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Neuropsychological and Neurophysiological Correlates of Idiom Understanding: How Many Hemispheres Are Involved?

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Introduction

As the philosopher John Searle claimed, idiomatic expressions are so pervasive in everyday language that speakers seem to follow an implicit rule: *Speak idiomatically unless there is some special reason not to* (Searle, 1979, p. 50). Figurative language is extremely pervasive in everyday language: according to an estimate proposed by Jackendoff (1995), there are as many fixed expressions as there are words in American English, more or less 80,000 (Jackendoff, 1995). Some years ago, Pollio, Barlow, Fine, and Pollio (1977) estimated that people use about 6 nonliteral fixed expressions per minute of discourse, specifically 1.8 new metaphors and 4.08 *conventionalized* metaphors (as *John is an elephant* or *That lawyer is a shark*). Assuming that people engage in conversation on average 2 hours a day, a person utters 4.7 million novel metaphors and 21.4 million frozen ones over a 60-year average lifespan.

In this chapter, we review the literature concerning the neural architecture underlying idiom comprehension in language-unimpaired and language-impaired participants. Just some words on the limitation of this review chapter: we only consider studies on the neuropsychological and neurophysiological correlates of idiom comprehension and leave aside studies concerning other forms of figurative language (e.g., metaphor, proverbs; see Thoma & Daum, 2006). Since we are specifically interested in the brain areas recruited during idiom processing, we did not consider the (few) studies on idiom comprehension that employed event-related scalp-recorded brain potentials (for an overview, see Vespignani, Canal, Molinaro, Fonda,

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& Cacciari, 2010). This technique in fact provides fine-grained information on the timing with which cognitive processes occur but it does not provide reliable information on the specific brain regions recruited.

The organization of the chapter is as follows: we start from defining the identity of the linguistic strings considered in this chapter, namely idiomatic expressions, and how these differ from other members of the huge family that goes under the name of *figurative language*. Then we examine the neuropsychological literature following a chronological criterion: first we consider the studies on idiom comprehension from the 1970s to the 1990s, and then the more recent studies. We move to the studies that directly assessed the neural architecture underlying idiom comprehension by employing transcranial magnetic stimulation (TMS), a technique that can be used to disrupt, reversibly and transiently, the normal activity of a brain region), and functional magnetic resonance imaging (fMRI). Finally we draw some conclusions about possible answers to the basic question that motivated this chapter, *How many hemispheres are involved?*

What an Idiom Is and Is Not

When a speaker/reader encounters a sentence, s/he is generally able to judge whether it is intended literally or not. The ease with which people deal with this distinction in everyday discourse belies the complexity of the distinction between literal and figurative language. Many researchers have expressed serious doubts as to whether a sharp distinction can (or should) be drawn between these two varieties of language. A partial and maybe more promising alternative is to use the notion of *level of conventionalization* that is generally considered to be based on a continuum that goes from *not conventional at all* to *fully conventional*. The position of idioms along this continuum can be conceived as closest to the *fully conventional* pole. Idiomatization in fact is a process: to reach the status of idiom, an expression must become conventionalized for a linguistic community (Cacciari, 1993).

Defining what an idiom is and the difference between an idiom and other types of figurative expression (e.g., metaphor, proverb, cliché, and collocation) might seem at a first glance a useless task. In contrast, as we will see in this chapter, there is an underestimation of the role played by the linguistic characteristics of the experimental stimuli employed in experimental and clinical studies, and very often researchers mistake an idiom for a proverb or a metaphor. Since, as we explain below, these expressions indeed differ from a semantic and syntactic point of view, this confusion might ~~indeed~~ be problematic. Therefore, it is necessary to point out not only what an idiom is but also what an idiom *is not*.

Operationally, *an idiomatic expression is a string of constituents whose meaning is not necessarily derived from that of the constituent parts*. The idiomatic meaning is stored in semantic memory together with word meanings, concepts, and many other types of multiword strings (e.g., lines of poetry, advertisings, and song titles). In

general the relationship between lexical items and phrasal meaning is to a large extent arbitrary and learned.

Idioms differ from metaphors (even though many idioms diachronically derive from metaphors) since metaphors (either the more frozen or conventionalized ones) do not have a unique standardized meaning and can convey more than one meaning (even a rather conventionalized metaphor as *John is an elephant* conveys different meanings, for instance that he is clumsy, extremely big, a blunderer, etc.). Idioms do have a unique meaning that can be specialized but not changed by context. We cannot retrieve and productively combine words online to create an idiomatic expression (Konopka & Bock, 2009). Some idioms allow semantic variations within a more or less fixed template, but this should not be confounded with true metaphorical language. In contrast, we can create a metaphor on the fly, albeit not necessarily a good one. Metaphors have to do with categorization processes (Cacciari & Glucksberg, 1994; Glucksberg, 2001) while idioms with meaning involve retrieval from semantic memory. Idioms also differ from proverbs (e.g., *You can't get blood from a stone*; *A point in time saves nine*) since the latter are full sentences, temporarily undefined, signaled by specific grammatical, phonetic and/or rhetorical patterns or by a binary structure (theme/comment). Proverbs are often used as general comments to shared communicative situations, and are generally true statements, both literally and figuratively (Ferretti, Schwint, & Katz, 2007; Turner & Katz, 1997).

The First Neuropsychological Studies on Idiom Comprehension: The Rise of the RH Hypothesis

The psycholinguistic models on idiom processing are generally based on language-unimpaired participants (for overviews, see Cacciari, Padovani, & Corradini, 2007; Cacciari & Tabossi, 1993; Vespignani et al., 2010) and assume that in order to understand an idiom, lexical integrity is required. Therefore, injuries to the left hemisphere (LH), typically resulting in aphasic impairments, ought to damage, along with other linguistic skills, patients' ability to comprehend idiomatic expressions. However, at odds with this prediction, a widely accepted view in the neuropsychological literature assumes that damage to the LH may have no major consequences on idiom comprehension, and it is the nondominant right hemisphere (RH) that is important for the processing of idiomatic expressions (Van Lancker Sidtis & Postman, 2006).

The idea that the comprehension of idiomatic expressions is predominantly subserved by the RH (henceforth referred to as *the RH hypothesis*) originates from a misinterpretation of the results of the first classical lesion study on metaphor comprehension (Winner & Gardner, 1977). Winner and Gardner found that aphasic left-brain-damaged (LBD) patients were correct when they had to associate a metaphoric expression with the matching picture, whereas right-brain-damaged (RBD) patients, despite being able to verbally explain the correct meaning of metaphors,

chose the pictures corresponding to the literal meaning. On the contrary, the five LBD patients who could be tested in the oral modality gave literal explanations despite choosing metaphorical pictures.

Since then, Winner and Gardner's results have been taken to support the RH hypothesis for figurative language comprehension tout court. However, this study concerned the comprehension of a specific type of figurative language, namely, metaphors and not idioms. Although this finding has been taken as evidence that RBD patients are impaired in comprehending all figurative language, it may only indicate that RBD patients are defective in comprehending metaphors, not necessarily idioms, and/or in picture matching. And in fact a greater difficulty with pictorial material is constantly reported when RBD patients are tested (e.g., Papagno, Curti, Rizzo, & Colombo, 2006).

Studies specifically focused on idiom comprehension in language-impaired patients did not provide conclusive evidence in support of RH hypothesis. The first researchers testing idiomatic expressions were Stachowiak, Huber, Poeck, and Kerschensteiner (1977) who were almost ignored in the neuropsychological literature on figurative language comprehension. They investigated the semantic and pragmatic strategies used for comprehending auditorily presented short stories containing idioms by four subgroups of aphasic patients (Broca, Wernicke, amnestic, and global aphasics), RBD patients, and normal controls. Participants were required to choose the picture (out of five) appropriate to the story. Half of the stories were commented using semantically transparent idioms and half with semantically opaque idioms (i.e., idioms with a close vs. remote relationship between literal and figurative meaning, respectively). Overall, the performance was better with transparent than with opaque idioms. The comprehension of idioms in the aphasic groups was not poorer than that of the other groups: in fact the distribution of idiomatic choices was similar across groups, except for the Wernicke group which produced slightly more literal responses. Stachowiak et al. (1977) interpreted the lack of a significant difference between aphasics and controls as suggesting that aphasics heavily relied on the pictorial information provided by context. Whether or not aphasic patients had difficulty in comprehending idioms if presented out of a verbal or pictorial context was not investigated. However, it is possible that if a particular word or sentence was not understood, enough cues in the context were available to let them infer the misunderstood part. Thus verbal redundancy could have made up for the difficulties at word and sentence levels.

Some years later, Van Lancker and Kempler (1987; see also Van Lancker Sidtis, Volume 1, Chapter 17) and Kempler, Van Lancker, Marchman, and Bates (1999) reported a *double dissociation* between idiom comprehension and novel sentence comprehension in LBD and RBD patients tested with a sentence-to-picture matching task: while RBD participants had normal performance on novel (literal) sentences and performed poorly on familiar (figurative) sentences, aphasic patients had the opposite pattern. The test consisted of 40 test items, namely 20 familiar phrases, including proverbs, idioms, and contextually bound social interaction formulas (*I'll get back to you later*), and 20 novel sentences constructed to match the familiar ones

in length, surface grammatical structure, and word frequency. The foils for familiar phrases were two concrete interpretations related to individual words in the stimulus sentence (the picture is described by a sentence including a content word of the familiar phrase); the third foil represented the opposite figurative meaning of the familiar phrase. In a first version there was a picture representing the literal interpretation, instead of ~~one~~ concrete interpretation. The target was a picture representing the figurative meaning of the sentence. However, several methodological flaws render the interpretations of these results somewhat difficult. For example, at a closer look one can see that even if literal and non-literal sentences were matched in structure, the linguistic expressions were rather heterogeneous and comprised idioms, proverbs, and collocations such as *I'll get back to you later*. Very few controls on the psycholinguistic properties of the stimuli were reported (familiarity, length, and syntactic structure). Moreover, clinical features such as the severity of aphasia and the presence of additional neuropsychological deficits (e.g., attentional, perceptual, or spatial deficits) were not reported. The time of testing with respect to the time of onset of aphasia was variable, and it was not specified whether patients underwent language rehabilitation. The possibility that language-impaired participants had additional neuropsychological deficits deserved more attention since when sensory or cognitive deficits associated with RH damage result in suboptimal processing of critical elements, or deplete available resources for further analysis, patients might be particularly likely to resort to the less demanding choice (the literal alternative). In fact, the pictures representing literal sentences might be less demanding for visuo-perceptual and visuospatial skills. Indeed the picture complexity of literal sentences is generally lower than that of idiomatic sentences: literal sentences typically only have a single concrete interpretation, and limited visuospatial and attentional resources might suffice. This is not true for pictures depicting idiomatic meanings that are often abstract and therefore difficult to represent at a pictorial level. It could then be the case that patients' performance was influenced by pictorial complexity and/or ambiguity. This is confirmed by a recent study on aphasics that showed significant correlations between idiom comprehension (tested with a sentence-to-picture matching task) and star cancellation or line bisection tests (Papagno et al., 2006). Finally, in Van Lancker and Kempler's study the performance of aphasic patients on familiar phrases was considered close to normal even though their mean percentage of correct responses was 72% as compared to 97.3% of controls. This suggests that LBD patients' performance was at least mildly impaired.

Similar concerns on the clinical implications and interpretation of the study of Van Lancker and Kempler (1987) were raised some years later by Tompkins, Boada, and McGarry (1992). Indeed, Tompkins et al. correctly pointed out that defining the meaning of an idiom or choosing a picture in a matching task are the end-products of multiple computations, so the sources of failure on such tasks are hard to correctly spell out. In other words, offline tasks are distant in time (and correspondingly in terms of cognitive operations) and far from being able to detect the initial retrieval or computation of meaning. By contrast, online tasks require a

response to some aspect of the input during, rather than after, comprehension processes. To investigate the extent to which online versus offline tasks might produce different results, Tompkins et al. tested 20 RBD patients (40% of them with neglect), 20 LBD (65% of them with aphasia), and 20 neurologically intact controls. Participants performed two idiom comprehension tasks: the primary task was an online word-monitoring task in which participants listened to a sentence and pressed a button as quickly as possible when they heard a specific target word. Target words (e.g., *rat*) were concrete nouns that were the final constituent of ambiguous familiar idioms (e.g. *smell a rat*). Target monitoring was measured in three experimental conditions: idiomatic contexts, literal contexts that biased toward a literal interpretation of ambiguous idioms, and control contexts in which the target did not occur in an idiom (e.g., *saw a rat*). Brain-damaged participants performed similarly to normal controls in that all responded faster to target nouns in idiomatic and literal contexts compared to control contexts. The secondary task was an offline task in which participants were asked to give a meaning definition of 12 highly familiar idiomatic strings. In this task, brain-damaged participants performed poorly and made more errors than controls, without any difference between RBD and LBD. Therefore, adults with unilateral brain damage were able to activate and retrieve the meaning of familiar idioms. Their idiom interpretation deficits most likely reflect impairment at some later stage of information processing. However, it should be noted that only 65% of LBD patients were aphasic and that the standard deviations in the word monitoring tasks were rather high suggesting a huge variability in the patients' performance. It is likely that if subgroups had been distinguished, the performance of aphasics would have been significantly worse than that of controls in the online task. In addition, as in previously mentioned studies, no information about the lesion site or size was given, but only a rough topological distribution in anterior, posterior, mixed, and subcortical lesions.

Recent Neuropsychological Studies on Idiom Comprehension: The Fall of the RH Hypothesis

The studies described above definitively showed that the hypothesis that the RH plays a major role in idiom comprehension has a number of important limitations. More recent neuropsychological studies provided direct evidence of the involvement of the LH, specifically of the temporal lobe, in idiom comprehension. It should be noted that the studies that appeared in this period of time differ in many methodological respects from the previous ones: for instance, many of the more recent studies provide detailed information about the criteria of selection of the participants, and on the anatomical assessment of the lesion sites; the experimental materials are more controlled as far as the psycholinguistic variables known to affect linguistic processing are concerned.

In a sentence-to-picture matching task, Papagno, Tabossi, Colombo, and Zampetti (2004) presented 10 aphasic patients and 10 healthy controls with highly familiar

unambiguous idioms (the literal meaning of the string was implausible or the sentence ill-formed). Each idiom was paired with pictures representing the idiomatic interpretation, the literal interpretation, or an unrelated situation. Aphasic patients were severely impaired in that they chose the wrong picture in half of the trials. When the same patients were asked to orally define the meaning of the same set of idioms, their accuracy dramatically increased (although their performance was significantly worse than that of controls). This suggests that the picture matching paradigm may underestimate the patient's ability to comprehend idioms.

The analysis of the individual errors in the sentence-to-picture matching task showed that patients did not choose at random: in fact they selected the unrelated alternative only a few times (the number of unrelated choices was comparable to that of the healthy participants). A further analysis of the responses given by aphasic patients with semantic deficits indicated that they took advantage of syntactic information: when presented with syntactically ill-formed idioms or with idioms with infrequent syntactic structures, patients with good syntactic competence made fewer literal errors than with well-formed idioms. In sum, these patients retrieved the figurative interpretation only when the linguistic analysis of the string failed to yield acceptable results. This suggests that aphasic patients made use of spared language abilities in order to comprehend idiomatic expressions, for example, syntactic competence (Papagno et al., 2004) when lexical-semantic knowledge was impaired. When semantic knowledge was defective, aphasic patients accepted the literal interpretation, even when semantically implausible, basically because their semantic deficits did not allow them to recognize sentence implausibility. On the contrary, semantic knowledge was used when syntactic analysis was defective.

Papagno and Genoni (2004) tested 11 aphasic patients with syntactic deficit but spared semantic knowledge (plus a corresponding number of healthy controls) with an auditory sentence presentation mode and two tasks: a sentence-to-picture matching task and a grammaticality judgment task. They showed that idiom comprehension was significantly impaired in patients as compared to controls. Moreover, the patients' ability to comprehend idioms inversely correlated with the plausibility of the literal interpretation of the idiom string: the more plausible the literal interpretation was, the greater was the probability that the patient selected the picture corresponding to the literal meaning. Interestingly, idiom comprehension correlated with grammaticality judgment and in particular with the patients' ability to recognize the correct grammatical form of an idiom. This is a further piece of evidence that the more language processing is preserved, the more idiom comprehension is preserved as well.

Papagno et al.'s study (2006) was explicitly designed to assess the comprehension of unambiguous idiom in RDB and LBD patients (15 and 12, respectively) by means of a string-to-picture matching task. While all LBD patients were aphasic, the RBD patients showed various degrees of visuospatial impairment. In fact, idiom comprehension significantly correlated with visuospatial tasks in RBD patients. Eight of the 12 LBD patients were impaired in idiom comprehension, and overall the performance of the LBD patients was significantly worse than that of their matched controls.

As Tompkins et al. (1992) noted, some of the deficits previously reported for RBD adults might be partly an artifact of the differential plausibility of the literal meanings, alone or in combination with patients' visuospatial deficits. The RBD patients, though impaired, performed significantly better than LBD patients; their performance was correlated with visuospatial abilities and was significantly affected by lesion site, being particularly impaired in patients with a cortical and/or subcortical frontal lesion.

The Effect of the Task and of the Type of Idiom

Idiomatic expressions do not form a homogeneous group: they might be semantically ambiguous or not, they might be more or less familiar, they might differ in terms of semantic transparency (i.e., the extent to which the idiomatic meaning is inferable from the literal meaning of the string). The possibility exists that different types of idiomatic expression could undergo different kinds of processing and that the comprehension of ambiguous versus unambiguous idioms might be selectively disrupted.

To test the effect of the ambiguity of the idiom string, Cacciari et al. (2006) investigated the comprehension of ambiguous idioms in 15 aphasic patients using a word-to-sentence matching task. Syntactically simple sentences containing an idiom were paired with four words: a word corresponding to the idiomatic interpretation of the string, a word semantically associated with the last constituent word of the idiom string, and two unrelated foils (one foil was either an abstract or concrete word depending on the semantic class of the idiom target, and the other a word that could literally complete the verb in the verb phrase). The task was to choose the target word with the best fit with the figurative meaning of the sentence. Aphasic patients were significantly more impaired than matched controls. Semantically associated errors were significantly more frequent than unrelated errors. This might depend either on a lack of recognition of the idiomatic nature of the string (Cacciari & Tabossi, 1988) that prevented aphasics from retrieving the idiom meaning from semantic memory or on deficient inhibition of the word meaning associated with the final constituent word of the idiom string. The retrieval of the figurative meaning might have been blocked by a sort of processing loop in which the patient was unable to get rid of the literal meaning of the string. Since the language resources of aphasics are damaged, a greater involvement of executive control was required thus depleting the attentional pool and preventing the appropriate suppression/inhibition of the literal meaning. However, this study was not designed to tease apart these two explanations.

However, the disproportionate choice of the literal answer may depend on the task. Therefore Papagno and Caporali's study (2007) investigated whether, and to what extent, idiom comprehension in aphasic patients was influenced by the task and by the ambiguous versus unambiguous nature of idioms. Fifteen aphasics (and 15 controls) were involved in two experiments: in the first experiment, they were

tested with three different tasks (sentence-to-picture and sentence-to-word matching tasks, and oral definition task) using simple sentences containing unambiguous idioms. The results showed high variability among aphasic patients, with some severely impaired and others performing nearly as well as the control group. The patients' performance was influenced by the severity of the language deficit (for instance, the oral definition task could not be performed by some nonfluent patients), but also and even more so by the type of task. While in fact it had no influence on the performance of neurologically unimpaired participants, it did affect aphasic patients and for a variety of reasons: reduced expressive skills in the oral definition task, and dysexecutive problems in the sentence-to-picture matching task (but also in the sentence-to-word matching task with ambiguous idioms, see Experiment 2). Indeed, a comparison of the results in the three tasks showed that aphasic patients performed significantly better with the sentence-to-word matching task (see Cacciari et al.'s 2006 study for the details on the experiment design) than with the other two tasks. In the sentence-to-word matching task, one foil was semantically associated with the last constituent word of the idiom string; and two words were unrelated foils. Specifically, the first type of unrelated word was either an abstract or a concrete word depending on the nature of the idiomatic target. The second type of unrelated foil was a word that could plausibly complete the verb in the verb phrase. The target was a word corresponding to the idiomatic interpretation of the sentence. The overt representation of the literal meaning in the sentence-to-picture matching task (i.e., a bizarre picture corresponding to the idiom's literal interpretation) had in fact a strong interference effect, similar to that observed in the Stroop test. When an explicit pictorial representation of the idiom's literal meaning was available, patients were unable to suppress it. This confirms that the literal interpretation somehow remained active while the sentence was processed, even when it had very low plausibility. In the sentence-to-word matching task none of the target words referred to the literal meaning of the idiom string, and this decreased the interference of the literal interpretation. Therefore the errors (very numerous as compared to controls) indeed indicate lack of knowledge of the idiomatic meaning. Since literal errors especially appeared when the literal interpretation was overtly *offered* to the patient, it could be the case that when the figurative meaning is lost (or not accessed) and the literal alternative (i.e., the word or picture corresponding to the literal interpretation of the idiom string) is absent, the patients chose the (wrong) answer that preserves the semantic class (abstract/concrete) of the correct choice. This further suggests some level of processing of the sentential meaning.

In the second experiment of Papagno and Caporali's study (2007), patients and controls were presented with simple sentences containing either ambiguous or unambiguous idioms in a sentence-to-word matching task. Again, patients performed significantly worse than controls, but with a different pattern of errors for unambiguous compared to ambiguous idioms (significantly more unrelated errors preserving the semantic class, and significantly more literal associate errors, respectively). This different pattern of errors, together with the absence of correlation with

general language impairment for unambiguous idioms, suggests that the two types of idiom might have been processed differently by aphasics. In support of this hypothesis, in this same study two patients were found with a double dissociation. One patient was severely impaired on ambiguous idiom comprehension, but had a noticeably better performance on unambiguous idioms, while the other made no errors on ambiguous idioms and performed at chance on unambiguous idioms.

Further evidence for differential processing of ambiguous and unambiguous idioms came from a single case study (Papagno & Cacciari, 2010). Idiom comprehension was investigated in an Italian semantic dementia patient (M.C.) with conceptual damages affecting both naming and comprehension of concrete nouns, while abstract nouns, verbs, and adjectives (both abstract and concrete) were spared (Papagno, Capasso, & Miceli, 2009). Since idioms convey abstract figurative meanings, we assessed whether idiom comprehension was preserved in M.C. as it was for abstract literal meanings, and tested the extent to which the number of meanings associated to a linguistic unit affected M.C.'s comprehension processes. Therefore we employed ambiguous and unambiguous idioms (together with polysemous and nonpolysemous words). Only the comprehension of unambiguous idioms (and of nonpolysemous words) was impaired despite the fact that both types of idiom string conveyed abstract mental states.

In sum, there is consistent evidence suggesting a double dissociation: while there are patients severely impaired on ambiguous idiom who display a noticeably better performance on unambiguous idioms, other patients make no errors on ambiguous idioms but perform at chance on unambiguous idioms. Overall, aphasic patients unexpectedly showed better performances with ~~un~~ambiguous idioms, as if a plausible literal meaning helped in retrieving the idiomatic meaning.

The observation of this double dissociation in patients has interesting parallels in the psycholinguistic literature on word processing in healthy participants. It has been often reported that semantically ambiguous words are recognized faster than nonambiguous words (e.g., Rubinstein, Garfield, & Millikan, 1970) especially in lexical decision studies. Several interpretations of this *ambiguity advantage* have been provided that postulate a lexical architecture based on either inhibitory lexical networks (e.g., Kellas, Ferraro, & Simpson, 1988) or competition between patterns of activation of word meanings (e.g., Gaskell & Marslen-Wilson, 1997). Recently this *ambiguity advantage* has been put under scrutiny by several authors (for an overview, see Rodd, Gaskell, & Marslen-Wilson, 2002). The main result is that multiple related word senses, as in polysemous words, produce a processing advantage while multiple unrelated meanings, as in homonyms, delay recognition producing an ambiguity disadvantage (e.g., Rodd et al., 2002). Rodd et al. interpreted these results as suggesting competition to activate a distributed semantic representation: while the different meanings of a homonym (e.g., *bank*) compete for activation and produce interference that delays recognition times, the rich and intertwined semantic representation associated with polysemous words that have many related senses (e.g., *rose*) facilitate their recognition. The possibility exists that ambiguous idioms behave as polysemous words, especially when there is a close semantic relationship

between the literal and figurative interpretation of the idiom string. Further evidence that, aside from ambiguity, not all idiomatic expressions are processed alike came from a case study of a Finnish deep dyslexic patient (Nenonen, Niemi, & Laine, 2002). The authors investigated the patient's comprehension of verb phrase and noun phrase idioms with a reading task. The authors found that the syntactic structure of the different types of Finnish idiom modulated the ability of the deep dyslexic to comprehend idioms. However, it is not clear to what extent these results were influenced by the nature of the task that might have been particularly problematic for a deep dyslexic.

Although we showed that there is ample evidence of impairment of idiomatic processing in aphasia, there are also aphasics with preserved idiom comprehension (Hillert, 2004). Hillert tested two German LBD patients (one with Wernicke's and the other with global aphasia), one RDB patient, and one healthy control using a cross-modal lexical decision paradigm. He found no difference between aphasics and the two controls. However, aside from the very scarce number of patients and controls, the results might have been influenced by the lower processing demand of the comprehension of the German noun compounds used in the study. Indeed, noun phrase idioms have proved to be easier to access than verb phrase idioms (Nenonen et al., 2002) that are the most frequent form of idiom in the literature on aphasic patients.

Transcranial Magnetic Stimulation and Brain Imaging Studies

Most of the neurophysiological studies on figurative language are devoted to metaphors and only a few investigated idiom comprehension. To our knowledge, there are only three studies that used the repetitive transcranial magnetic stimulation (rTMS) technique and three fMRI studies (we do not consider two fMRI studies, Boulenger, Hauk, & Pulvermüller, 2009, and Aziz-Zadeh & Damasio, 2008, on the relationship between language and motor system, that used idioms and metaphors as experimental materials). We start with rTMS studies.

The first study that used an *interference approach* by means of offline rTMS to investigate the neural substrates of idiom comprehension was that of Oliveri, Romero, and Papagno (2004). In this study familiar unambiguous idiom strings were paired with two pictures representing the idiomatic or the literal meaning of the string. Fifteen healthy participants were asked to decide which one of the pictures matched the string meaning. The scalp positions for stimulation were the posterior temporal site (corresponding to BA 22) and a frontal site (BA 44/45) both on the RH and LH (plus a baseline without stimulation). In general, the reaction times increased following LH rTMS while they were unaffected by RH rTMS. The distribution of reaction times and errors was mostly affected by stimulation of the left temporal site as compared to the other sites and to the baseline. Left frontal rTMS induced less prominent, nonsignificant, disruption whereas right temporal rTMS facilitated participants' performance.

A subsequent rTMS study by the same group (Fogliata et al., 2007) was devoted to testing the temporal dynamics of activation of left prefrontal and temporal cortices. If the prefrontal cortex is involved in activating the figurative interpretation of unambiguous idioms, its activation should appear early in idiom processing. On the other hand, the authors hypothesized that if a suppression mechanism is at work, the frontal activity might persist even when the temporal activity decreases. To this end, rTMS was applied over the left middle frontal gyrus (BA 9) and left superior/middle temporal cortex (BA 22) at four different time points (0, 40, 80, and 120 ms after picture presentation). Forty-three participants were presented with short sentences that could be literal or contain a familiar unambiguous idiom. Each sentence was paired with four pictures (for idioms they represented the correct idiomatic meaning, the literal meaning, a context containing the noun phrase of the idiom, or an unrelated situation). Again, a sentence-to-picture matching task was used. The rTMS interfered with the task when delivered 80 ms after picture presentation at both frontal and temporal sites. However, stimulation at 120 ms after picture representation had an effect on accuracy, which occurred only at the prefrontal site, supporting the idea that a mechanism of inhibition/suppression was at work. In contrast, literal sentence comprehension was unaffected by prefrontal stimulation at any times suggesting that the role of the prefrontal cortex was specific to idiom comprehension (see the study by Romero Lauro, Tettamanti, Cappa, & Papagno, 2008, presented below).

In another study (Rizzo, Sandrini, & Papagno, 2007) that used the same online stimulation paradigm and experimental materials, the scalp sites stimulated with the rTMS in 14 participants were the right and left dorsolateral prefrontal cortex (DLPFC). The study was designed to use the interference paradigm provided by rTMS for testing the hypothesis that lesions in these areas might be at the origin of the impairment in idiom comprehension found in RBD patients. Both left and right rTMS slowed down the reaction times of all sentences (consistently with the brain imaging literature on the involvement of the DLPFC in sentence processing) and decreased idiom's accuracy. In sum, both the left and right DLPFC were involved in the selection of the appropriate response in the case of idioms, presumably because of inhibition of the literal meanings.

We now turn to fMRI studies (Mashal, Faust, Hendler, & Jung-Beeman, 2008; Romero Lauro et al., 2008; Zempleni, Haverkort, Renken, & Stowe, 2007, see also Rapp, Volume 1, Chapter 20). In an event-related fMRI study, Zempleni et al. (2007) visually presented 17 participants with literally plausible idioms in sentences that biased the readers toward the figurative or literal interpretation of the idiom strings. These were contrasted with sentences containing unambiguous idioms and literal sentences. Participants read the sentences for comprehension and carried out a relatedness decision whenever a word printed in red appeared after a sentence (which happened only on filler sentences). The major finding of this study is that idiom comprehension (for both ambiguous and unambiguous idioms), as measured by contrasting figurative versus literal sentences, was

supported by bilateral inferior frontal gyri and left middle temporal gyrus. The right middle temporal gyrus was also involved, but almost exclusively for ambiguous idioms.

Another event-related fMRI study was carried out by Romero Lauro et al. (2008). They asked 22 participants to decide whether the meaning of a sentence, that either was literal or contained an ambiguous or an unambiguous idiom, matched a picture. The results revealed that making judgments about literal and idiomatic sentences yielded a common network of cortical activity, involving language areas of the LH. However, the nonliteral task elicited overall greater activation, both in terms of magnitude and spatial extent. In particular, Romero Lauro et al. found a bilateral frontotemporal network of increased cortical activity for idiomatic compared with literal sentences. The idiomatic condition activated bilaterally the inferior frontal gyrus and the anterior middle temporal gyrus (BA 21). Specifically, the left superior frontal (approximately covering BA 9), as well as the left inferior frontal gyrus, were specifically involved in processing idiomatic sentences. As to the RH, activation was seen in the middle temporal gyrus and in the temporal pole. In contrast with Zempleni et al.'s study, Romero Lauro et al. did not find any difference between ambiguous and unambiguous idioms.

The last fMRI study on idiom comprehension was carried out by Mashal et al. (2008) who examined the role of the LH and RH in processing the dominant/idiomatic and the subordinate/literal meaning of familiar ambiguous idioms (a behavioral divided visual field experiment was also carried out, but we concentrate on the fMRI experiment). The study is based on the *graded salience hypothesis* (Giora, 2003) that predicts that subordinate/literal interpretations are processed in the RH while dominant/idiomatic interpretations primarily engage the LH. This hypothesis is at odds with what was found by Romero Lauro et al. (2008) but is compatible with Zempleni et al.'s (2007) results. Fourteen participants were instructed to perform one of two different tasks: to think about the idiomatic meaning of the sentences or to think about the literal meaning of the idiom or of the literal sentence (a third of the sentences were literal and the remaining contained ambiguous idioms). Prior to each block, instructions on how to process the sentences, idiomatically or literally, were visualized to the participants. No control is reported on whether or not participants indeed identified the idiomatic meaning, or thought of the idiomatic versus literal meaning (note that 50 out of 75 experimental sentences contained idioms). This is a serious confound especially because of the interpretations assigned to the brain activity reported in this study. The brain activation obtained for the (*presumed*, in our view) idiomatic processing of idioms, compared to the literal processing of the literal sentences, showed that three areas of the LH had greater activation: the inferior frontal gyrus, the middle temporal gyrus and the thalamus, as in the previous studies. The comparison between the (again *presumed*) literal processing of idioms with the (*presumed*) idiomatic processing of idioms showed greater activation in the RH middle temporal gyrus (as in Zempleni et al., 2007, while in Romero Lauro et al., 2008, such activation concerned unambiguous idioms as well), in the anterior part of the right superior temporal

gyrus and in the left and right anterior insula. The opposite contrast (idiomatic vs. literal processing of idioms) identified significant activation only in the left inferior frontal gyrus.

These fMRI results (together with the behavioral results obtained with the divided visual field paradigm) were interpreted by Mashal et al. (2008) as evidence of an RH advantage in processing subordinate/nonsalient literal meaning of familiar ambiguous idioms, and an LH advantage in processing the dominant/idiomatic meaning of the idiom strings. However, as we said, the most problematic aspect of this interesting study remains the fact that there is no overt task (either online or offline) that could to some extent guarantee that indeed participants entered into either a literal or an idiomatic mode of processing as instructed prior to the block beginning and remained *faithful* and stable to that processing mode for the entire block. It should be noted that these results in large part are inconsistent with the bilateral activation patterns found in both Zempleni et al. (2007) and Romero Lauro et al. (2008). In contrast, the left-sided brain activations observed by Mashal et al. (2008) are consistent with lesion data of aphasic patients where a left temporal lesion is associated with a literal interpretation of the sentence. In fact, when the LH *is* damaged and the RH is not, the idiom's literal interpretation is the first to be activated and produced by the patient.

Mashal et al. interpreted their results as evidence for the graded salience hypothesis (Giora, 2003). However it is not clear to what extent the notion of salience interacts or overlaps with that of meaning dominance: as has been shown by decades of studies on lexical ambiguity processing, when a word or a string of words has two meanings, one of them typically is dominant (and corresponds to the prepotent response). Idioms are no exception and the results can be reinterpreted as showing that dominant (often more frequent) meanings are elaborated mostly via the LH, regardless of their literal or figurative nature.

Conclusion

As we hope it is clear from this chapter, the identification of the neuropsychological and neurophysiological correlates of idiom understanding is still a fascinating challenge for models of language processing. The title contains a basic question that has animated the first phase of the studies on idiom comprehension in language-impaired participants and has continued to exert a role also in the second phase: How many hemispheres are involved in idiom comprehension?

A simple way to respond is that both hemispheres indeed play a role in idiom language, although not an equally dominant one (for an interesting hypothesis on the labor division of the LH and RH to be applied to figurative language comprehension, see Beeman, 1998, and Mirous & Beeman, Volume 1, Chapter 16). This should come as no surprise since after all idioms are linguistic units, and the prevalence of the LH in sentence processing is well established. The explicit comparison of RBD and LBD patients (as in Papagno et al., 2006) and the literature on each of

these groups indicated that LBD patients were impaired in idiom comprehension. The impaired performance on idioms of RBD patients was related to: (1) visuospatial deficits that were particularly relevant when patients were tested with pictorial materials; (2) lesions localized in the prefrontal (cortical or subcortical) region. This was confirmed by the fact that, when these lesions were absent, RBD patients' performance on idioms was not different from that of controls. The evidence reported in many neuropsychological and neurophysiological studies on a role of the right (and not only the left) dorsolateral prefrontal cortex (but also of the subcortical white matter) could explain why figurative (and idiomatic in particular) language impairment has been considered a right-brain-damage consequence: since the exact lesion site was often not reported, it could well be the case that a number of patients had prefrontal lesions.

From an anatomical point of view, two sites are thought to be relevant for the patients' performance: a cortical and/or subcortical frontal area particularly involved in the comprehension of ambiguous idioms, and a cortical temporal region constantly involved when unambiguous idiom comprehension is impaired. These results were supported by rTMS studies on healthy participants using both offline (Oliveri et al., 2004) and online paradigms (Fogliata et al., 2007; Rizzo et al., 2007).

Prefrontal regions appear to be involved in: (1) the retrieval of the figurative meaning of idioms from semantic memory; (2) monitoring of the response; and (3) inhibition of an alternative interpretation (especially with the picture matching task). Once a sentence containing an idiom is linguistically processed and two possible interpretations are available, a response must be selected and the outcome monitored. Selection and monitoring of internally generated responses are likely to be performed by the central executive whose neural correlates are supposed to be in the prefrontal lobe. Indeed, as we saw, patients with prefrontal lesions produce a higher number of literal interpretations as compared to patients with lesions not involving the prefrontal lobe. The role of the prefrontal cortex in language control has been demonstrated in a number of studies with sentence processing tasks in which the listener/reader needs to maintain the information online for a certain period (Friederici, 2002).

In a nutshell, idiom comprehension seems to be subserved by a bilateral neural network as opposed to the exclusive participation of the RH. Specifically, converging evidence from lesion studies and rTMS and fMRI studies indicates that the neural network activated during idiom comprehension also involves: (1) in the LH, the temporal cortex and the superior medial frontal gyrus and the inferior frontal gyrus; (2) in the RH, the superior and middle temporal gyri, the temporal pole, and the inferior frontal gyrus.

References

Aziz-Zadeh, L., & Damasio, A. (2008). Embodied semantics for actions: Findings from functional brain imaging. *Journal of Physiology*, *102*, 35–39.

Beeman, M. (1998). Coarse semantic coding and discourse comprehension. In M. Beeman & C. Chiarello (Eds.), *Right hemisphere language comprehension. Perspective from cognitive neuroscience* (pp. 255–284). Mahwah, NJ: Erlbaum.

Boulenger, V., Hauk, O., & Pulvermüller, F. (2009). Grasping ideas with the motor system: Semantic somatotopy in idiom comprehension. *Cerebral Cortex*, *19*, 1905–1914.

Cacciari, C. (1993). The place of idioms in a literal and metaphorical world. In C. Cacciari & P. Tabossi (Eds.), *Idioms. Processing, structure, and interpretation* (pp. 27–55). Hillsdale, NJ: Erlbaum.

Cacciari, C., & Glucksberg, S. (1994). Understanding figurative language. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 447–477). New York: Academic Press.

Cacciari, C., Padovani, R., & Corradini, P. (2007). Exploring the relationship between individuals' speed of processing and their comprehension of spoken idioms. *European Journal of Cognitive Psychology*, *19*(3), 417–445

Cacciari, C., Reati, F., Colombo, M. R., Padovani, R., Rizzo, S., & Papagno, C. (2006). The comprehension of ambiguous idioms in aphasic patients. *Neuropsychologia*, *44*, 1305–1314.

Cacciari, C., & Tabossi, P. (1988). The comprehension of idioms. *Journal of Memory and Language*, *27*, 668–683.

Cacciari, C., & Tabossi, P. (Eds.). (1993). *Idioms. Processing, structure, and interpretation*. Hillsdale, NJ: Erlbaum.

Ferretti, T. R., Schwint, C. A., & Katz, A. (2007). Electrophysiological and behavioral measures of the influence of literal and figurative contextual constraint on proverb comprehension. *Brain and Language*, *101*, 38–49.

Fogliata, A., Rizzo, S., Reati, F., Miniussi, C., Oliveri, M., & Papagno, C. (2007). The time course of idiom processing. *Neuropsychologia*, *45*, 3215–3222.

Friederici, A. D. (2002). Towards a neural basis of auditory sentence processing. *Trends in Cognitive Sciences*, *6*, 78–84.

Gaskell, M. G., & Marslen-Wilson, W. D. (1997). Integrating form and meaning: A distributed model of speech perception. *Language and Cognitive Processes*, *12*, 613–656.

Giora, R. (2003). *On our minds. Salience, context and figurative language*. Oxford: Oxford University Press.

Glucksberg, S. (2001). *Understanding figurative language*. Oxford: Oxford University Press.

Hillert, D. (2004). Spared access to idiomatic and literal meanings: A single-case approach. *Brain and Language*, *89*, 207–215.

Jackendoff, R. (1995). The boundaries of the lexicon. In M. Everaert, E. van den Linden, A. Schenk, & R. Schreuder (Eds.), *Idioms: structural and psychological perspectives* (pp. 133–166). Hillsdale, NJ: Erlbaum.

Kellas, G., Ferraro, F. R., & Simpson, G. B. (1988). Lexical ambiguity and the time course of attentional allocation in word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *14*, 601–609.

Kempler, D., Van Lancker, D., Marchman, V., & Bates, E. (1999). Idiom comprehension in children and adults with unilateral brain damage. *Developmental Neuropsychology*, *15*, 327–349.

Konopcka, A. E., & Bock, K. (2009). Lexical or syntactic control of sentence formulation? Structural generalizations from idiom production. *Cognitive Psychology*, *58*, 68–101.

Mashal, N., Faust, M., Hendler, T., & Jung-Beeman, M. (2008). Hemispheric differences in processing the literal interpretation of idioms: Converging evidence from behavioral and fMRI studies. *Cortex*, *44*, 848–860.

Nenonen, M., Niemi, J., & Laine, M. (2002). Representation and processing of idioms: Evidence from aphasia. *Journal of Neurolinguistics*, *1*, 43–58.

Oliveri, M., Romero, L., & Papagno, C. (2004). Left but not right temporal lobe involvement in opaque idiom comprehension: A repetitive transcranial magnetic stimulation study. *Journal of Cognitive Neuroscience*, *16*, 848–855.

Papagno, C., & Cacciari, C. (2010). The comprehension of idioms in a patient with a reversed concreteness effect. *Journal of Neurolinguistics*. doi:10.1016/j,jneuroling.2010.06.002

Papagno, C., Capasso, R., Miceli G. (2009). Reversed concreteness effect for nouns in a subject with semantic dementia. *Neuropsychologia*, *47*, 1138–1148. doi:10.1016/j.neuropsychologia.2009.01.019

Papagno, C., Capasso, R., Zerboni, H., & Miceli, G. (2009). A reverse concreteness effect in a subject with semantic dementia. *Brain and Language*, *103*, 90–91.

Papagno, C., & Caporali, A. (2007). Testing idiom comprehension in aphasic patients: The effects of task and idiom type. *Brain and Language*, *100*, 208–220.

Papagno, C., Curti, R., Rizzo, S., Crippa, F., & Colombo, M. R. (2006). Is the right hemisphere involved in idiom comprehension? A neuropsychological study. *Neuropsychology*, *20*, 598–606.

Papagno, C., & Genoni, A. (2004). The role of syntactic competence in idiom comprehension: A study on aphasic patients. *Journal of Neurolinguistics*, *17*, 371–382.

Papagno, C., Lucchelli, F., Muggia, S., & Rizzo, S. (2003). Idiom comprehension in Alzheimer's disease: The role of the central executive. *Brain*, *126*, 2419–2430.

Papagno, C., Tabossi, P., Colombo, M., & Zampetti, P. (2004). Idiom comprehension in aphasic patients. *Brain and Language*, *89*, 226–234.

Pollio, H., Barlow, J., Fine, H., & Pollio, M. (1977). *Metaphor and the poetics of growth: Figurative language in psychology, psychotherapy and education*. Hillsdale, NJ: Erlbaum.

Rizzo, S., Sandrini, M., & Papagno, C. (2007). The dorsolateral prefrontal cortex in idiom interpretation: An rTMS study. *Brain Research Bulletin*, *71*, 523–528.

Rodd, J., Gaskell, G., & Marslen-Wilson, W. (2002). Making sense of semantic ambiguity: Semantic competition in lexical access. *Journal of Memory and Language*, *46*, 245–266.

Romero Lauro, L. J., Tettamanti, M., Cappa, S. F., & Papagno, C. (2008). Idiom comprehension: A prefrontal task? *Cerebral Cortex*, *18*, 162–170.

Rubinstein, H., Garfield, L., & Millikan, J. A. (1970). Homographic entries in the internal lexicon. *Journal of Verbal Learning and Verbal Behavior*, *9*, 487–494.

Searle, J. R. (1979). *Expression and meaning: Studies in the theory of speech acts*. Cambridge: Cambridge University Press.

Stachowiak, F., Huber, W., Poeck, K., & Kerschensteiner, M. (1977). Text comprehension in aphasia. *Brain and Language*, *4*, 177–195.

Thoma, P., & Daum, I. (2006). Neurocognitive mechanisms of figurative language processing. Evidence from clinical dysfunctions. *Neuroscience and Behavioral Review*, *30*, 1182–1205.

Tompkins, C. A., Boada, R., & McGarry, K. (1992). The access and processing of familiar idioms by brain-damaged and normally aging adults. *Journal of Speech and Hearing Research*, *35*, 626–637.

Turner, N., & Katz, A. (1997). The availability of conventional and of literal meaning during the comprehension of proverbs. *Pragmatics and Cognition*, *5*, 199–233.

Van Lancker, D., & Kempler, D. (1987). Comprehension of familiar phrases by left but not by right hemisphere damaged patients. *Brain and Language*, *32*, 265–277.

Van Lancker Sidtis D., & Postman, W. A. (2006). Formulaic expressions in spontaneous speech of left and right hemisphere damaged subjects. *Aphasiology*, *20*(5), 411–426.

Vespignani, F., Canal, P., Molinaro, N., Fonda, S., & Cacciari, C. (2010). Predictive mechanisms in idiom comprehension. *Journal of Cognitive Neuroscience*, *22*(8), 1682–1700.

Zempleni, M. Z., Haverkort, M., Renken, R., & Stowe, L. A. (2007). Evidence for bilateral involvement in idiom comprehension: An fMRI study. *NeuroImage*, *34*, 1280–1291

Winner, E., & Gardner, H. (1977). The comprehension of metaphor in brain-damaged patients. *Brain*, *100*, 717–729.