation during judgment of the plausibility of metaphorical sentences compared to literal ones. Bottini et al. (1994) also highlighted the importance of the task's semantic load for the relative hemispheric involvement during metaphor processing. For example, a lexical decision task where subjects had to identify non-words embedded within metaphorical and literal sentences reveals greater right-hemispheric activation than a metaphorical sentence comprehension task. Furthermore, some studies suggest that it is not metaphoricity *per se* which determines the involvement of each brain hemisphere. It is rather the degree of saliency. An expression is considered as salient when its meaning is familiar, conventional, highly frequent and predictable (Giora et al., 2000). Jung-Beeman (2005) suggests there is a core, bilateral, neural network which is involved in the semantic processing of metaphors. Specifically, the right hemisphere is predominantly involved for the processing of novel metaphors compared to conventional ones (Ahrens et al., 2007; Cardillo, Schmidt, Kranjec,

& Chatterjee, 2010; Cardillo et al., 2012; Faust & Mashal, 2007; Mashal et al., 2005; Schmidt et al., 2007), for the processing of non-salient meanings compared to salient ones (Giora et al., 2000), and for the processing of distant semantic relationships compared to closely related word meanings (Mashal et al., 2007).

Some fMRI studies failed to fully support the Right Hemisphere Hypothesis for Metaphor. For example, Stringaris et al. (2007) provided neuro-imaging data while participants judged the plausibility of metaphorical and literal sentences and failed to show a differential activation of the right-inferior frontal gyrus for the comparison literal vs. metaphorical. Also, Rapp et al. (2004; 2007) used metaphorical judgment ("is the sentence metaphorical or literal") and connotation judgment ("does the sentence have positive or negative connotations") of sentences, and they did not find any activation in the right-hemispheric structures for the metaphorical sentences. Benedek et al. (2014) investigated production of metaphor using a paraphrase task. Participants were presented with a short sentence (e.g., "the lamp is glaring") and asked to provide either a literal ("bright") or a metaphorical ("a supernova") word that replaces the adjective without changing the meaning very much. The regions more activated for the metaphorical condition than for the literal condition are activated either bilaterally or only in the left hemisphere.

Mixed results regarding the Right Hemisphere Hypothesis for Metaphor may relate to various factors. First, different methodologies reveal different aspects of metaphorical processing. For example, the cognitive activity measured in behavioural experiments (as in reaction times in Anaki et al., 1998) differs from the neural correlates of the activity captured in brain-imaging studies (as in BOLD signal in regions of interest in Rapp et al., 2004 and Stringaris, et al., 2007). Although equivalence in findings would clearly support a certain hypothesis about how the two hemispheres contribute to metaphorical and literal interpretations of linguistic stimuli, different findings from different methodologies are not necessarily contradictory. If two cognitive tasks (metaphorical vs. literal processing) result in different reaction times, this does not necessarily mean that they will be sub-served by different neural pathways. Second, the nature of stimuli differs greatly across studies. For example, in some studies (e.g., Stringaris et al., 2007), the degree of saliency or novelty of the linguistic expressions has not been accounted for, whereas it is controlled in others (e.g., Mashal et al., 2005). Similarly, some studies focus on metaphorical comprehension for single words (e.g., Anaki et al., 1998) as opposed to sentences (e.g., Rapp et al., 2004; 2007). Finally, the involvement of each hemisphere during metaphorical processing is task sensitive. For example, plausibility judgment (e.g., in Stringaris et al., 2007) may involve too many cognitive processes that it has washed out the critical difference between literal and metaphorical stimuli thus failing to reveal any metaphor specific activations. To sum up, any study focusing on the hemispheric involvement during metaphorical processing and using any type of methodologies needs to carefully account for the role of semantics so that the involvement of the right hemisphere is neither masked nor marked due to non-metaphor specific processing demands or other linguistic variables.

As the above literature review reveals, the role of the two hemispheres and that of semantics in metaphorical processing remains controversial. In addition, most of the studies investigated metaphorical comprehension, rather than *production* (as far as we know, Benedek et al., 2014 is the only production study). Thus, it still remains unresolved if the right hemisphere is involved in metaphorical processing during speech production and if semantic processing is crucial for this particular involvement.

The contributions of the two hemispheres during cognitive processes (e.g., linguistic, visual imagery, and emotional tasks) have been investigated using measurement of mouth asymmetry. The foundational assumption of this measurement is that each side of the lower facial areal is controlled by the contra-lateral cortex (Adams et al., 1997; Gardner, 1969).

Therefore, if one hemisphere is particularly involved in a task that requires mouth opening, there will be greater opening on the contra-lateral side of the mouth.

Several studies validated asymmetries in mouth openings during speech production as an indicator of the role of the two hemispheres in various speech production tasks. For example, Graves and Landis (1985; 1990) indicated that healthy, right-handed speakers open the right side of their mouth wider than the left during propositional speech (e.g., spontaneous speech, word list generation, repetition), thus suggesting the left hemisphere control over speech production. This pattern is reversed (left side opens wider than the right) during automatic speech (e.g., singing, counting, reciting the days of the week), which is considered to be processed by the right hemisphere (see for a review Lindell, 2006). In addition, Code, Lincoln, and Dredge (2005) compared the mouth asymmetry patterns during propositional speech production by right-handed stuttering and non-stuttering speakers. They found a bilateral pattern for stutterers compared to a clear right-sided mouth asymmetry for the non-stutterers. This finding supports models about a distinct hemispheric control of speech production in stutters and non-stutters, thus further highlighting the sensitivity of the mouth asymmetry technique.

The mouth asymmetry as an indicator of hemispheric specialisation has also been validated in studies of emotional expressions (e.g. smile). Graves, Goodglass, and Landis (1982) showed that healthy, right-handed participants open the right side of the mouth more widely than the left during propositional speech linguistic tasks compared to spontaneous smiles. This reflects the left hemisphere cerebral specialization for language and the right hemisphere involvement for emotion processing during smiles. Similarly, Wyler et al. (1987) showed a clear left-sided mouth asymmetry during smiles, which is particularly apparent during spontaneous compared to posed smiles (Wylie & Goodale, 1988). Developmental studies with infants have also successfully used the mouth asymmetry technique to investigate the lateralisation of emotional expressions. For example, Holowka and Petitto (2002) showed that infants (5-12 months old) open the right side of their mouth wider than the left when they are babbling (a precursor to speech) compared to smiling. Interestingly, Schuetze and Reid (2005) showed a right-hemispheric control for negative emotional expressions (left-sided bias in mouth movements of sadness) which strengthens with age (from 12 to 24 months old), while this pattern was absent for the control of positive emotional expressions.

The above studies show that the mouth asymmetry technique is sensitive to differential hemispheric involvement across tasks. In addition, it is a non-invasive, inexpensive and safe technique inferring relative involvement of the hemispheres in real time, during actual speech production. However, this technique has not been used to investigate the hemispheric involvement for metaphorical speech production, which is still a very much-unresolved question.

Argyriou and Kita (2013) tested right-handed speakers (different participants from the current study) and showed that right-sided mouth asymmetry reduced when they explained metaphorical phrases compared to concrete ones (e.g., “to spin a yarn” vs. “to spin a golf ball”). This finding is in line with the relative right-hemispheric involvement during metaphor compared to concrete explanations. However, what is not clear from this study is whether semantic processing during metaphorical speech production particularly involved the right-hemisphere. This is an important limitation as semantics is a crucial component of metaphor theories (e.g., Giora et al., 2000; Lakoff & Johnson, 1980).

The key aim of the present study is to shed light on lateralisation of metaphor processing during speech *production* rather than comprehension, using the mouth asymmetry technique, and to investigate the role of semantics in the involvement of the right hemisphere. More specifically, we investigated whether metaphorical processing particularly involves the right hemisphere such that it reduces the right-sided mouth asymmetry during metaphorical compared to concrete speech production. In addition, we investigated whether semantics is crucial to the right-hemispheric involvement for metaphorical speech production such that the decrease of the right-sided mouth asymmetry during metaphorical compared to concrete speech production is particularly pronounced for production of content words, which carry meaning.

In order to test the first research question, we manipulated the content of speech production. That is, participants explained English phrases with either metaphorical or concrete meanings (e.g., “to spin a yarn”, “to spin a golf ball” respectively). We compared the laterality of maximum mouth openings (mouth opened wider at the right or left side or equally opened) in right-handed, male participants during metaphorical and concrete explanations. In line with previous research (Graves et al., 1982; Graves & Landis, 1985), we expect an overall right-side bias of maximum mouth openings in the explanation of phrases suggesting the role of the language dominant left hemisphere during speech production. Crucially, we hypothesised that, if metaphor production particularly involves the right hemisphere, the right-side bias of maximum mouth openings will be reduced when participants explain metaphorical compared to concrete phrases.

In addition, we investigated whether the relative right-hemispheric involvement during the metaphorical task is particularly pronounced for the production of content words (e.g., verbs, nouns) compared to function words (e.g., conjunctions, determiners). This is plausible, firstly, because content words carry relatively more semantic information, thus presumably the meaning related to metaphor, while function words are less semantically rich, and sub-serve structural functions (Bradley & Garrett, 1983; Hinojosa et al., 2001). In addition, content words are less lateralized than function words. For example, Mohr, Pulvermüller, and Zaidel (1994) used the divided visual field technique in a lexical decision task (content and function words, non-words). They showed that function words presented in the right-visual field were processed faster than when presented in the left. This finding suggested that the processing of function words relies heavily on the left-hemisphere. On the contrary, a clear visual field advantage was not found for the processing of content words. In addition, Bradley and Garrett (1983) showed that content and function words are identified equally accurately when presented in the right visual field. However, function words presented in the left visual field were identified less accurately than content words presented in the same field. These findings suggest that content words are bilaterally processed in left and right hemispheres, while function words seem to be strongly left hemispheric lateralized. The present study tested whether the relative involvement of the right hemisphere during metaphorical production and, thus, the expected reduction in the right-sided mouth asymmetry during metaphorical compared to concrete explanations is driven by semantically rich content words. Crucially, we hypothesised that if semantics is central for the right-hemispheric involvement for metaphorical speech production, the reduced right-sided mouth asymmetry in the metaphorical task compared to the concrete task will be particularly pronounced for the production of content words.

6.4 Method

Participants

28 subjects (age: *M* = 19.5 years, *SD* = 1.9) took part in the experiment for a course credit or payment of £2. All participants were male, right-handed, native English speakers, monolinguals before the age of 5 years (via self-report), and students at the University of Birmingham. We focused on males only because their bilateral representation of language processing is less frequent compared to females (J. McGlone, 1980). Handedness was assessed with a 12-items questionnaire based on the Edinburgh Handedness Inventory

(Oldfield, 1971). Two bimanual items (from Oldfield's long list) were added to his recommended 10-items questionnaire to equate the number of unimanual and bimanual items. Text S1 in Appendix Chapter 3 includes the questionnaire. Each "left" answer was scored with 0, each "either" answer with 0.5, and each "right" answer with 1. A total score of 8.5 and above determined right-handedness (M = 10.98, SD = .97). None of the participants had any previous serious injury to the face or jaw.

Stimuli

The stimuli were three phrases for the metaphorical and three for the concrete condition. There was one "backup" phrase for each condition, in case participants could not recognize one of the main stimuli. The metaphorical stimuli were English idiomatic expressions with metaphorical meanings (e.g., "to pour oil onto the fire"). The concrete stimuli were matched to the metaphorical ones to refer to a physical event similar to the literal meaning of the metaphorical phrases (e.g., "to pour oil into the pan"). See Table 6.1 for the complete list of stimuli. Ten participants explained the reserve item for the metaphorical and concrete conditions.

Table 6.1 Complete list of stimuli for the metaphorical and concrete conditions. The first three items in each column are the main items. The items in parentheses are reserve items used when the participants did not know the main items.

Metaphorical phrases	Concrete phrases
To pour oil onto the fire	To pour oil into a pan
To set your sights higher	To put a shelf higher
To spin a yarn	To spin a golf ball

(To hit the nail on the head)	(To hit someone on the head)

Procedure

Participants were tested individually. They were seated on a chair, which was located between two tables of the same height (71 cm tall), and were asked to keep both hands still on specified marks (white sticky dots) on the tables throughout the task. Hand prohibition was a necessary experimental control, in order to collect a laterality measurement without the influence of gestural hand movements as gestures are sensitive to the division of labour between the two hemispheres in speaking tasks (Kita, de Condappa, et al., 2007). The experimenter was standing and facing the participant, and the video camera recording participants' responses (Sanyo HD camera) was placed in front of the experimenter. Video-recording zoomed-in on the face area. Stimuli were presented one by one on a white sheet of paper (72 Times New Roman), which was held by the experimenter until the participant started giving their response.

Participants were instructed to explain the meaning of the phrases as if they were explaining it to a non-native English speaker. To encourage metaphorical thinking in the metaphor condition, participants were instructed to include an explanation as to how the literal meaning can be mapped on to the metaphorical meaning of the phrase and to give as much detail as possible (e.g., in the expression "to spin a yarn", "yarn" refers to a long, complicated story, and "spinning" refers to creating this story). For the concrete phrases, participants were instructed to paraphrase the phrase using synonyms and give as much detail as possible (see Table 6.2 for examples of the explanations participants produced). The order of the conditions (metaphorical – concrete) was counterbalanced across participants. At the end of the task, participants were debriefed about the purpose of the study.

Table 6.2 Examples of produced explanations for each linguistic task.

Concrete Explanations	Metaphorical Explanations
"To spin a golf ball, the golf ball is a ball you hit and try and get it in the hole, it is a small ball normally white and to spin it is to rotate it round"	"To spin a yarn, that is to tell a story, the spinning implies you are making it up as you go along as if you are spinning cotton and the yarn is the story that you are making up"
"To pour oil into a pan would mean that you take a bottle of liquid that originated from a kind of plant or fuel source and you tip the container into a pan which is a cooking utensil"	"To pour oil onto the fire, if you pour oil into the fire it's going to make it spark up so if there is a situation where your anger is firing, to pour oil into the fire would be to stir things up and make it even more ferocious".

Maximum mouth openings coding

The video recordings were analysed using ELAN software (developed by the Max Planck Institute for Psycholinguists, Nijmegen, the Netherlands). Each video was analysed on a frame-by-frame basis to identify the maximum mouth openings in each phrase explanation. One maximum opening was defined as the widest point the mouth opens since the lips open to the lips resting or the lips meeting completely. We coded the laterality at each maximum mouth opening. The options for laterality classification were: right-side dominant (the right side of the mouth opens wider than the left), left-side dominant (the left side of the mouth opens wider than the right), or sides equally open (see Figure 6.1 for examples). Maximum openings for filled pauses (e.g. "eerm") were coded but not included in the analysis, neither were the ones whilst participants were repeating the phrase to be explained in the beginning of each trial. We coded 60 maximum mouth openings (or as many as possible if less than 60 were available for coding because verbal responses were short) per condition per participants (in total we coded 1549 mouth openings in the concrete task and 1517 in the metaphorical task). We followed Graves et al. (1982) who coded the first ten successive lip openings per participant, and we coded double the amount because we had two factors in the analysis. Text S3 in Appendix Chapter 3 presents the coding manual.

One individual "blind" coder was trained and coded 26% of the data. Mouth openings from 7 randomly selected participants were coded in terms of right, left or equal sided mouth asymmetry (in total 798 maximum openings were double coded). Coding of mouth laterality matched between the two coders 84% of the time (Cohen's $\kappa = .705$, $p < .001$).

For all analyses, the first coder's original coding was used. See Chapter 3, Section 3.4.1 for informed decisions regarding inter-coding.

Figure 6.1 (From left to right) Examples of equal, right-side dominant, left-side dominant maximum mouth openings. "Right" and "Left" refer to the speakers' right and left.

Word-class coding

The word produced during each maximum mouth opening was coded as being "content" or a "function" word. The following grammatical classes were used to determine a content word: verbs (excluding auxiliary verbs), nouns, adjectives and adverbs. The following grammatical classes were used to determine a function word: determiners, conjunctions, auxiliary verbs and pronouns (see Table 6.3 for examples). Note that we did not include openings produced with prepositions in the analysis, because of their dual role as both function and content words (e.g., "want to achieve", the preposition "to" does not carry meaning thus is a function word; "add to a situation", the preposition "to" is a content word which carries spatial meaning).

Table 6.3 Examples of words classified as content or function words.

Word type	Examples
Content Words	Aim, Keep, Structure, Higher, Constantly
Function Words	*Determiners*: A(n), Another, Any, Some, The
	Conjunctions: And, If, Or, So
	Auxiliary Verbs: Are, Be, Being, Could, Do
	Prounouns: I, It, That (is), Those, Yourself

6.5 Design and measurements

A right-sided mouth asymmetry index was computed for each participant in each linguistic task based on the laterality (right-R, left-L, equal-E) of participants' first twenty maximum mouth openings per trial: (R-L)/(R+L+E) (adopted from Holowka and Petitto, 2002). Mean scores were calculated for each task (metaphorical vs. concrete), and for each word-class (content vs. function). Thus, a positive mean score indicated more instances of right-side dominant mouth openings (left-hemispheric lateralisation), and a negative mean score indicated more instances of left-side dominant mouth openings (right-hemispheric lateralisation).

The dependent variable was the right-sided mouth asymmetry index. The experiment had a 2 x 2 factorial design with two independent variables: type of task (metaphorical, concrete; within-subjects manipulation) and word-class (content, function; within-subjects manipulation).

6.6 Results

We coded 3066 maximum mouth openings across participants (1549 in concrete and 1517 in metaphorical task). On average, for each participant we coded 55.32 (SD = 7.66) mouth openings in the concrete task and 54.18 (SD = 10.61) in the metaphorical task. Though we aimed to code 60 mouth openings per condition per participant, the means were less than 60 because some participants gave short explanations and thus we could only obtain less than 60 mouth opening per condition. Furthermore, some mouth openings were excluded from the analysis because of low visual clarity of the recording (i.e., 33 mouth openings in the concrete task and 49 in the metaphorical task were coded as "unclear"). Out of the 3066 mouth openings which were coded we further excluded from the analysis 253 openings produced with filler pauses (e.g., "eerm") and 240 openings produced with prepositions (e.g., up, to). Out of 1248 maximum openings, which were included in the analysis from the concrete task, 65% were produced with content and 35% with function words. Similarly, out of the 1325 maximum mouth openings in the metaphorical task, 67% were produced with content and 33% with function words (see Table 6.4 for means). The proportion of content words in the concrete task did not differ significantly compared to the proportion of content words in the metaphorical task, t (27) = -1.425, p = .166. Therefore, the proportion of each word class (content vs. function) is comparable for each linguistic task (concrete vs. metaphorical).

Table 6.4 Mean number of words coded in each linguistic task and word-class, the mean word lengths (e.g., the number of letters) for the coded words, and the mean word count per explanation (e.g., the length of explanation) in each linguistic task. The means are all across participants. The numbers in brackets represent the standard deviation.

	Concrete Task		Metaphorical Task	
	Content Words	Function Words	Content Words	Function Words
Number of words coded	20.07 (*6.90*)	15.5 (*4.09*)	31.85 (*7.77*)	15.46 (*5.85*)
Word length	5.19 (*.59*)	3.18 (*.57*)	6.14 (*.61*)	3.59 (*.76*)
Length of explanation (word count)	37.31 (*9.93*)		44.04 (*12.0*)	

First, we compared the number of mouth openings included in the analyses to follow. The number of mouth openings is comparable for each linguistic task (concrete vs. metaphorical), t (27) = -1.662, p = .108. See Table 6.5 for average proportion of mouth openings coded (equal, left-dominant, right-dominant) and included for the calculation of the laterality index for each condition (concrete, metaphorical) and type of word (content, function).

Table 6.5 Mean proportion of coded mouth openings (equal, left-dominant, right-dominant) and included in the analyses for each linguistic task (concrete, metaphorical) and word type (content, function). The means are all across participants. The numbers in brackets represent the standard deviation.

		Concrete Task	Metaphorical Task
Content Words	Equal	0.13 (*0.09*)	0.12 (*0.09*)
	Left-dominant	0.06 (*0.07*)	0.18 (*0.09*)
	Right-dominant	0.47 (*0.12*)	0.38 (*0.14*)
Function Words	Equal	0.07 (*0.07*)	0.06 (*0.04*)
	Left-dominant	0.02 (*0.03*)	0.06 (*0.05*)
	Right-dominant	0.25 (*0.09*)	0.20 (*0.07*)

In addition, we compared the mean length of the explanations in each condition (see Table 6.4 for means). Explanations produced in the concrete task were significantly shorter than metaphorical explanations, t (27) = -2.79, $p < .05$. However, there was no significant correlation ($p > .05$) between the right-sided mouth asymmetry and the length of explanations in either task (concrete and metaphorical). Therefore, there is no evidence that any mouth asymmetry difference between the two tasks could be caused by the length of explanations.

We also compared the mean word length (e.g., the number of letters) in each word class (see Table 6.4 for means). As expected (Gordon & Caramazza, 1982) function words were significantly shorter than content words, t (27) = -16.054, $p < .001$. However, there was no significant correlation ($p > .05$) between the right-sided mouth asymmetry and the word length in either task (concrete and metaphorical). Therefore, there is no evidence that any mouth asymmetry difference between the two word classes could be caused by word lengths.

Then, we analysed whether mouth openings were right-side dominant. The right-sided mouth asymmetry index (as described in section 6.4 “Design and Measurement”) was significantly larger than zero in the concrete condition for content (t (27) = 12.726, p < .001) and function words (t (27) = 11.890, p < .001), and in the metaphorical condition for content (t (27) = 5.089, p < .001) and function words (t (27) = 7.081, p < .001) (see Figure 6.2 for the means). Thus, speech production, in general, relies on left-hemisphere processing.

Next, we analysed whether mouth-opening asymmetry differed between the two linguistic tasks and during the production of the two different word-classes. A 2 x 2 repeated measures within subjects ANOVA yielded a significant main effect of linguistic task (concrete vs. metaphorical), F (1, 27) = 34.638, p < .001, η_p^2 = .562. As predicted, participants demonstrated a significantly lower right-side bias in mouth openings during metaphorical explanations compared to the concrete ones (see Figure 6.2). In addition, there was a significant main effect of word-class (content vs. function), F (1, 27) = 4.994, p = .034, η_p^2 = .156. In particular, participants demonstrated a significantly lower right-side bias in mouth openings when they produced content compared to function words (see Figure 6.2). Finally, there was significant interaction between linguistic task and word-class, F (1, 27) = 5.322, p = .029, η_p^2 = .165. This indicates that the linguistic task had different effect on right-sided mouth asymmetry depending on what class of word (content vs. function) people produced. Post-hoc t-tests with Bonferroni corrected alpha level (p = .0125) between conditions indicated that right-sided mouth asymmetry was significantly lower in the metaphorical task than the concrete task for content words (t (27) = -6.679, p < .001), and for function words (t (27) = -3.306, p = .003); right-sided mouth asymmetry was lower for content words than function words during the metaphorical task (t (27) = -2.791, p = .010), but not during the concrete task (t (27) = -.181, p = .857) (see Figure 6.2). Thus, the interaction is because the task effect (i.e., reduced right-sided mouth asymmetry in the metaphorical task) is larger for content words than for function words. As evident in Table 6.5, the right-sided mouth asymmetry is lower in the metaphorical task because the right-side dominant openings decrease and the left-side dominant openings increase.

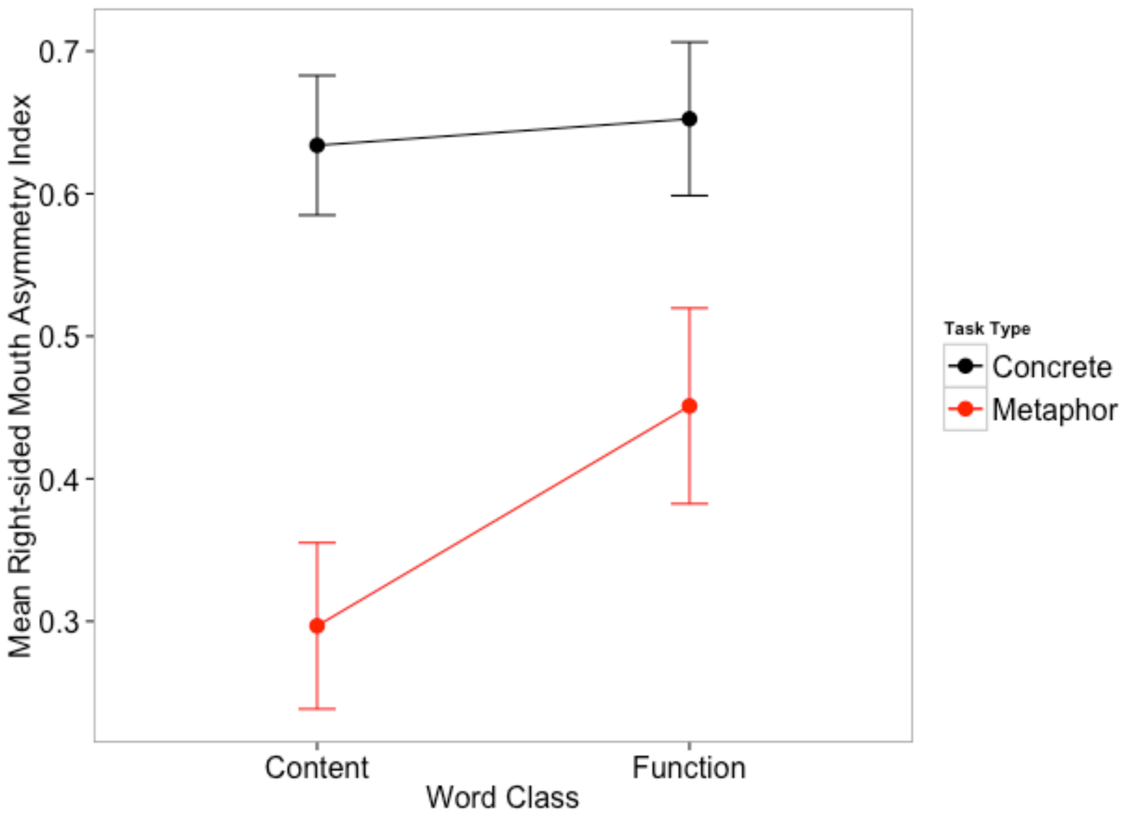

Figure 6.2 Mean right-sided mouth asymmetry index (R-L)/(R+L+E) per linguistic task and word-class produced, where R = right-side dominant mouth opening, L = left-side dominant, E = lips equally opened. The larger value indicates stronger right-side dominance in mouth openings, thus stronger left-hemispheric specialization. Error bars represent 1 standard error of the means.

The next analysis aimed to further support that the differences in mouth asymmetry were resulting from the manipulation of the variable in interest (metaphor vs. concrete) rather than the words produced. Thus, we focused on words that appeared in both concrete and metaphorical conditions at least once. The analysis included 613 content word tokens (49% of all content word tokens produced) and 777 function word tokens (59% of all function word tokens produced) (see Text S1 in Appendix Chapter 6 for a full list of the words and their token frequencies in each condition). The analysis was limited to 682 maximum mouth openings in the concrete task and 708 in the metaphorical task. Results remained the same (see Figure 6.3). The 2 x 2 repeated measures within subjects ANOVA yielded a significant main effect of linguistic task (concrete vs. metaphorical), F (1, 27) = 24.175, $p < .001$, $\eta_p^2 =$ .472. Participants demonstrated a significantly lower right-side bias in mouth openings during metaphorical explanations compared to the concrete ones. In addition, there was a marginally significant main effect of word-class (content vs. function), F (1, 27) = 4.015, $p = .050$, $\eta_p^2 =$ .129. Participants demonstrated a significantly lower right-side bias in mouth openings when they produced content compared to function words. Finally, there was a significant interaction between linguistic task and word-class, F (1, 27) = 5.947, $p = .022$, $\eta_p^2 = .181$. In summary, the pattern of results remained the same as in the previous analysis. Thus, there is no evidence that the effects are driven by the words spoken uniquely in the metaphorical or concrete condition.

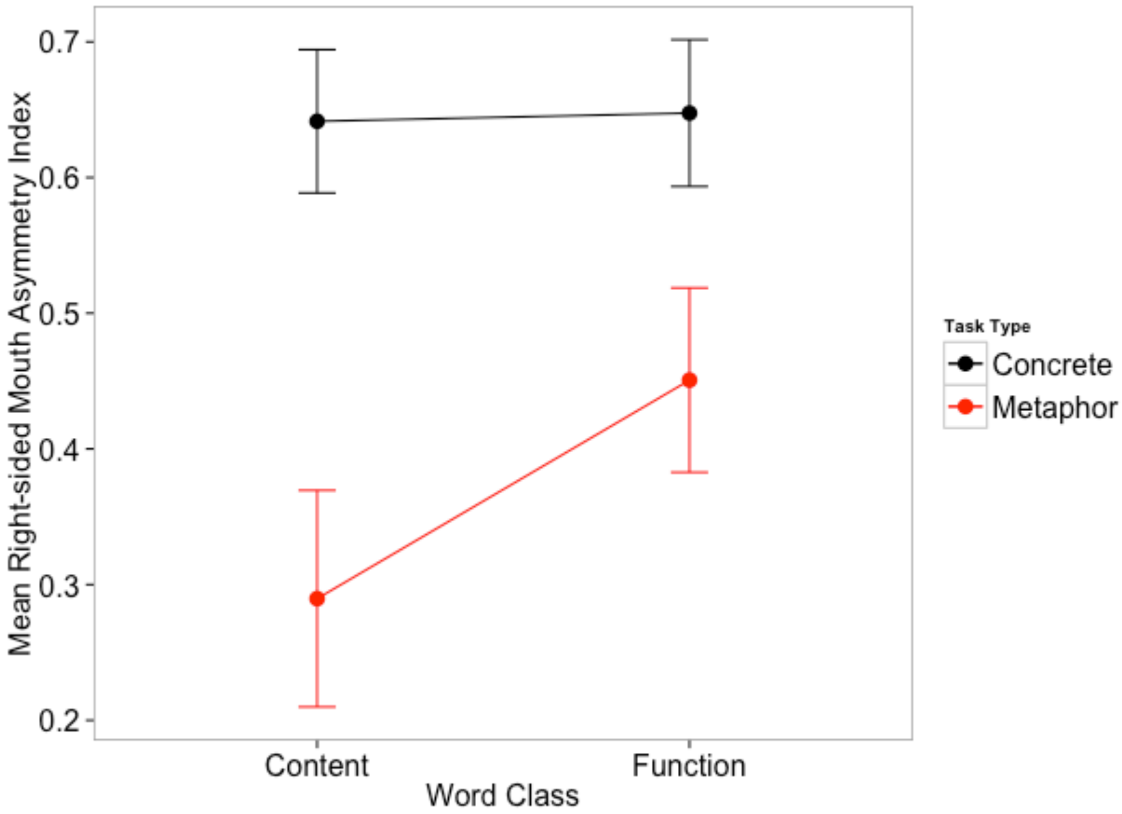

Figure 6.3 This analysis included only the words produced at least once in both concrete and metaphorical task. Mean right-sided mouth asymmetry index (R-L)/(R+L+E) per linguistic task and word-class produced, where R = right-side dominant mouth opening, L = left-side dominant, E = lips equally opened. The larger value indicates stronger right-side dominance in mouth openings, thus stronger left-hemispheric specialization. Error bars represent 1 standard error.

6.7 Discussion

The present study investigated whether metaphorical processing particularly involves the right hemisphere such that it reduces the right-side bias in mouth openings during metaphorical speech production. First, we compared speakers' mouth asymmetry during explanation of phrases with metaphorical and concrete meanings. The mouth opened more widely on the right side during speaking in both the metaphorical and concrete conditions suggesting the involvement of the left hemisphere during speech production. However, the right-sided mouth asymmetry significantly reduced in the metaphor compared to the concrete task. In addition, we crucially showed that the reduced right-sided mouth asymmetry during metaphorical explanation, as compared to concrete explanations, is particularly pronounced during the production of content words than that of function words. We propose that semantics is crucial for the right-hemispheric involvement in metaphorical speech production.

The present findings are in line with the Right Hemisphere Hypothesis for Metaphor (e.g., Brownell et al., 1990) according to which the right hemisphere is predominantly involved in metaphor processing. Although several studies manipulated linguistic content (literal vs. non-literal stimuli) to assess the neural basis for metaphor processing (e.g., Brownell et al., 1990; Anaki, et al., 1998), only one study (Benedek et al. (2014) has explored the involvement of the right hemisphere during metaphorical speech *production*. The “open-endedness” and the description of the metaphorical mapping in the current task was effective as it revealed the differential hemispheric involvement between metaphorical and literal explanations. Participants in this task were free to choose from a wide range of possible responses. This “semantic exploration” between possible meanings is crucial for metaphorical processing, which entails the creation of a semantic link between otherwise distant concepts (Jung-Beeman, 2005). Therefore, this task was able to capture the crucial element for the right-hemispheric involvement for metaphor processing. Furthermore, the study of metaphor production during an on-line task (as opposed to passive tasks of covert reading and comprehension) offers a new approach to how speakers develop new ideas, which is important to communication *per se* and theories about creative cognition (e.g., Benedek et al., 2014; Dietrich & Kanso, 2010).

Moreover, the present study is in accordance with research on the involvement of each hemisphere for the representation of content and function words (Mohr et al., 1994). For example, the present study found that for content words, the right-sided mouth asymmetry was significantly smaller during metaphorical explanations than concrete explanations. This finding suggested that the hemispheric involvement for the production of content words can be determined by the semantic meaning they carry. When content words are produced to represent concepts related to metaphorical concepts, as opposed to concrete and literal concepts, the right hemisphere is particularly involved. Firstly, this finding validates our initial hypothesis that semantics is crucial for the reduced right-sided mouth asymmetry in metaphorical as compared to literal speech production. In addition, it is compatible with observations that content words are bilaterally represented, thus do not demonstrate a processing advantage when presented in either (left or right) visual field (e.g., Bradley & Garrett, 1983; Mohr et al., 1994) .

Not only for content words, but also for function words, the right-sided mouth asymmetry reduced for metaphor explanation. This may be because function words also carry semantic information related to metaphor, albeit less substantially than content words. For example, pronouns classified as function words may refer to content words in preceding discourse. If the content words' meaning has been processed in the right hemisphere, the right hemisphere may also play an important role in producing a subsequent co-referential pronoun. In addition, it is possible that left-hemisphere involvement by content words during metaphor explanations was carried over to the production of function words as well. For example, when a function word is produced in a sequence of content words within an utterance, it is possible that the right hemisphere involvement may be carried over to the function word. This is possible if it incurs a processing cost to switch on and off the right-hemisphere's involvement in speech production. Then, even if it is not efficient to process a function word with the right-hemisphere's involvement, it may sometimes be overall more efficient to keep the right-hemisphere's involvement (not to switch it on and off too often).

In addition, present results are compatible with previous studies on task-dependent mouth asymmetry. Mouth asymmetry studies have shown that tasks involving right hemisphere processes (e.g., emotional tasks, automatic speech) lead to reduced right-sided asymmetry in mouth opening. For example, right-sided asymmetry was reduced when spontaneously smiling compared to generating word lists (Graves et al., 1982) and it was also smaller when singing and counting (serial speech) than naming pictures and spontaneously speaking (propositional speech) (Graves & Landis, 1985). The present study is the first study to show the same effect for metaphor. Thus, this study further validated mouth asymmetry as an indicator of lateralisation of processes underlying various communication behaviours.

But what exactly is happening in the two brain hemispheres during metaphorical explanation? We may speculate what in light of metaphor theories. Metaphor is a way of speaking about one conceptual domain in terms of another (Lakoff & Johnson, 1980b). In particular, during metaphorical explanation speakers explain the metaphorical mapping of a concrete concept (source domain of metaphor) onto a more abstract one (target domain of metaphor) (e.g., when explaining the phrase "to spin a yarn", the spinning represents the elaborate creation and narration of a story). This specific process of mapping during metaphorical processing is essentially the speaker's effort to bring closer two semantically distant concepts (e.g., the action of spinning and the action of narrating). Such semantic processes are an instance of the processing of coarse semantic links, which is more strongly represented in the right hemisphere than the left (following the Fine-Coarse Coding Theory; Jung-Beeman, 2005). Crucially, the current study found a significant interaction between linguistic task and word-class. That is, the right-sided mouth asymmetry was significantly lower when participants explained metaphorical phrases than concrete phrases and this difference was particularly pronounced for production of content words. Presumably, when speakers produced content words for the explanation of metaphors, they produced words which carry semantic information related to the metaphorical mapping. For example, in the phrase “to spin a yarn”, a source domain concept, “objects (yarn)”, maps to a target domain concept, “story”. Through the metaphorical mapping, some attributes can also be mapped from the source to the target domain. So, “a *complicated* (content word) object like a yarn is used to represent a *complicated* story”. This mapping is lexically encoded more often with content words compared to function ones, because function words do not carry enough semantic content to allow for the representation of abstract concepts in the form of concrete senses (Gonzálvez-García, Peña-Cervel, & Pérez-Hernández, 2013). Therefore, we propose that during metaphorical speech production semantics might be what determines the relative involvement of the right hemisphere.

The current study used so-called frozen metaphors in idiomatic phrases, which in some studies did not involve the right hemisphere as well as novel metaphors (Cardillo et al., 2012; Mashal et al., 2005). We argue that how much the right hemisphere is involved in metaphor processing depends not only on the type of stimulus materials but also on the task. The current study showed that, with frozen metaphors, if the participants were required to explicitly think about the metaphorical mapping between source and target domains (e.g., in the phrase “to spin a yarn”, the yarn represents a long complicated story), the right hemisphere got involved in the process.

In general, in the discussion of the Right Hemisphere Hypothesis for Metaphor (e.g., Brownell et al., 1990), it may be important to carefully examine the nature of task used in each study. For example, the fMRI study by Rapp et al. (2007) failed to show activation of the right hemisphere whilst participants silently read sentences (literal and non-literal) and performed metaphorical judgments (“is it a metaphor or not?”) and connotation judgments (“does it have a positive or negative connotation?”). The task did not require processing of the mapping between source and target domains. For example, the metaphorical judgment could have been made based on semantic anomaly in the literal interpretation. In sentences such as "the director was a bulldozer" participants could judge if the sentence is literally plausible or not, without thinking about the metaphorical mapping. If so, these tasks probably did not strongly activate metaphorical thinking, thus failed to activate the right hemisphere.

The present study validates the effectiveness of the mouth asymmetry technique and opens new doors for future research. For example, it would be interesting to observe the sequence of mouth asymmetries as this might reveal how the two hemispheres collaboratively produce an utterance. Mouth asymmetry is a suitable technique for such questions, which would be difficult to answer with functional imaging techniques due to low time-resolution (fMRI) or articulatory movement artefacts (EEG). Finally, calculating the mouth asymmetry index during metaphorical tasks could supplement future studies with an individual-subjects localization approach and lead to a clearer picture of the neural basis of metaphorical processing.

6.8 Conclusions

In conclusion, the reduced right-sided mouth asymmetry during metaphorical compared to concrete explanations is particularly driven by the production of content words related to metaphor. Thus, indicating that semantic processing and metaphorical representation of meaning is crucial for the relative involvement of the right hemisphere for metaphorical speech production. The study also validated the sensitivity of the mouth asymmetry technique to capture the differential hemispheric involvement for different verbal tasks, and also for different word-classes.

7 General discussion

The current thesis focused on understanding the interactions among gesture production and language processing. We investigated how the way we gesture interacts with and perhaps determines our spoken utterances. More specifically, we tried to understand the mechanism underlying gestures' self-oriented functions, by investigating its relation to gesture handedness and hemispheric involvement for cognitive processing, that is by investigating the different impact that right- and left-hand gestures have on several types of metaphor processing. In addition, we collected individual, indirect measurements for the hemispheric involvement for speech production tasks. This way we investigated whether left-hand gestures' facilitative effect on metaphor processing relates to the right-hemispheric involvement for speech production. Finally, we investigated if semantic processing is important for the relative involvement of the right hemisphere for metaphor processing. The current section summarises the key findings from each experimental chapter, discusses the theoretical and practical implications, and outlines the limitations of the thesis. Suggestions for future research are also considered.

7.1 Summary of main findings and conclusions

Chapter 3 investigated whether co-speech gestures with a particular hand enhance cognitive processing involving the hemisphere contra-lateral to the gesturing hand, such that left-hand gestures enhance metaphor processing which particularly involves the right hemisphere. The study found that left-hand gestures enhanced explanations of metaphorical phrases compared to right-hand gestures or not gesturing at all. Importantly, this left-over-right-hand gesturing advantage was higher for people with stronger right-hemispheric involvement for speech production as measured by asymmetric mouth movements during speaking. In addition, a control experiment ruled out the possibility that the observed effect was due to prohibiting the one hand rather than gesturing with the other. Producing left-hand representational gestures by choice, compared to choosing not to gesture with the left hand, enhanced the metaphorical mapping from concrete conceptual domains on to more abstract ones, which depends on processes in the right-hemisphere (while this was not the case for the right hand). We concluded that co-speech gestures with a particular hand give feedback to, enhance cognitive processes involving the hemisphere contra-lateral to the gesturing hand ("hemisphere-specific feedback hypothesis"), and in turn modulate the content of speech.

Chapter 4 investigated whether co-speech gestures with a particular hand trigger processing involving the contra-lateral hemisphere, and if gestures facilitate cognitive processes because of their motoric or depictive properties. This study used a different dependent variable from Chapter 3; that is, we measured the spontaneous use of metaphor related expressions during explanation of abstract phrases. The study provided no evidence that left-hand gestures trigger the use of metaphorical language within abstract context compared to right-hand gestures or not gesturing at all. In addition, it provided no evidence that gestures compared to meaningless tapping hand movements trigger the use of metaphorical language. However, we found that lengthier explanations increased the likelihood of using metaphorical language. The possibility of 'verbosity' determining metaphorical language use (e.g., the more we speak, the more likely we are to use metaphors), and that of gestures affecting verbosity should be further explored.

Chapter 5 investigated whether action gestures when produced alone (without speech), prime the semantic categorisation of subsequent action sentences as literal or metaphorical. Do action gestures that match the meaning of a subsequent sentence help (i.e., fast response) the semantic categorisation of the sentence as metaphorical or literal? It also investigated the role of the hand choice for gesturing for the potential priming effect. The study provided no evidence for priming effects of gestures when produced alone on semantic categorisation of sentences. We only found that producing gestures (matching or mismatching with the sentences) slowed down the categorisation of subsequent sentences compared to producing no gestures. This finding suggested that the baseline condition of no gesturing had a reduced cognitive load compared to the gesturing conditions. In addition, there was no evidence for different priming effects between metaphorical and literal action sentences, and no evidence that matching left hand gestures particularly facilitate the semantic categorisation of metaphorical rather than literal sentences. The null results are not sufficient to understand the effect of gesture when produced alone on semantic processing, and further research is needed.

Chapter 6 investigated whether semantics plays a crucial role for the right-hemispheric involvement during metaphorical speech production. We used the mouth asymmetry technique to capture the hemispheric involvement during speech production. The study found that the right-sided mouth asymmetry reduced during metaphorical compared to concrete explanations, and this reduction was driven by the production of content rather than function words. We concluded that semantics, as in producing content words to represent distant, metaphorical mappings, is why the right hemisphere is particularly involved during metaphorical speech production.

7.2 Implications

7.2.1 Embodiment

The thesis built on the embodied semantic perspective, which suggests that action-perception mechanisms are functionally important components of the semantic systems in the brain (Pulvermüller, 2013). It has been proposed that sensory-motor activation is automatic, fast and somatotopic when processing meaning that describes action (Boulenger et al., 2006;

Buccino et al., 2005; Gallese & Lakoff, 2005; Glenberg & Kaschak, 2002; Glenberg & Robertson, 2000; Hauk et al., 2004; Pulvermüller, 1999). This has also been confirmed for processing metaphorical action sentences (Desai et al., 2011; 2013), idiomatic sentences (Boulenger et al., 2009), and abstract transfer sentences (Glenberg et al., 2008). In addition, gestural representation of action may modulate processing of metaphorical action meaning (Wilson & Gibbs, 2007). The thesis aimed to advance the field by investigating how gesture production, concurrent with speech and isolated, influences people's representation, comprehension and production of abstract meaning in the form of metaphor.

The thesis goes beyond the previous literature in an important way. Chapter 3 showed that left hand gestures enhanced metaphor explanation (descriptively so did right hand gestures). In line with the Gesture-as-Action-Simulation account (Hostetter & Alibali, 2008) and the Information Packaging Account (Kita, 2000), it seems that gestures served as simulators of concrete concepts and helped the conceptual mapping of concrete meaning on to abstract meaning in the form of metaphor. Explanation of metaphors involves activation of imagery that relies on simulations of perception and action (Lakoff & Johnson, 1980a), therefore this process can be enhanced by gestures that highlight visuo-motor information (Alibali et al., 2011). Chapter 4 aimed to further extend the embodied accounts using a different task, which measured the spontaneous use of metaphor related expressions within abstract context. It predicted that gestures, as opposed to meaningless tapping movements, might trigger representation of abstract meaning in the form of metaphor, and in turn increase the likelihood for metaphorical language use. In addition, Chapter 5 predicted that comprehension of metaphorical and literal action sentences would rely on sensory-motor information encoded in gestures, hence preceding, matching, action gestures would prime sentence comprehension. However, the null results from those two chapters were not sufficient to confirm either the embodied or disembodied accounts.

7.2.2 Functions of gestures

The thesis built on theories about gestures' facilitative effects on cognitive processes, namely theories about self-oriented functions of gestures, and advanced the field by identifying a mechanism behind them. It has been suggested that gestures may help speakers identify which lexical features to use, as the Lexical Processing model suggests (Krauss & Hadar, 2001; Rauscher et al., 1996). Also, gestures may reinforce our mental images and help maintain them in memory, as the Image Maintenance account suggests (de Ruiter, 1995; Wesp et al., 2001). In addition, gestures may help speakers identify which features of a mental image to mention and organise information to be uttered, as the Information Packaging account suggests (Alibali & Kita, 2010; Alibali, Kita & Young, 2000; Kita, 2000). Finally, gestures may lighten up cognitive load in working memory (Goldin-Meadow et al., 2001). The current thesis investigated, for the first time, whether right and left hand gestures differ in the degree of impact they have on language processing.

Chapter 3 provided evidence that right and left hand gestures differed in the degree of the facilitative effect they have on metaphor explanation. When encouraged to gesture with one of the hands, while the other hand was prohibited from gesturing, speakers produced more enhanced metaphorical explanations when gesturing with the left hand, compared to the right hand or not gesturing at all. This indicated that left-hand gestures enhanced performance in the explanation task because they enhanced metaphorical processing involving the contra-lateral right hemisphere. This left-hand gesturing advantage cannot be due to distraction or discomfort due to prohibition of right-hand gesturing. This is because, spontaneous left hand gestures enhanced explanations compared to not gesturing with it by choice, and not gesturing by choice vs. by instruction did not influence the level of metaphoricity. Furthermore, this left-over-right-hand gesturing advantage was higher for speakers with stronger right hemispheric involvement during speech production. This correlational finding further suggested the hemisphere specific impact of gestures and confirmed that the somewhat small difference between the two gesturing conditions (the mean difference of metaphoricity levels in the left hand gesturing condition minus the right hand gesturing condition is .14 with $SD = .30$) is important and relates to the degree of the right hemispheric processing of the participants. This study extended previous findings showing that hemispheric involvement during linguistic tasks may determine hand choice for gesturing (Kimura, 1973; Kita et al., 2007; Mumford & Kita, under review) by providing evidence for the reverse link. In addition, it extended the Information Packaging Hypothesis for self-oriented functions of gestures (Alibali & Kita, 2010; Alibali, et al., 2000; Kita, 2000), by showing that left hand gestures help the conceptual mapping from a source to a target domain of metaphor, thereby influences thinking (Alibali et al., 2011) and content of verbal output (Alibali & Kita, 2010; Rime et al., 1984). How exactly does this work? Gestures, and especially those with the left hand, offer a visuo-motor representation of a concept, which taps into and boosts speakers' conceptual knowledge, and in turn helps the right-hemisphere specific process of mapping concrete concepts on to abstract ones in the form of metaphor (Jung-Beeman, 2005; Lakoff & Johnson, 1980a). We introduced this as the "hemisphere-specific feedback hypothesis" for gestures self-oriented functions, such that gestures with a particular hand facilitate cognitive processes in the contra-lateral hemisphere. Thus, gestures are not merely hand waving. They rather shape our thoughts and can modulate the content of what we say.

Chapters 4 and 5 provided no evidence for the hemisphere-specific feedback hypothesis in tasks other that metaphorical explanation such as metaphorical judgment (task difference is further discussed in the next section). However, the unexpected (although tenuous) pattern of results in Chapter 4, that gestures (regardless of the hand used) compared to meaningless tapping movements increased the length of explanations (i.e., number of words uttered) points towards an influential role of gestures on properties of speech, such as "verbosity", and could be further explored.

7.2.3 Gestures, metaphor and the right-hemisphere

Chapters 3, 4 and 5 drew upon the relative hemispheric involvement of the right hemisphere for metaphor processing (Winner & Garnder, 1977; Anaki et al., 1998; Bottini et al., 1994), and investigated whether gestures with the left hand can facilitate this right hemisphere specific metaphor processing. Previous research (Kimura, 1973; Kita, de Condappa, et al., 2007; Mumford & Kita, under review) showed that relative hemispheric involvement for a linguistic task determines hand choice for gesturing. For example, Kita, de Condappa, et al. (2007) showed that right hand preference for gestures reduced when explaining metaphorical compared to non-metaphorical phrases. The current thesis, for the first time, explored the reverse causal chain. Although there are studies showing that gestures increase production of spatial metaphors (Bos & Cienki, 2011), there is no study investigating the differential effect that left and right hand gestures might have on such a facilitation effect. Only Ciantar, Finch, and Copland (2013) explored the effect of hand choice for movement, but they used complex meaningless movements (rather than gestures), and they focused on memory tasks (rather than a hemispheric specific linguistic task such as metaphor processing). In addition, the current thesis drew upon the Conceptual Metaphor Theory (Lakoff & Johnson, 1980a) and investigated whether conceptual knowledge and metaphorical mappings underlie and motivate different components of metaphor processing (e.g., metaphorical explanation, production and categorisation) such that they will be enhanced by gestural representation of sensory-motor information.

Chapter 3 provided, for the first time, evidence that gesturing with the left hand enhanced metaphorical explanation involving the right hemisphere compared to right hand gesturing and not gesturing at all. This finding was further strengthened because the left-over-right-hand gesturing facilitation effect on metaphor explanation positively correlated with the right hemispheric involvement during speech production. In addition, metaphor explanation was improved when participants spontaneously gestured with the left hand compared to not gesturing with it by choice (while this was not found for the right hand). It seems that representing meaning with the left hand "feeds back" and facilitates the processing of metaphorical mapping (e.g., explain how the "beans" represent a "secret" in the phrase "to spill the beans"), which is crucial for metaphor processing and the involvement of the right hemisphere during metaphorical explanation (Jung-Beeman, 2005; Lakoff & Johnson, 1980a).

Chapters 4 and 5 provided no evidence for such facilitation on metaphor production and semantic categorisation. This may relate to differential hemispheric involvement for different tasks. It could be that explanation of metaphors, to include the underlying conceptual metaphor and metaphorical mapping, engages the right hemisphere and allows the left hand gesture to enhance processing. In contrast, spontaneous use of metaphor related expressions (Chapter 4) and semantic classification of a sentence as metaphorical or not (Chapter 5) might not require processing of the metaphorical mapping, and thus are not right hemisphere specific processing. These tasks may not be sensitive and hemisphere specific enough to allow facilitative effects from left hand gestures. The thesis combines the Conceptual Metaphor Theory (R. W. Gibbs et al., 1997; Lakoff & Johnson, 1980a; Nayak & Gibbs, 1990) and the Right Hemisphere Hypothesis for Metaphor (Anaki et al., 1998; Bottini et al., 1994; Winner & Gardner, 1977), and partially supports them (based on findings from Chapter 3). That is, metaphor explanation depends heavily on the knowledge of conceptual metaphors and understanding of distant, metaphorical mappings hence it is right hemisphere specific, and is facilitated by representation of sensory-motor information in gestures (Chapter 3). However, this may not be the case for spontaneous production of metaphorical expressions or classification of sentences as metaphorical or not (Chapters 4 and 5). Our findings do not provide evidence to support the alternative metaphor theories as discussed in section 2.2.1. Finally, the current thesis points towards differential effects of gestures on metaphor processing depending on the degree of right hemispheric involvement and the reliance on metaphorical mappings. This is in line with the differential effects of gestures on different stages of analogical reasoning found in Cooperrider and Goldin-Meadow (2014). Given that both tasks rely on some sort of 'transfer' (e.g., metaphorical and analogical transfer), it would be interesting for future research to explore the left vs. right hand gesturing differences in analogical reasoning tasks.

7.2.4 Metaphor and the right-hemisphere

Chapter 6 addressed the issue of whether the right hemisphere is involved during metaphor production, and if semantics is crucial for this involvement. As far as we know, there is only one study focusing on metaphor production (Benedek et al., 2014), and one exploring the role of semantics on metaphor processing (Cardillo et al., 2012). However, Benedek et al. (2014) did not explore the role of semantics. Also, Cardillo et al. (2012) proposed that semantic rather than syntactic features are important for the hemispheric involvement during metaphor processing. However, they focused on comprehension, rather than production, and they did not assess non-metaphorical stimuli. Our study filled in this gap. We found that, while overall the right side of the mouth opened wider than the left when speaking (thus suggesting the involvement of the language dominant left hemisphere for speech production; in line with Graves & Landis, 1985; 1990), this right-sided mouth asymmetry significantly reduced during metaphorical compared to non-metaphorical (e.g., concrete) speech production. Importantly, this reduction was particularly pronounced for the production of content rather than function words. The study confirmed the Right Hemisphere Hypothesis for Metaphor (Anaki et al., 1998; Bottini et al., 1994; Winner & Gardner, 1977) providing evidence, for the first time, from online, production tasks. Additionally, it extended the theoretical explanation for this right hemispheric involvement for metaphor (Jung-Beeman, 2005). It showed that during metaphor production, semantics and, in particular, using content words to represent the distant, metaphorical mappings might determine the relative involvement of the right hemisphere.

7.2.5 Experimental design

The current thesis can inform the experimental design of future studies on self-oriented functions of gestures, the differential effects of right-hand and left-hand gestures, the hemispheric involvement for cognitive tasks, and metaphor processing.

Firstly, the experimental manipulations of gesture elicitation via gesture encouragement and gesture prohibition proved effective. Encouraging participants to gesture has been used in a number of studies (Broaders et al., 2007; Chu & Kita, 2011; Cook et al., 2012). Our data from Chapters 3 and 4 showed that the majority of the gestures produced following encouragement instructions were representational gestures (rather than, for example, stress related self-touching gestures). In addition, our data from Chapter 3 showed that the observed effects are due to gesturing with the one hand, rather than prohibiting the other. The control study in Chapter 3 showed that metaphorical explanation was enhanced when spontaneously gesturing with the left hand compared to not gesturing with it by choice, and for both right and left hands performance was comparable when not gesturing by choice vs. by instruction. Therefore, gesture prohibition is not artificial or distracting (in line with Goldin-Meadow et al., 2001, and Goldin-Meadow & Wagner, 2005), but it is also not sufficient to explain the observed effects of enhanced metaphorical explanation.

Secondly, the order in which participants performed each condition (e.g., first gesture with the left hand, then with the right, and in the end do not gesture) may affect performance in tasks that measure the effect of gesture handedness on properties of speech production. Data from the order analysis in Chapter 4 showed that for participants who were prohibited from moving in the first block of trials gesturing, as predicted, increased the likelihood for metaphorical language use compared to no gesturing, and, tapping reduced metaphorical language use compared to no tapping. Descriptively, and as predicted, the difference between gesturing and tapping was more apparent within the left hand free condition. Importantly, metaphorical language use did not differ in the baseline, prohibition conditions for the gesturing and tapping groups. This was not the case for participants who were prohibited in the second/third blocks. It seems that gesture production in the first block(s) increased the likelihood for metaphorical language use and this effect lingered on to the subsequent blocks, when gesturing was prohibited, indicating a "sustained beneficial" effect of gestures on metaphorical language use. This finding is in line with Chu and Kita (2011) who showed that the beneficial effect of co-thought gestures in a mental rotation task could be extended even in a subsequent block of trials in which gesturing is prohibited. But, more importantly, it indicates that a random, instead of blocked, order of trials with left, right and no gesturing could be more effective when measuring spontaneous speech production as a function of hand choice for gesturing.

Thirdly, different tasks and measurements may give different results. We have already discussed (section 7.2.3 "Gesture, metaphor and the right-hemisphere") that measuring levels of metaphoricity in explanations of metaphorical mappings may be more sensitive to activate the right-hemisphere specific component of metaphor processing and manifest the hemisphere-specific facilitative effect from gestures, compared to measuring spontaneous production of metaphor related expressions. In addition, Chapter 6 indicated that semantic categorisation of sentences (e.g., decide if a sentence is metaphorical or literal) is a complex, multifaceted task, which requires more than one level of processing: conceptual representation of the sentence meaning, comprehension and then categorisation as a response. Therefore, it may be difficult to measure the priming effect from gestures on this complicated response. For example, it is possible that gestures prime the representation of a subsequent sentence, but not its semantic classification. This finding suggested that, when targets are sentences, we could use the priming paradigm combined with different tasks. For example, categorisation tasks that refer to general categories (e.g., is a sentence sensible or not) reduce the development of response strategies (Bowers & Turner, 2003) (e.g., if the O-NP is abstract, the sentence is metaphorical, and if it is concrete, the sentence is literal) .

Finally, the mouth asymmetry technique is a valid, sensitive, online, non-invasive and inexpensive measurement that could be used to capture differential hemispheric involvement for different speech production tasks, and even for production of different types of words. For example, Chapter 3 and 6 used two different samples, and they both showed that the right-sided mouth asymmetry reduced while explaining metaphorical compared to non-metaphorical phrases. Mouth asymmetry can be particularly useful for speech production studies with an individual-subjects localisation approach of language processing.

7.3 Limitations

There are some limitations to the current thesis that we should consider while interpreting the findings. Firstly, our sample included right-handers only. Like all studies on metaphor and gesture, we controlled for manual handedness, in order to control for patterns of cerebral dominance for speech and gesture production. However, it would be useful to explore how gesture and speech interact in the brain of left-handers. Secondly, our sample is mixed in terms of gender. In Chapters 3 and 6, we deliberately tested males only to control for cerebral asymmetries often found in women (Hausmann & Güntürkün, 2000). In Chapters 4 and 5, we aimed to extend findings by including females. However, practical difficulties during recruitment did not allow us to test a proportionate sample of males and females, but future studies should allow so. Additionally, we focused on uni-manual gestures only and not bi-manual. This was a necessary manipulation to test our hemisphere-specific feedback hypothesis. However, it is not artificial, because uni-manual and bimanual gestures are spontaneously produced in natural conversations (K. Miller & Franz, 2005). Finally, one could argue that the small sample size was a possible limitation. However, given the observed significant differences between left and right gesture and left and no gesture with a sample size of 31 (Chapter 3), and following Howell (2007, p.226) that 'retrospective power offers no additional information for explaining non-significant results', we cannot suggest that small sample size resulted to non-significant findings in the remaining chapters. Of course, future research could employ power analysis *a priori* to determine sample size.

7.4 Future work

The current thesis has also raised interesting questions and motivated future research at least towards four directions.

Firstly, future research could investigate the qualitative differences between left-hand and right-hand gestures. Anecdotal evidence from already collected data in the thesis suggests that left-hand gestures tend to be more "exploratory" compared to right-hand gestures (e.g., when using the left hand, participants would produce fluid gestures placing their abstract thoughts in the space in front of their body, while right-hand gestures would firmly represent an object). In addition, it was easier to segment gestures with the right than left hand. We could further explore these qualitative differences between left and right hand gestures, and their differential effects on speaking and thinking.

Secondly, future research could investigate the effect of gestures on qualitative properties of speech. The study in Chapter 4, unexpectedly, showed that lengthier explanations increased the likelihood of using metaphor related expressions. We could explore further the facilitative effect that gestures might have on "verbosity" and in turn creative thinking.

Thirdly, future research could investigate the variations in metaphor comprehension and production at an individual level. Experiment 1 in Chapter 3 showed that people vary in the degree of right-hemispheric involvement in speech production, and this variation relates to the degree of the left-hand gesture facilitation effect on metaphorical explanation. Individual variation in cognitive processing (e.g., ability of people to understand distant semantic links) and its relation to variations in metaphorical processing could be further explored to inform experimental designs of future studies on metaphor. Furthermore, we could develop a project to measure hemispheric involvement during speech production via a direct physiological method, instead of the indirect mouth asymmetry measurement.

Finally, future research could investigate the neural substrates of metaphorical and literal action comprehension. We could combine the cross modal semantic priming paradigm from Chapter 5 with brain-imaging methodologies to investigate whether the sensory-motor system is modulated similarly (e.g., strength and/or location of activity) as a function of linguistic properties (i.e., comprehension of metaphorical and literal action sentences) and matching of stimuli (i.e., congruent and incongruent combinations between gesture primes and target sentences, no prime).

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Appendix Chapter 3

Supplemental Material Text S1

The following inventory was adjusted from Oldfield (1971).

The modified Edinburgh Handedness Inventory

Please indicate your preference in the use of your hands in the following activities by circling the appropriate option. If you are indifferent, select “Either”.

1. With which hand do you normally write?	left	either	right
2. With which hand do you draw?	left	either	right
3. Which hand would you use to throw a ball to hit a target?	left	either	right
4. With which hand do you use your toothbrush?	left	either	right
5. Which hand holds a knife when you are cutting things? (not with a fork)	left	either	right
6. Which hand holds the thread when you are threading a needle?	left	either	right
7. When you strike a match, which hand holds the match?	left	either	right
8. When you open a box, which hand holds the lid?	left	either	right
9. Which hand holds the spoon when you are eating a soup?	left	either	right
10. With which hand do you use scissors?	left	either	right
11. Which hand is at the upper part of the broom?	left	either	right
12. Which hand holds the hammer when you are driving a nail?	left	either	right

Supplemental Material Text S2

Coding Manual for Metaphoricity Levels in the Metaphorical Explanation Task

(Developed by Paraskevi Argyriou and Sotaro Kita)

You (the coder) will need to code the metaphoricity of the explanations that 31 participants (orally) gave for a total of 18 metaphorical idiomatic expressions, such as "to spill the beans". The level of metaphoricity is measured based on whether the explanations include an explicit link between the literal and metaphorical meanings, that is, whether participants explicitly referred to the metaphorical mapping between the source and target domains of the conceptual metaphor underlying each idiomatic expression. According to the conceptual metaphor theory (Lakoff & Johnson, 1980a, 1980b), metaphor is a matter of conceptualizing one conceptual, abstract domain (target domain) in terms of another, concrete (source domain). For example, "time passing" is often understood in terms of "motion", hence expressions such as "the time is here… the time for action has arrived".

The metaphoricity of each explanation was rated on a three-point scale (0 to 2) using the following guidelines: a ''0'' rating indicated that the explanation did not contain words or phrases referring to the source domain of the relevant conceptual metaphor, therefore there was no metaphorical cross-domain mapping; a rating of ''1'' indicated that the explanation contained words or phrases that might be construed as references to the source domain, but the references were ambiguous or vague, and the mapping between the two domains implicit or underspecified; a rating of ''2'' indicated that the explanation contained words or phrases that explicitly and clearly refer to the source and target domains, and the mapping was explicit.

Exemplar coding for the expression “To dodge the bullet”

1. To dodge the bullet, means when you have a situation where you might be under some kind of danger or attack or something like that. And you find a way to to save yourself from that. And it's pretty self-evident that if a bullet's coming towards you, it's gonna harm you if it touches you, or it hits you. So you you run, and jump out the way.

<u>This explanation is coded with “0” because it is too concrete (referring only to the source domain), and the speaker does not mention how “bullet” and “dodge” represent abstract concepts, "to avoid something dangerous".</u>

2. To dodge the bullet means to sort of avoid something bad that could have happened to you. The bullet representing the bad thing because bullets can kill you and to dodge the bullet that means you don't get shot.

<u>This explanation is coded with “1” because it vaguely refers to the metaphorical mapping for "bullet" (= “bullet representing the bad thing”). The representation of “dodging” is quite concrete (= “you don’t get shot” rather than “avoiding something dangerous”).</u>

3. To dodge the bullet means to avoid consequence, that’s sort of bad consequence of one of your actions. And the bullet signifies the consequence, which is sort of punishment. And so to dodge means, you avoid it.

<u>This explanation is coded with “2” because it explicitly refers to the two key metaphorical mappings (= “bullet signifies consequence”, “dodge means avoid”)</u>

Specific coding issues for the application of the coding to the speech data:

1. Coding is done in Microsoft Excel file, where each raw includes the verbal response for each metaphorical explanation. You add the number 0, 1, 2 in the column named "Metaphoricity Rating".

2. We are not coding for accuracy. In some cases participants give an "unconventional" metaphorical mapping, which is "wrong" from the viewpoint of dictionary definitions. However, this should not affect the metaphoricity coding. If the explanation includes the mapping and the representation of the concepts, even though this might be different from what you (the coder) have in mind or the dictionary definitions, you should code it with a "2". For example, the explanation below should be coded with "2" because it explicitly represents the concepts (= "bullet is the main important thing", "to dodge is to try to get out") even if they are not the right ones according to the dictionary.

E.g., "To dodge the bullet. Well, to dodge, well the bullet is the main important thing, which is happening in the current moment, if you were trying to dodge it, it means that you're trying to get out having to think about the important issue of yeah I think, possibly."

3. The length of the explanation is not necessarily related with how elaborate the explanation is in terms of metaphoricity; in some cases short descriptions include the representation of each concept and the metaphorical mapping, thus may be coded with a "2". (Short descriptions may lack examples of situations for which the expressions can be used, which are not relevant for the coding)

4. The order that the representations should not affect the coding. So, for example in the explanation of the expression "to dodge the bullet" you might see the representation of the bullet first and then the one for dodging, or vice-versa.

5. If a response includes the meaning of the expression only (e.g., "to spill the beans is to tell a secret"), then it should be coded with a "0".

Supplemental material Text S3

Coding manual for maximum mouth opening laterality

(Developed by Sotaro Kita, Sarah Aldgate, Heather Golden, and Paraskevi Argyriou)

1. During speech the mouth opens and closes repeatedly without full closure except for the beginning and the end. We measure the laterality of the mouth (right, left, equal) at each maximum opening.

2. The coder selects one of the following options: the right side opens more, the left side opens more or they open equally. You make a judgment about opening based on the vertical dimension (not horizontal). Note, that during the production of one word more than one mouth openings might occur. The following pieces of information help determine the judgment:

(a) You can compare the maximum distance between the upper and the lower lips on the right and the left hand side. How much of the teeth you can see in each side can be helpful. But, note that you need to take into account how straight the teeth are arranged on each side.

(b) A "pull" in the upper or lower lip in a particular direction is informative. Sometimes, the muscle around the upper or the lower lip is contracted more so than the opposite side (i.e., left vs. right). When the upper lip is pulled, it looks thinner. When the bottom lip is pulled, it looks thicker. Note, however, you need to take into account the fact that some people naturally have a lip thinner/thicker on one side than the other. In some cases the wider opening is on the opposite side of the lip that is pulled. For example, the upper left lip is pulled and the right side of the mouth opens wider (This should be coded as "the right side opens more").

(c) How the lips are joined in the two corners of the mouth can be informative.

(d) How the lips open and close before and after the maximum opening may be informative. If one side opens sooner then that side maybe the side that opens at the maximum opening. (Note that which side opens wider may change during opening. But, we code the laterality for the maximum opening only). If one side closes sooner then that side may have been opened less wide than the other.

Specific coding issues for the application of the coding to the video recordings:

(1) You do not code the mouth openings in the beginning of each trial when participants repeat the phrase to be explained (e.g., “To spin a yarn means that”).

(2) You do not code the mouth when it opens for non-speaking purposes, such as smiles.

Supplemental Material Text S4

Analysis with metaphoricity treated as ordinal

Data from the metaphorical explanation task were analysed using cumulative link mixed effects (CLM) models and the package *ordinal* in the R Project for Statistical Computing environment, version 3.1.1 (Bates & Sarkar, 2012; Hothorn et al., 2012; R Development Core Team, 2011). Results remained the same. All ordered mixed effects regressions in the present study were carried out with "clmm()" function with Laplace approximation.

We fit CLM model to the measurement of the level of the metaphoricity. In the model, the hand, which was free for gesturing (left, right, no hand) was fixed effect and the "no hand" condition was treated as the reference category. We included random intercepts and slopes by subjects and items (phrases) for the fixed factor. We obtained *p*-values following the likelihood-ratio test approach for model comparison.

The contrasts of the maximal model are reported in Table 1. Likelihood model comparison with the null model with no fixed effect (same random effect structure) indicated that the addition of which hand was free for gesturing (left, right, none) improved the model fit: $\chi^2(2) = 15.171$, $p < .001$. Thus, gestures with the left compared to the right hand and not gesturing at all enhanced metaphorical processing as measured through the level of metaphoricity in metaphorical explanation.

Table 1 Contrasts of the model.

	Estimate	SE	z-value	p-value
No – Left Hand	-.952	.229	-4.157	< .001

No – Right Hand	-.428	.227	-1.879	.060
Right – Left Hand	-.524	.227	-2.303	.021

Supplementary material Text S5

Analysis with length of explanations as dependent variable

In this section, we focused on a different property of participants' responses, which is not metaphor related. We investigated whether which hand was free might have an effect on the length of participants' metaphorical explanations measured in number of words produced (M = 97.05, SD = 43.13). Note that this measurement does not capture number of different words produced. Any potential effect on length of explanations or speech rate may confound the observed effects on levels of metaphoricity (i.e., participants may be more metaphorical when they gestured with the left hand because they also produced more words compared to the other conditions). However, our research questions or theoretical background do not predict such effects, therefore we do not make strong claims based on this post-hoc, supplementary analysis.

We fit LME model to the measurement of length of explanations. Hand free (left, right, no hand) was fixed effect and the "no hand" condition was the reference category. We included random intercepts and slopes by subjects and items (phrases) for the fixed factor.

Model estimates are reported in Table 1. Likelihood model comparison with the null model with no fixed effect (same random effect structure) indicated that the addition of gesture handedness (left, right, none) did not improve the model fit: $\chi^2(2) = 2.699$, $p = .259$. Simultaneous tests for general linear hypotheses (Tukey Contrasts) revealed non-significant contrasts (see Table 2). Thus, we have no evidence that left or right hand gesturing or not gesturing at all affects the length of metaphorical explanations.

Table 1 Model estimates for the effect of hand free on length of explanations. No hand condition is the reference category.

	Estimate	SE	t-value
(Intercept)	93.248	6.716	13.884
Left Hand	3.848	2.970	1.296
Right Hand	5.902	3.832	1.540

Table 2 Contrasts for the effect of gesture handedness on length of explanations.

	Estimate	SE	z-value	p-value
No – Left Hand	-3.848	2.970	-1.296	.395
Right – Left Hand	2.054	3.630	.566	.837
No – Right Hand	-5.902	3.832	-1.540	.270

Next, we assessed the relationship between length of explanations and levels of metaphoricity. Averaged across participants, we found no significant correlation between the length of the explanations and levels of metaphoricity, r (29) = -.206, 95% CI [-.522, .159], p = .264. Thus, we have no evidence that metaphoricity levels in explanations relate to the amount of words participants produced.

Supplemental Material Text S6

Analysis of the mouth asymmetry data

We tested which side of the mouth opened wider during metaphorical and concrete explanation tasks. The left-side mouth dominance index was significantly lower than zero in the concrete (*M* = -.11, *SE* = .08, range = -.09 to 0.77), t (30) = -2.71, p = .011 but not in the metaphorical (*M* = -.24, *SE* = .09, range = -1 to .77), t (30) = -1.39, p = .176, condition. That is, in the concrete condition, the right side of the mouth opened wider than the left reflecting the important role of the left hemisphere for speaking. In the metaphorical condition, the same tendency was found numerically, but was not statistically significant.

In addition, we compared asymmetry of mouth openings during concrete and metaphorical explanations. A one-way repeated-measures ANOVA performed on the left-side mouth dominance index with linguistic task as the independent variable yielded significant effect of the task, F (1,30) = 6.45, p = .016, η_p^2 = .18. The left-side dominance score was significantly higher in metaphorical explanations (*M* = -.11, *SE* = .08, range = -.09 to 0.77) than in concrete explanations (*M* = -.24, *SE* = .09, range = -1 to .77). This replicates the results from Argyriou et al. (2015) and indicates that the right hemisphere was particularly involved during metaphorical phrase explanations, providing more evidence for the Right Hemisphere Hypothesis for Metaphor (Bottini et al., 1994). It is also line with other studies showing that mouth asymmetry measurement is sensitive to the relative involvement of the two brain hemispheres in speaking tasks (Graves & Landis, 1990). Finally, it further validates the mouth opening asymmetry as an index of the hemispheric involvement in speech production during the explanation tasks used in the current study.

Supplemental Material Text S7

Analysis with metaphoricity treated as ordinal

Data from the metaphorical explanation task were analysed using cumulative link mixed effects (CLM) models and the package *ordinal* in the R Project for Statistical Computing environment, version 3.1.1 (Bates & Sarkar, 2012; Hothorn et al., 2012; R Development Core Team, 2011). All ordered mixed effects regressions in the present study were carried out with "clmm()" function with Laplace approximation.

We fit CLM model to the measurement of the level of the metaphoricity. The model included two fixed effect factors and the interaction between the two. The one fixed factor was the hand free (left, right; dummy coded; "right" was the reference category). The model automatically selected "right" as the reference category against which the comparisons are made. The second fixed factor was presence/absence of spontaneous gestures (dummy coded; "absence" was the reference category). We included random intercepts and slopes by subjects and items (phrases) for the main effects and interaction of the fixed effect factors.

Model estimates are reported in Table 1. We compared the maximal model with the reduced model including the main effects only (same random effect structure). Adding the interaction did not significantly improve the model fit: $\chi^2(1) = .984$, $p = .321$. Though the interaction was not significant we further explored the contrasts for two reasons. Firstly, we had a priori predictions for the comparison of the spontaneous presence/absence of gestures within each hand condition. Secondly, a large number of missing values in the data made the test of interaction less powerful. Only 12 out of 32 participants had cells in all four conditions and fully contributed data for estimating the interaction effect. This was, mainly, because many participants did not have any trials without right-hand gestures (e.g., they spontaneously gestured in all right-hand free trials) and some participants did not have any trials with spontaneous left-hand gesture. In contrast, more participants could be included if we analysed the effect of presence/absence of spontaneous gestures for the left hand and for the right hand separately (e.g., 19 participants for the left hand and 18 participants for the right hand), which would lead to more reliable results. The tests of (function *lsmeans*()) revealed that the contrast between presence and absence of spontaneous gestures was significant for the left hand, but not for the right hand (the rest of the contrasts were not significant) (see Table 2). Thus, spontaneously gesturing with the left hand increased the level of metaphoricity in metaphorical explanation compared to not gesturing with it by choice.

Table 6 Coefficients of the maximal model. Right Hand Free and Absence of Spontaneous Gesture are the reference categories

Fixed Effect	Estimate	SE	p-value
Left Hand	-.447	.795	.574
Gesture Present	.658	.626	.294
Left Hand: Gesture Present	.791	.800	.323

Table 2 Contrasts for interaction.

	Estimate	SE	z-value	p-value
Left Hand Gesture Present vs. Absent	1.450	.466	3.107	.010
Right Hand Gesture Present vs. Absent	.658	.626	1.050	.719

Appendix Chapter 4

Supplemental Material Text S1

Coding Manual for Metaphor Identification in the Abstract Explanation Task

(Developed by Paraskevi Argyriou, Sotaro Kita, Louisa Hughes, University of Birmingham)

<u>Criteria for metaphor identification:</u>

1. Idiomatic metaphorical expressions, such as, "to sit on the fence", "to tie up loose ends" are identified as metaphorical units.

E.g. "To finalise details is like at the end of a process to almost tying up the loose ends".

2. A unit is metaphorical if there is a physically/spatially related concrete equivalent expression, which can serve as the source domain of the metaphor.

E.g. "let a memory go" ~ "let the dog go/ let my hand go" (= concrete; we let an object go) [MEMORIES ARE OBJECTS], thus the first "let go" is metaphorical.

E.g. "give away information" ~ "give away old clothes" (= concrete; we give away objects) [IDEAS/INFORMATION ARE OBJECTS] [SAYING IS GIVING], thus the first "give away" is metaphorical.

3. A unit is metaphorical if the coder can detect an underlying conceptual metaphor such as [IDEAS ARE OBJECTS] [LOVE IS A JOURNEY] etc. For every unit identified as metaphor, the coder should be able to detect (and note down) these conceptual schemas; either the underlying conceptual metaphor and/or the systematic metaphor (= more specific context metaphorical schema; note in italics).

E.g. "focus on important aspects" [UNDERSTANDING IS SEEING]

E.g. “get knocked back” [LIFE IS A WAR] DISAGREEING IS FIGHTING

Note 1: Most of the times criteria 2 and 3 are met together. However, coder should be always able to identify a conceptual metaphor. So, there might be cases where only criterion 3 is met. Then, again the unit should be identified as metaphor. Think of the example “to look to the future”. The expression “look to” does not have an equivalent concrete/physical (in English we use “look at something” instead of “look to”). However, it is identified as metaphor because there is an underlying conceptual metaphor [TIME IS VISIBLE SPACE].

Note 2: If a coder is “sitting on the fence” for identifying the conceptual metaphor because of ambiguity, then the explanation should be coded as non-metaphoric. For example, “go against that” > is not clear where the referential pronoun “that” is referring.

Note 3: The coder should read the explanation from start to end before coding. There might be cases when an expression is identified as metaphorical only after you read the proceeding sentence. For example, “to control means to put chains to someone, to restrain someone and influence their behavior like parents do with their children”. The expression in red when read alone without proceeding to the next sentence, is concrete and literal. However, it should be identified as a metaphor because it cannot be a literal reference to putting chains to children.

<u>Special cases:</u>

1. Do not include similes (metaphorical or non-metaphorical ones). E.g., “a catastrophe is like the worst possible thing that could happen”.

a. NOTE: “like” can be used as a filled pause when for example speakers are struggling to find the correct word. This use of “like” is not similes.

2. Do not include personifications (= humane features to inanimate concepts). E.g., “this is an unhelpful situation”. [A SITUATION IS A PERSON]

a. BUT do include examples when you can explain them with a different (from the [STH IS A PERSON]) underlying conceptual schema: e.g. “a situation rises” [A SITUATION IS AN OBJECT WHICH BECOMES VISIBLE]

3. Do not include highly frequent nouns: thing, -thing (as in something), part, way (if we do, it will result to very lengthy lists of metaphors and ceiling effects).

4. Common verbs, such as, keep, give, carry, get, go, come, have need special attention

Do not include cases, such as, “keep (on) trying” but do include cases such as, “keep a secret” (= the verb “keep” has a possessive meaning and “secret” is an abstract concept considered as an object in possession).

Do not include cases, such as, “carry (on) doing” but do include cases such as, “carry a meaning” (= the verb “carry” has a possessive meaning and “meaning” is an abstract concept considered as an object in possession).

Do not include cases, such as, “give up on someone” but do include cases such as, “give someone information” (= the verb “give” has a transitive meaning and “information” is an abstract concept considered as an object to be transferred).

Do not include cases, such as, “get used to something” but do include cases such as, “get your point across”; “it’s gotten out of hand”

Do not include cases, such as, “go on with what you do”, “something goes wrong” but do include cases such as, “go back in time and think what you have done” (= the verb “go” has the meaning of physical movement and “time” is considered a space to move into).

Do not include cases, such as, “come up with an idea” but do include cases such as, “an idea came to my mind” (= the verb “come” has the meaning of physical movement and “idea” is an abstract concept considered as a concrete object moving and entering a space).

Do not include cases, such as, “have a discussion” when “have” has no possessive meaning, rather represents the “experience of discussing”, or cases when “have” is used as an auxiliary verb (e.g., I have played) but do include cases such as, “have free time” (= the verb have has a possessive meaning and “time” is an abstract concept considered as an object in possession).

5. Do not include prepositions, such as, in(to), over, behind, on, up, down, within, between, out of, from through, by, for, of.

a. BUT do include examples when a unit (verb + preposition) creates a spatial source domain for a metaphor.

E.g. “to forgive is to put behind you something bad that has happened”. EXPERIENCES ARE OBJECTS, TIME IS A LINEAR PATH, PAST IS BEHIND.

6. Do not include highly frequent adjectives about size or texture, such as big, small, huge, hard, tough. E.g., “small details”, “big problem”, “huge disruption”, “hard question”. And especially the metacognitive comments by speakers, such as, “this is hard to explain without using the abstract word”.

Supplemental Material Text S2

Effect of type of hand movement and hand free on the length of explanations

In this section, we focused on a different property of participants' responses, which was not metaphor related. We investigated whether type of hand movement and hand free might have an effect on the length of participants' abstract explanations measured in number of words produced (*M* = 56.45, *SD* = 21.86). Note, this measurement does not capture number of different words produced.

We fit LME model to the measurement length of explanations (= number of words used in each explanation). The model included two fixed effect factors and the interaction between the two. The one fixed factor was the type of hand movement (tap, gesture; dummy coded; "tapping group" was the reference category). The second fixed factor was the hand free (left, right, no hand; "No hand" was the reference category). The random effects structure was kept maximal. The model included (a) random intercepts and slopes by subjects for the effect of hand free (type of hand movement was between-subjects manipulation hence a random slope by subjects was not necessary) and (b) random intercepts and slopes by items for the interaction between type of hand movement and hand free.

Model estimates are reported in Table 1. We compared the maximal model with the reduced model with the main effects only (same random effect structure). Adding the interaction between the type of hand movement (gesture, tap) and hand free (left, right, none) did not significantly improve the model fit: χ^2 (2) = .887, *p* = .641 (see Figure 1).

Table 1 Parameters estimates for the model with the main effects and interaction between the type of hand movement and hand free and on length of explanations. "No hand" and "tap" group were the reference categories.

	Estimate	SE	t-value
(Intercept)	51.582	2.858	18.044
Left Hand	.167	1.991	.084
Right Hand	-2.292	2.023	-1.133
Gesture	10.439	3.987	2.618
Left Hand:Gesture	.252	2.737	.092
Right Hand:Gesture	2.611	2.896	.902

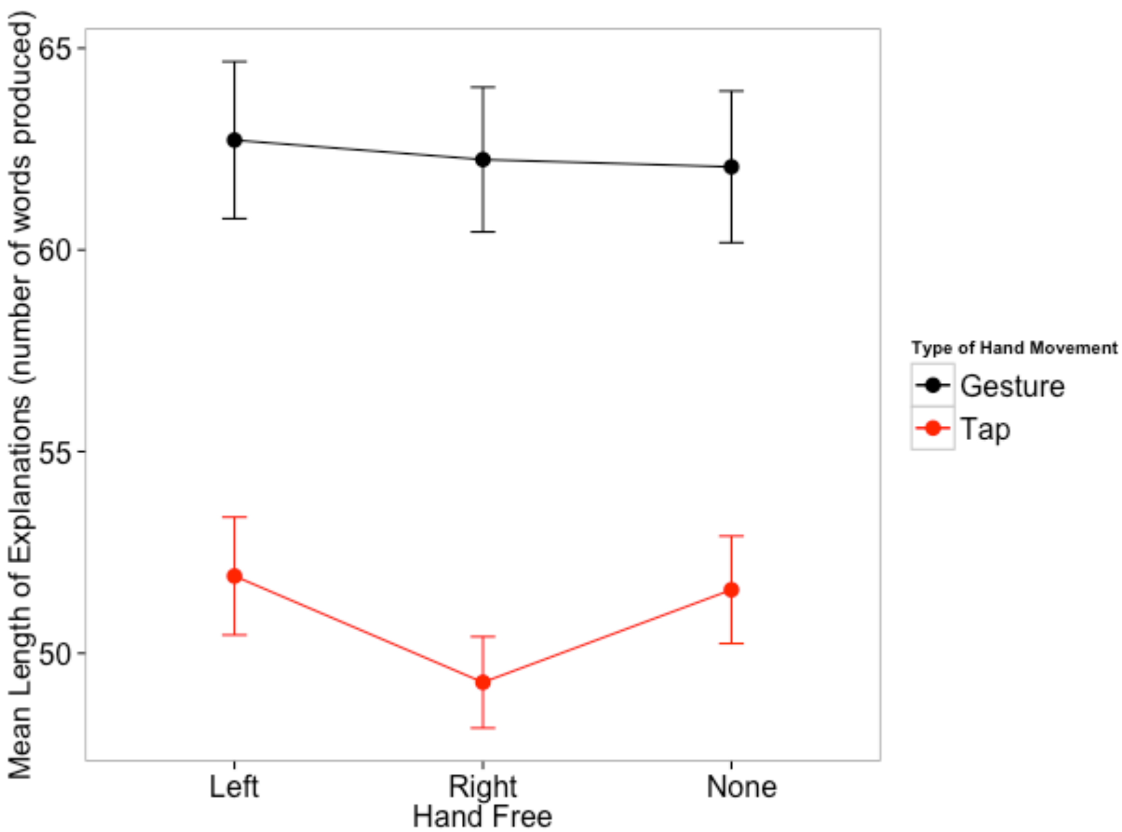

Figure 1 Mean length of explanations (= number of words uttered) in each gesturing and tapping condition. Error bars represent 1 standard error of the means.

We proceeded to model reduction and comparisons to investigate the main effect of type of hand movement. We compared the model with the main effects of type of hand movement and hand free with the model with the main effect of hand free only. Adding the effect of the type of hand movement (gesture, tap) improved the model fit: $\chi^2 (1) = 10.843$, $p < .001$. Simultaneous tests for general linear hypotheses (Tukey Contrasts) showed that participants who gestured were more talkative and produced lengthier explanations compared to those who tapped (see Table 2).

Table 2 Significant Tukey contrasts for the model with the main effect of type of hand movement on the length of explanations.

	Estimate	SE	z-value	p-value
Gesture – Tap	11.853	3.467	3.419	< .001

Note that this was an unexpected finding, which does not fall within the focus of the present thesis. However, it seems that there is difference even between the baseline conditions; that is when participants from either group did not move. Therefore, interpretation is tenuous and the effect of type of hand movement on 'verbosity' should be investigated in future research (i.e., in a within subjects design).

Appendix Chapter 5

Supplemental Material Text S1

Pre-test

In the following sections the pre-test is described in detail. Pre-testing was essential to select the stimuli for the main experiment. It was completed in two phases by participants different from the ones participated in the main experiment.

Pre-test Phase 1

Material and methods

Participants

12 subjects (5 males; age: M = 22.17 years, SD = 3.27) took part in the experiment for payment of £6 upon completion of the tasks. All participants were right-handed, English native speakers and students at the University of Birmingham. Handedness was assessed with a 12-items questionnaire based on the Edinburgh Handedness Inventory (Oldfield, 1971). Two bimanual items (from Oldfield's long list) were added to his recommended 10-items questionnaire to equate the number of unimanual and bimanual items. Text S1 in Appendix Chapter 3 includes the questionnaire. Each "left" answer was scored with 0, each "either" answer with 0.5, and each "right" answer with 1. A total score of 8.5 and above determined right-handedness (M = 11.17, SD = .49).

Stimuli

Videos We selected 10 English transitive action verbs (see Table 1). We asked 3 native English speakers, right-handers to gesturally depict the 10 action verbs. We created a detailed description of the kinematic parameters for each gesture (see Text S2 in the current Appendix for details). A right-handed male was recruited and videotaped while performing the 10 unimanual (right-hand only) gestures following this detailed description. Stimuli were videotaped in order to obtain first-person perspective, they were object-empty gestures (no physical object was present) although the action directs to an object - this way in the main priming task we would test visuo-semantic activations prompted exclusively from gesture execution rather than physically presented objects - and they lasted 2.5 seconds each (see Figure 1 for static example).

Table 1 Complete list of action verbs used to be gesturally depicted in videos

Action verbs				
Bash	Bend	Grasp	Pull	Push
Raise	Shake	Spin	Stir	Twist

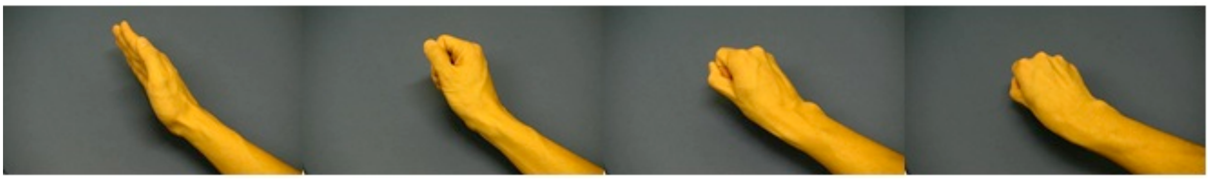

Figure 1 Snapshots from video stimulus to depict action “to bend”.

Sentences We used the 10 action verbs and created 3 sentences with metaphorical and 3 with literal meaning for each verb (see Table 2). Each pair of metaphorical and literal sentences shared the same subject noun phrase (S-NP hereafter), the same verb (in simple past form) and differed in the object noun phrase (O-NP hereafter). The S-NP was always an animate agent (e.g., The artist). The metaphorical sentence had an abstract O-NP (e.g., the idea) and the literal sentence had a concrete O-NP (e.g., the painting). In total, we created and tested 62 sentences. Note, that for the verb "twist" we created 4 sentences with metaphorical and 4 with literal meaning. Each metaphorical and literal pair was matched for frequency of the object noun phrase using the CELEX English linguistic database. A paired samples t-test yielded non-significant difference between the frequency of the literal and metaphorical O-NP: t (30) = .55 p = .581.

Table 2 Complete list of literal and metaphorical action pairs of sentences. Pairs were matched for the frequency of the O-NP.

Metaphorical Action Sentences	Literal Action Sentences
The artist bashed the proposal	The artist bashed the painting
The employee bashed the idea	The employee bashed the door
The reporter bashed the decision	The reporter bashed the window
The worker bent the rule	The worker bent the wire
The technician bent the facts	The technician bent the stick
The builder bent the truth	The builder bent the wood
The student grasped the solution	The student grasped the flowers
The boy grasped the meaning	The boy grasped the bottle
The daughter grasped the concept	The daughter grasped the handle
The leader pulled the financing	The leader pulled the lever
The performer pulled the audience	The performer pulled the handle
The producer pulled the movie	The producer pulled the flower

The minister pushed the plan	The minister pushed the desk
The leader pushed the reforms	The leader pushed the button
The workers pushed the scheme	The workers pushed the handle
The boss raised the wage	The boss raised the beer
The mother raised the income	The mother raised the bottle
The decorator raised the price	The decorator raised the box
The terrorist shook the authority	The terrorist shook the weapons
The thief shook the borough	The thief shook the matchbox
The fireman shook the nation	The fireman shook the tree
The player spun the truth	The player spun the ball
The lady spun the tale	The lady spun the thread
The presenter spun the news	The presenter spun the wheel
The artist stirred the emotions	The artist stirred the paint
The cook stirred the senses	The cook stirred the beans
The magician stirred the crowd	The magician stirred the liquid
The climber twisted the facts	The climber twisted the rope
The man twisted the plot	The man twisted the wire
The designer twisted the truth	The designer twisted the hair
The scientist twisted the proof	The scientist twisted the wire

Procedure

The first task (approx. 25-30 minutes) was a *judgment of similarity of the gesture videos*. This task informed us to create the mismatching combinations for the incongruent conditions between prime and target in the main experiment. Participants watched two gesture videos in successive order (video gesture A first and video gesture B second). The videos were presented in a laptop screen (MacBook Pro, 13 inches) through a PowerPoint presentation. They were asked to rate on a scale from -3 to +3 "how similar is the meaning represented with gesture A to the meaning represented with gesture B" ("-3" being "extremely dissimilar", "-2" being "very dissimilar", "-1" being "moderately dissimilar", "0" being "difficult to say if similar or dissimilar", "+1" being "moderately similar", "+2" being "very similar", "+3" being "extremely similar"). The similarity rating focused on semantics, that is the meaning represented by each gesture and how participants would label it, rather than the kimematic parameters of the hand movement (e.g. hand shape, position of fingers, speed of movement, direction of movement, sharpness of movement). We tested all 55 possible combinations. The order of the video presentation (first-second video) was counterbalanced across participants. The task ran in 3 blocks (20 trials, 20 trials, 15 trials) with two brief breaks when/if needed. Participants gave their responses orally and experimenter kept a note of their rating.

Next, there was a task (approx. 7 minutes) of *video naming* to ensure that participants interpret the meaning of the gestures as expected. The experimenter showed each gesture video once and asked participants "please watch the video and tell me what is the meaning of the gesture you saw by using an action verb to label each gesture". Participants gave their responses orally and experimenter kept a note of their labelling.

In turn, participants completed 3 computer-based tasks to collect information for the target sentences in terms of the following: (a) *surprising element of the O-NP following the S-*

NP (O-NP predictability)*,* (b) *level of figurativeness*, (c) *familiarity* of the verb phrase (verb + O-NP). All tasks were run through experimental software E-Prime. Each trial started with a fixation point (a red dot) in the middle of the screen. For tasks (a) and (b) sentences were presented as follows: first the S-NP (e.g., "The artist") appeared on the centre of the screen for 700 msec. It stayed in the middle of the screen and then the verb and the O-NP (e.g., "bashed the proposal") was displayed a bit lower on the screen until a response was given. For task (a) (no more than 7 minutes) participants were asked to rate on a scale from -3 to +3 "how surprising was the second part of the sentence you read" ("-3" being "extremely unsurprising", "-2" being "very unsurprising", "-1" being "moderately unsurprising", "0" being "difficult to say if unsurprising or surprising", "+1" being "moderately surprising", "+2" being "very surprising", "+3" being "extremely surprising"). For task (b) (no more than 7 minutes) participants were asked to rate on a scale from -3 to +3 "how metaphorical was the sentence you read" ("-3" being "extremely literal", "-2" being "very literal", "-1" being "moderately literal", "0" being "difficult to say if literal or metaphorical", "+1" being "moderately metaphorical", "+2" being "very metaphorical", "+3" being "extremely metaphorical"). For task (c) (no more than 5 minutes) participants saw the verb phrases in one part (e.g., "bash the proposal"; "bash the painting") and rated on a scale from -3 to +3 "how familiar to you was the phrase you read" ("-3" being "extremely unfamiliar", "-2" being "very unfamiliar", "-1" being "moderately unfamiliar", "0" being "difficult to say if unfamiliar or familiar", "+1" being "moderately familiar", "+2" being "very familiar", "+3" being "extremely familiar"). Order of trials (literal – metaphorical) was random. Response was given through keyboard by pressing the respective key from 1 to 7. A reminder of each scale was given throughout the task as shown in Figure 2.

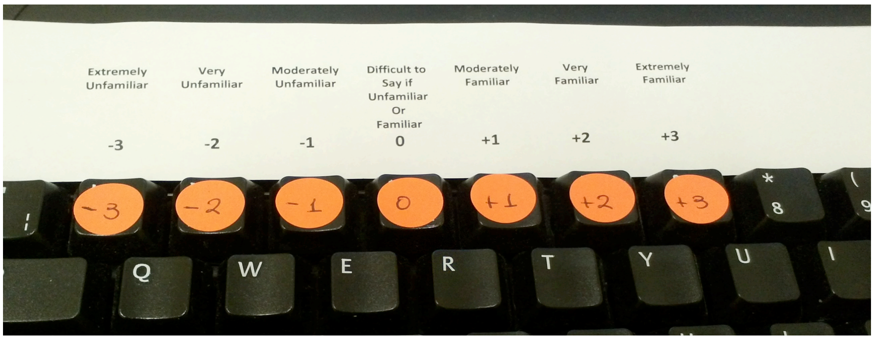

Figure 2 Scale reminder for rating tasks.

Results

In general, participants rated the combinations of the gesture videos as being “moderately to very dissimilar” (*M* = -1.58, *SD* = .56). From all possible combinations we selected the five most dissimilar ones (mean ranging from “very” to “extremely dissimilar”) (see Table 3). For example, in the incongruent conditions in the main experiment we used: raise (gesture prime) – twist (target sentence) and twist (gesture prime) – raise (target sentence).

Table 3 Incongruent pairs for main experiment. Means are all across participants (N= 12).

Incongruent Pairs		Mean Similarity Judgment
Raise	Twist	-2.50
Spin	Bend	-2.17
Pull	Shake	-2.42
Push	Grasp	-2.25
Bash	Stir	-2.42

In general, participants gave the gesture videos the expected associated meaning. Note, that even if they did not use the exact action verb they would use synonyms (e.g., "grab" instead of "grasp") or they would answer "yes" in experimenter's question "would this mean grasp?" See Text S3 in the current Appendix for complete list of the verbal labels given to the 10 gestures.

The complete list of the paired sentences did not differ significantly in terms of the O-NP predictability, t (30) = 1.868, p = .072, and verb phrase familiarity, t (30) = -.642, p = .526. As expected, there was a significant difference in terms of figurativeness with metaphorical sentences being rated as more metaphoric than the literal, t (30) = 28.309, p < .001.

We reduced this balanced list of sentences into 20 pairs of literal and metaphorical sentences. To do so, we carefully examined each sentence pair and excluded pairs according to the following criteria: (a) rating on each scale (predictability, figurativeness, familiarity) was 2SDs above/below the mean, (b) sentence pair had more than 1 points difference in O-NP predictability and familiarity rating, (c) metaphorical sentence was rated as literal or vice-versa. Therefore, we created a reduced list to be used in the main experiment (see Table 4). Paired comparisons between the metaphorical and the literal sentences of the reduced list yielded the following results: (a) frequency of O-NP, t (19) = .272, p = .788, (b) predictability of the O-NP, t (19) = 2.284, p = .034, (c) familiarity, t (19) = -1.056, p = .304, and (d) figurativeness, t (19) = 27.075, p < .001.

Table 4 The list of sentence stimuli for the main experiment.

Metaphorical Action Sentences	Literal Action Sentences
The employee bashed the idea	The employee bashed the door
The reporter bashed the decision	The reporter bashed the window
The worker bent the rule	The worker bent the wire
The technician bent the facts	The technician bent the stick
The boy grasped the meaning	The boy grasped the bottle
The daughter grasped the concept	The daughter grasped the handle
The leader pulled the financing	The leader pulled the lever
The performer pulled the audience	The performer pulled the handle
The leader pushed the reforms	The leader pushed the button
The workers pushed the scheme	The workers pushed the handle
The mother raised the income	The mother raised the bottle
The decorator raised the price	The decorator raised the box
The terrorist shook the authority	The terrorist shook the weapons
The thief shook the borough	The thief shook the matchbox
The lady spun the tale	The lady spun the thread
The presenter spun the news	The presenter spun the wheel
The artist stirred the emotions	The artist stirred the paint
The magician stirred the crowd	The magician stirred the liquid

The man twisted the plot	The man twisted the wire
The designer twisted the truth	The designer twisted the hair

Conclusions

The pairs of metaphorical and literal sentences to be used in the main experiment (a) were perfectly matched for the frequency of the O-NP and for familiarity of the verb phrase, (b) had a difference in terms of the O-NP predictability, with the literal sentences having a more surprising O-NP to follow the S-NP than the metaphorical sentences, and (c) were clearly differentiated in terms of figurativeness. We believe that performance in the main task could not be modulated by the observed differences in the O-NP predictability.

Pre-test phase 2

Material and methods

Participants

12 subjects (3 males; age: M = 22.42 years, SD = 6.01) took part in the experiment for 0.2 credits upon completion of the tasks. All participants were right-handed, English native speakers and students at the University of Birmingham. Handedness was assessed with a 12-items questionnaire based on the Edinburgh Handedness Inventory (Oldfield, 1971). Two bimanual items (from Oldfield's long list) were added to his recommended 10-items questionnaire to equate the number of unimanual and bimanual items. Each "left" answer was scored with 0, each "either" answer with 0.5, and each "right" answer with 1. A total score of 8.5 and above determined right-handedness (M = 11.25, SD = .94). Text S1 in Appendix Chapter 3 includes the questionnaire.

Stimuli

Based on the data from the first phase of the pre-test we created all 80 possible combinations for the video-sentence similarity task. For example, participants would watch the video with the gesture "raise" and (a) read the sentences "the mother raised the income" (Congruent and Metaphorical), "the decorator raised the price" (Congruent and Metaphorical), "the mother raised the bottle" (Congruent and Literal), "the decorator raised the box" (Congruent and Literal), and (b) read the sentences "the man twisted the plot" (Incongruent and Metaphorical), "the designer twisted the truth" (Incongruent and Metaphorical), "the man twisted the wire" (Incongruent and Literal), "the designer twisted the hair" (Incongruent and Literal).

Procedure

For the task of the video-sentence similarity (approx. 15 minutes) participants watched the videos with the gestures, and after the video they read the sentences presented in two parts as follows: first the S-NP (e.g., "The artist") appeared on the centre of the screen for 700 msec. It stayed in the middle of the screen and then the verb and the O-NP (e.g., "bashed the proposal") was displayed a bit lower on the screen until a response was given. They were asked to rate on a scale from -3 to +3 "how well did the meaning of the gesture you watched match the meaning of the sentence you read" ("-3" being "extremely bad match", "-2" being very bad match", "-1" being "moderately bad match", "0" being "neither bad nor good match/ difficult to say if bad or good match", "+1" being "moderately good match", "+2" being "very good match", "+3" being "extremely good match"). We expected that (a) the congruent conditions will be rated as "good matches" and the incongruent conditions as “bad matches”, and (b) there will be no significant difference between metaphorical and literal sentences for the congruency rating.

Results

A 2 x 2 repeated measures ANOVA yielded a significant main effect of prime type (congruent, incongruent), F (1, 11) = 677.357, p < .001, η_p^2 = .984. On average and as expected, participants rated the incongruent video-sentence combinations as “very bad matches” (M = -2.096, SE = .115) and the congruent combinations as “very good to extremely good matches” (M = 2.263, SE = .103). There was no significant effect of the sentence type (metaphorical, concrete), F (1, 11) = 2.292, p = .158. On average, participants rated the metaphorical (M = .031, SE = .088) and literal (M = .135, SE = .066) sentences as “moderately good matches” with the preceding video gesture. There was no significant interaction between prime and sentence type F (1, 11) = 4.129, p = .067.

Conclusions

The combinations of gesture videos-sentences, which were the prime-target combinations in the main experiment, were successfully constructed in terms of congruency, and were matched for both metaphorical and literal sentences.

Supplemental Material Text S2

Gestures' description for gesture enactment

Bash: Tight fist (thumb on the index finger, fingers facing left). Forward rapid movement (as if I am bashing something in front of me, in the centre). 3 quick repetitions.

Bend: Fist tightly closed; thumb on the index finger, facing down. Slow rotatory movement from the elbow from left to right.

Grasp: Open palm, facing left, loose fingers. Hand moves to the centre. Fingers close to create a fist. Vertical upward movements (not towards body) and tight closure.

Pull: Palm semi-close as in before forming a fist, horizontal movement from outside towards body while fist is closing (thumb on the index finger). Basically, reach out, clench, and pull.

Push: Palm open, facing front, comes close to the body. Rapid and forceful movement away from the body (palm remains as it is).

Raise: Open palm, fingers loose, facing up and slow movement upwards (as if something on the palm).

Shake: Open palm facing left as if holding big glass. Hand moves from side to side (horizontally).

Spin: Index finger sticking out and pointing left. Circular movement of the arm horizontally.

Stir: Fingers closed, facing down (as if holding stick). Hand comes in front of the body in the centre. Rotatory movement with the whole arm clockwise (as if stirring something in a big bowl).

Twist: Closed fingers, thumb on the index finger. Rotatory movement of the wrist from left to right (as if turning a key in a key hole).

Supplemental Material Text S3

Complete list of verbal labels given to gesture videos.

Video Watched	First Verbal Label	Number of Participants	Second Verbal Label	Number of Participants
Bash	Bang	1	***Bash***	***3***
	Bash	***3***	Punch	2
	Punch	7	Hit	1
	Push	1	Saw	1
Bend	***Bend***	***2***	***Bend***	***4***
	Pour	7	Pour	2
	Turn	2		
	Twist	1		
Grasp	Close	1	Collate	1
	Grab	4	Grab	1
	Grasp	***5***	***Grasp***	***1***
	Pick up	2	Pick up	1
Pull	Lift	1	***Pull***	***2***
	Pour	2		
	Pull	***9***		
Push	***Push***	***11***	Clear away	1

	Stop	1	Shove	1
			Stop	2
			Wait	1
Raise	Hold	1	Drink	1
	Lift	2	Lift	3
	Pick up	4	Pick up	3
	Raise	***5***	***Raise***	***1***
			Salute	1
Shake	***Shake***	***12***	Mix	1
			Size	1
Spin	Circle	1	Keep going	1
	Go around	1	Mix	1
	Spin	***7***	Repeat	1
	Turn around	1	Rotate	1
	Twirl	2	Stir	2
			Twirl	2
Stir	Mix	1	Mix	4
	Stir	***11***		
Twist	Turn	6	Open	1
	Twist	***4***	Turn	3

Unlock	2	Turn over	1
		Twist	***1***
		Unlock	1

Supplemental Material Text S4

Example of a sentence repetition for each experimental condition

1. Congruent Metaphorical Left [Condition CML] *e.g. The employee bashed the idea*
2. Incongruent Metaphorical Left [Condition InML] *e.g. The employee bashed the idea*
3. Congruent Metaphorical Right [Condition CMR] *e.g. The employee bashed the idea*
4. Incongruent Metaphorical Right [Condition InMR] *e.g. The employee bashed the idea*
5. Metaphorical [Baseline with no prime] *e.g. The employee bashed the idea*
6. Metaphorical [Baseline with no prime] *e.g. The employee bashed the idea*
7. Congruent Literal Left [Condition CLL] *e.g. The employee bashed the door*
8. Incongruent Literal Left [Condition InLL] *e.g. The employee bashed the door*
9. Congruent Literal Right [Condition CLR] *e.g. The employee bashed the door*
10. Incongruent Literal Right [Condition InLR] *e.g. The employee bashed the door*
11. Literal [Baseline with no prime] *e.g. The employee bashed the door*
12. Literal [Baseline with no prime] *e.g. The employee bashed the door*
13. Congruent Metaphorical Left [Condition CML] *e.g. The reporter bashed the decision*
14. Incongruent Metaphorical Left [Condition InML] *e.g. The reporter bashed the decision*
15. Congruent Metaphorical Right [Condition CMR] *e.g. The reporter bashed the decision*

16. Incongruent Metaphorical Right [Condition InMR] *e.g. The reporter bashed the decision*

17. Metaphorical [Baseline with no prime] *e.g. The reporter bashed the decision*

18. Metaphorical [Baseline with no prime] *e.g. The reporter bashed the decision*

19. Congruent Literal Left [Condition CLL] *e.g. The reporter bashed the window*

20. Incongruent Literal Left [Condition InLL] *e.g. The reporter bashed the window*

21. Congruent Literal Right [Condition CLR] *e.g. The reporter bashed the window*

22. Incongruent Literal Right [Condition InLR] *e.g. The reporter bashed the window*

23. Literal [Baseline with no prime] *e.g. The reporter bashed the window*

24. Literal [Baseline with no prime] *e.g. The reporter bashed the window*

Supplemental Material Text S5

Results from rating tasks in detail

All participants rated the stimuli after the main task. In this section, we compared the ratings between the literal and metaphorical sentences. This way we ensured that no other linguistic properties could account for any observed effects between metaphorical and literal sentences, and that the target stimuli were carefully controlled based on the ratings' by the same participants who completed the main task.

There were no significant differences between the literal and metaphorical sentences in terms of their familiarity t (37) = -.561, p = .578. Participants rated the metaphorical sentences as "moderately familiar" (M = 1.089, SE = .11) and the literal sentences as "moderately familiar" (M = .998, SE = .14) at a comparable level. As expected and to confirm the figurativeness level of the stimuli, there was a significant difference between the literal and metaphorical sentences in terms of their figurativeness t (37) = -27.536, p < .001. Participants rated the metaphorical sentences as "very metaphorical" (M = 2.014, SE = .08) and the literal sentences as "very literal" (M = -2.081, SE = .08). Overall, participants rated both metaphorical and literal sentences as having a "moderately unsurprising" second half (Verb + O-NP) part following the S-NP. As in the pre-test, there was a significant difference between the literal and metaphorical sentences in terms of the predictability of the verb phrase (t (37) = 2.814, p = .008) with participants rating the literal sentences as having a more surprising verb phrase (M = -.443, SE = .12) than the metaphorical sentences (M = -.778, SE = .09). However, we do not think this difference is relevant to the nature of the task and to participants' performance.

For the video-sentence similarity task, overall participants rated that the meaning of the sentence and the meaning of the gesture were a "very good match" for both literal and metaphorical sentences in the congruent combinations. Also, they rated that the meaning of the sentence and the meaning of the gesture were a "very bad match" for both literal and metaphorical sentences in the incongruent combinations. A 2 x 2 repeated measures ANOVA yielded a non-significant effect of the sentence type F (1, 37) = 3.132, p = .085, a significant effect of the prime type F (1, 37) = 904.704, p < .001 and (contrary to the pre-test) a significant interaction effect F (1, 37) = 35.881, p < .001. This indicates that similarity ratings were more moderate for the metaphorical (M = 1.84, SE = .085) than the literal sentences (M = 2.14, SE = .075) (see Figure 1). This is not surprising. Comparing the meaning of an abstract metaphorical sentence to that of a concrete visual action gesture was more "difficult" than comparing literal sentences with gesture videos. Hence, participants' ratings were accurate for both metaphorical and literal sentences, but expressed in a "less confident" way for the metaphorical sentences. We believe this difference could not account for any observed differences in the main task, where the videos were not used.

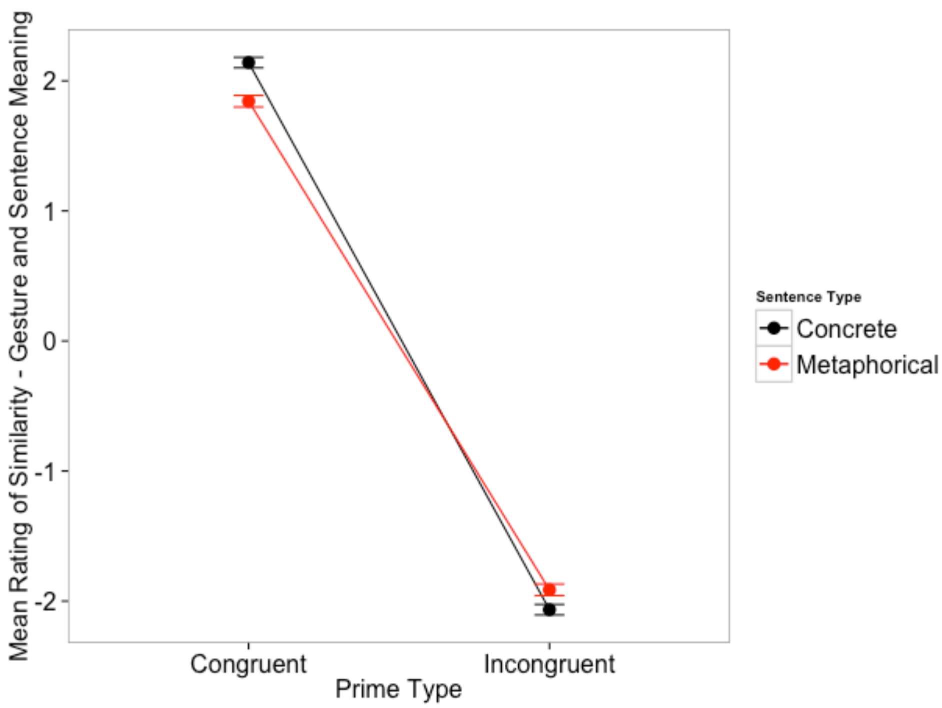

Figure 1 Rating of similarity between the meaning of the gestures and the meaning of the sentences.

Supplemental Material Text S6

Accuracy Results

Firstly, we assessed the 2 x 3 interaction between sentence type and prime type. We fit GLME model to the measurement of accuracy of semantic categorisation. The model included two fixed effect factors and the interaction between the two. The one fixed factor was the sentence type (metaphorical, literal; dummy coded; "literal" was the reference category). The second fixed factor was the prime type (congruent, incongruent, no prime; "no prime" condition was the reference category). For the random effects structure it was necessary to use a data-driven approach and simplify it to reach convergence. The maximal model to include (a) random intercept and slope by subjects for the interaction between sentence type and prime type and (b) random intercept and slope by items for prime type did not converge. Thus, we included random intercepts only by subjects and items (phrases) assuming that sentence and prime type are invariant across subjects and items.

Model estimates are reported in Table 1. We compared the maximal model with the reduced including the main fixed effects only (same random effect structure). Adding the interaction between sentence and prime type did not significantly improve the model fit: χ^2 (2) = .191, p = .908 (see Figure 1). Thus, there is no evidence that the interaction between type of action sentences (metaphorical or literal) and prime type (congruent, incongruent, no prime) modulated the accuracy of participants' semantic categorisation task.

Table 1 Parameters estimates for the model with the main effects and interaction of the sentence and prime type on accuracy of semantic categorisation. “Literal” sentences and “No prime” were the reference categories.

	Estimate	SE	z-value	p-value
(Intercept)	3.832	.255	14.973	< .001
Metaphorical	.588	.276	2.127	.033
Congruent	-.006	.195	-.035	.972
Incongruent	-.057	.194	-.298	.765
Metaphorical:Congruent	.107	.324	.333	.739
Metaphorical:Incongruent	-.032	.314	-.105	.916

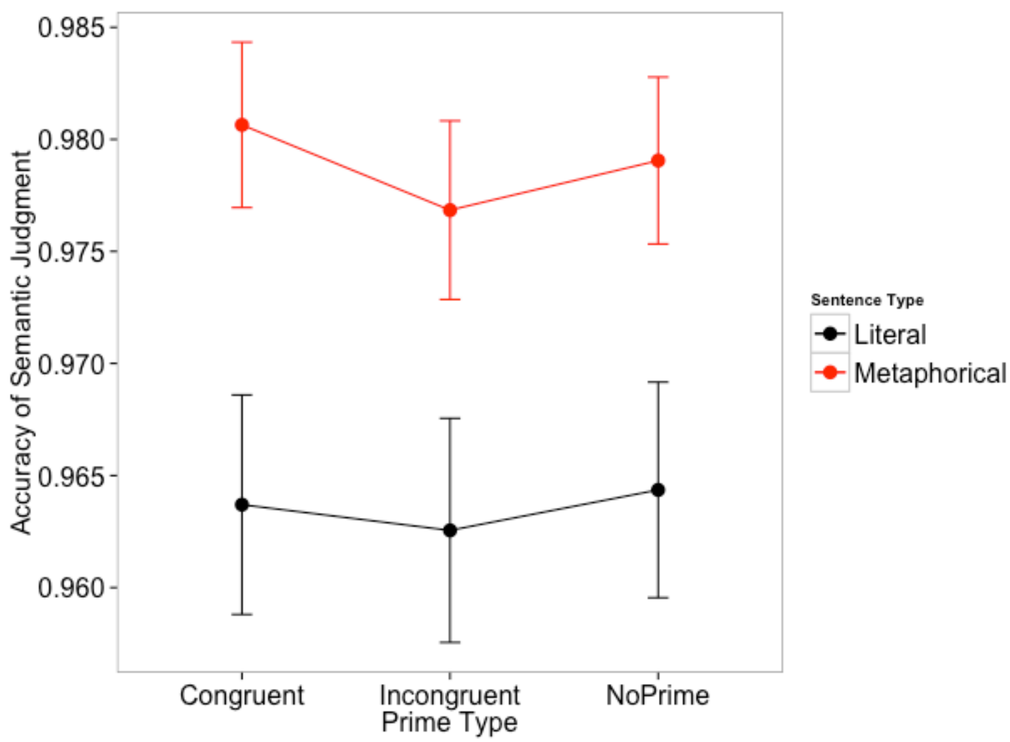

Figure 1 Accuracy of semantic categorisation of literal and metaphorical sentences in the three priming conditions. Error bars represent 1 standard error of the means.

Next, we proceeded to model reduction and comparisons to investigate the main effect of prime type. We compared the model including the main effects of sentence and prime type with the model including the main effect of sentence type only. Adding the effect of prime type (congruent, incongruent, no prime) did not significantly improve model fit: χ^2 (2) = .430, p = .806. In addition, we compared the model including the main effects of sentence and prime type with the model including the main effect of prime type only. Adding the effect of sentence type (metaphorical, literal) improved model fit: χ^2 (1) = 7.806, p = .005. In particular, participants were more likely to be accurate when categorising metaphorical than literal action sentences (see Table 2).

Table 2 Tukey contrasts for the model with the main effect of sentence type on accuracy of semantic categorisation.

	Estimate	SE	z-value	p-value
Metaphorical – Literal	.609	.207	2.933	.003

Secondly, we assessed the 2 x 2 x 2 interaction between sentence type (metaphorical, literal), prime type (congruent, incongruent) and hand (left, right). We excluded the baseline condition of “no prime” (trials reduced to 5722). We fit GLME model to the measurement of accuracy. The model included three fixed effect factors and the interaction between the three. The one fixed factor was the sentence type (metaphorical, literal; dummy coded; “literal” was the reference category). The second fixed factor was the prime type (congruent incongruent; “incongruent” was the reference category). The third fixed factor was the hand used for gesturing (left, right; “right” was the reference category). For the random effects structure we had to use a data-driven approach and simplify the model to reach convergence. The maximal model to include (a) random intercept and slope by subjects for the interaction between sentence type, prime type and hand, and (b) random intercept and slope by items for the interaction between prime type and hand did not converge. Thus, we included random intercepts only by subjects and items (phrases) assuming that sentence type, prime type and hand used were invariant across subjects and items.

Model estimates are reported in Table 3. We compared the maximal model with the reduced model including the main fixed effects only (same random effect structure). Adding the three way interaction between sentence, prime type and hand did not significantly improve the model fit: $\chi^2(4) = 1.806$, $p = .771$ (see Figure). Thus, there is no evidence that the interaction between the type of action sentence (metaphorical or literal), prime type (congruent, incongruent) and hand used for gesturing (left, right) modulated participants' accuracy in the semantic categorisation task.

Table 3 Parameters estimates for the model with the main effects and three-way interaction of sentence type, prime type and hand used for gesturing on accuracy. "Literal" sentences, "Incongruent" condition and "Right Hand" were the reference categories.

	Estimate	SE	z-value	p-value
(Intercept)	3.664	.270	13.525	< .001
Metaphorical	.636	.362	1.754	.079
Congruent	.014	.280	.050	.960
Left Hand	-.129	.271	-.478	.632
Metaphorical:Congruent	-.156	.454	-.344	.730

Metaphorical:Left Hand	-.206	.438	-.472	.637
Congruent:Left Hand	.078	.385	.205	.837
Metaphorical:Congruent:Left Hand	.592	.643	.921	.357

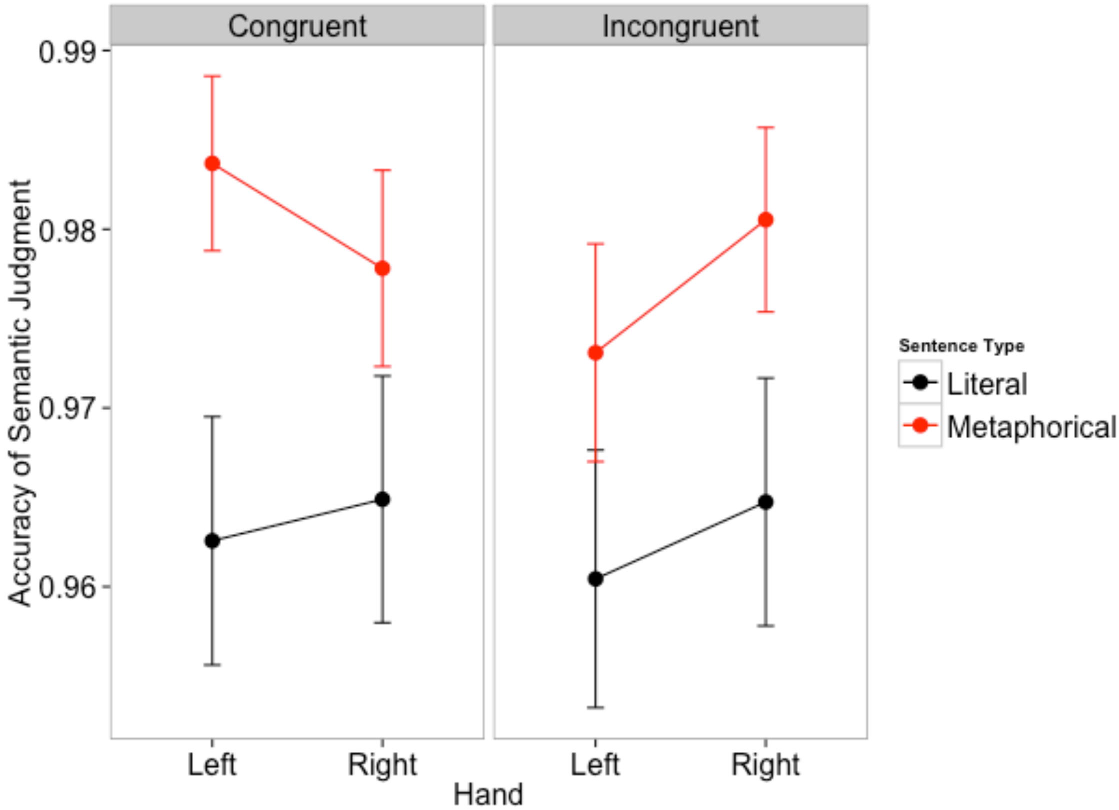

Figure 2 Accuracy for the semantic categorisation of the literal and metaphorical sentences for congruent and incongruent conditions, with the left and the right hand. Error bars represent 1 standard error of the means.

Next, we proceeded to model reduction and comparisons to investigate the two-way interaction between sentence and prime type. We compared the model including the two-way interaction with the reduced model including the main fixed effects only (same random effect structure). Adding the interaction did not significantly improve model fit: $\chi^2\,(1) = .158$, p =

.690. Thus, there is no evidence that the interaction between the type of action sentence (metaphorical or literal) and the prime type (congruent, incongruent) modulated participants' accuracy in the semantic categorisation task.

Finally, we proceeded to model reduction and comparisons to investigate the main effect of prime type. We compared the model including the main effects of sentence and prime type with the model including the main effect of sentence type only. Adding the effect of prime type did not improve model fit: χ^2 (1) = .419, p = .517. In addition, we compared the model including the main effects of sentence and prime type with the model including the main effect of prime type only. Adding the effect of sentence type improved model fit: χ^2 (1) = 6.14, p = .013. Simultaneous tests for general linear hypotheses (Tukey Contrasts) revealed that participants' semantic categorisation was more accurate for metaphorical than literal sentences (see Table 4).

Table 4 Tukey Contrasts for the model with the main effect of sentence type on accuracy.

	Estimate	SE	z-value	p-value
Metaphorical – Literal	.584	.222	2.631	.008

To sum up, we did not draw conclusions from the accuracy analysis, however it is worth to note that the sentence type had a significant effect on the accuracy of categorisation. Participants were more accurate in the semantic categorisation of metaphorical than literal action sentences. Note, this finding was not predicted and it was revealed while overall accuracy was at ceiling. A possible explanation for this could be that participants had a response bias towards the marked metaphorical stimuli.

Appendix Chapter 6

Supplemental Material Text S1

Information about words that appear in both concrete and metaphorical conditions

The table below includes the complete list of words that appeared in both concrete and metaphorical conditions at least once. We provide information about the token frequency in each condition in percentages (the number in brackets indicates the exact count of the word's occurrence in each condition). Note, that some words appear in both word categories. For example, "any" was coded as a content word when used as adverb and as function word when used as determiner. We indicate in brackets the role of the word based on the context.

Content Words			**Function Words**		
	Concrete Task	**Metaphorical Task**		**Concrete Task**	**Metaphorical Task**
Action	60% (3)	40% (2)	A	68% (39)	32% (18)
Any (*Adverb*)	67% (2)	33% (1)	All	50% (1)	50% (1)
Bad	6% (1)	94% (15)	And	60% (56)	40% (37)
Basically	31%	69%	Any	50%	50%

	(5)	(11)	(*Determiner*)	(1)	(1)
Being (*Intransitive*)	33% (2)	67% (4)	Be (*Auxiliary*)	33% (12)	67% (24)
Certain	67% (2)	33% (1)	Before (*Conjunction*)	67% (2)	33% (1)
Current	17% (1)	83% (5)	Being (*Auxiliary*)	17% (1)	83% (5)
Different	60% (3)	40% (2)	Can	60% (3)	40% (2)
Fire	13% (4)	88% (28)	Have (*Auxiliary*)	50% (1)	50% (1)
Generally	50% (2)	50% (2)	Is	70% (70)	30% (30)
Get	8% (1)	92% (11)	It	63% (27)	37% (16)
Got	67% (2)	33% (1)	One (*Determiner*)	50% (2)	50% (2)
Hammer	50% (1)	50% (1)	Or	74% (14)	26% (5)
Have	71%	29%	So	30%	70%

(*Transitive*)	(5)	(2)		(18)	(42)
Head	50% (11)	50% (11)	Someone	57% (8)	43% (6)
High	25% (1)	75% (3)	Something	37% (13)	63% (22)
Higher	45% (22)	55% (27)	Than	50% (2)	50% (2)
Hit	61% (14)	39% (9)	That	47% (24)	53% (27)
Hitting	33% (2)	67% (4)	The	27% (15)	73% (40)
Indicates	50% (1)	50% (1)	Them	33% (2)	67% (4)
Involve	50% (2)	50% (2)	This	43% (3)	57% (4)
Just	50% (2)	50% (2)	What	33% (1)	67% (2)
Kind	25% (3)	75% (9)	When	38% (6)	63% (10)
Know	50%	50%	Where	55%	45%

	(2)	(2)		(6)	(5)
Like	35% (7)	65% (13)	Which	71% (10)	29% (4)
Low	50% (1)	50% (1)	Would	38% (9)	63% (15)
Made	50% (3)	50% (3)	You	53% (41)	47% (36)
Make	15% (2)	85% (11)	Your	37% (10)	63% (17)
Maybe	29% (2)	71% (5)			
Mean	29% (2)	71% (5)			
Meaning	50% (1)	50% (1)			
Means	40% (10)	60% (15)			
Nail	6% (1)	94% (16)			
Normally	25%	75%			

	(2)	(6)	
Object	95% (19)	5% (1)	
Oil	57% (28)	43% (21)	
Part	33% (1)	67% (2)	
Poor	50% (1)	50% (1)	
Pour	79% (11)	21% (3)	
Pouring	38% (3)	63% (5)	
Put	96% (25)	4% (1)	
Quite	13% (1)	88% (7)	
Really	25% (1)	75% (3)	
Refer	40%	60%	

	(2)	(3)	
Representing	17% (1)	83% (5)	
Round	63% (5)	38% (3)	
Sky	67% (2)	33% (1)	
Sort	39% (7)	61% (11)	
Spending	33% (1)	67% (2)	
Spin	69% (9)	31% (4)	
Spinning	29% (2)	71% (5)	
Substance	71% (5)	29% (2)	
Then	50% (5)	50% (5)	
Things	79%	21%	

	(15)	(4)	
Touch	50% (1)	50% (1)	
Try	33% (1)	67% (2)	
Used	85% (11)	15% (2)	
Very	67% (2)	33% (1)	
Wrong	50% (1)	50% (1)	