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Lateralized processing of novel metaphors: Disentangling figurativeness and novelty

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ABSTRACT

One of the intriguing and sometimes controversial findings in figurative language research is a right-hemisphere processing advantage for novel metaphors. The current divided visual field study introduced novel literal expressions as a control condition to assess processing novelty independent of figurativeness. Participants evaluated word pairs belonging to one of the five categories: (1) conventional metaphorical, (2) conventional literal, (3) novel metaphorical, (4) novel literal, and (5) unrelated expressions in a semantic decision task. We presented expressions without sentence context and controlled for additional factors including emotional valence, arousal, and imageability that could potentially influence hemispheric processing. We also utilized an eye-tracker to ensure lateralized presentation. We did not find the previously reported right-hemispherical processing advantage for novel metaphors. Processing was faster in the left hemisphere for all types of word pairs, and accuracy was also higher in the right visual field - left hemisphere. Novel metaphors were processed just as fast as novel literal expressions, suggesting that the primary challenge during the comprehension of novel expressions is not a serial processing of salience, but perhaps a more left hemisphere weighted semantic integration. Our results cast doubt on the right-hemisphere theory of metaphors, and raise the possibility that other uncontrolled variables were responsible for previous results. The lateralization of processing of two word expressions seems to be more contingent on the specific task at hand than their figurativeness or saliency.

1. Introduction

In recent decades, experimental work on the neural processing of figurative language has been expanding rapidly. One of the main reasons for the broad interest is the finding that certain patient populations, including people diagnosed with right-hemisphere lesions, schizophrenia, Asperger's syndrome, and Alzheimer's disease, appear to have problems interpreting figures of speech, and specifically metaphors, while they retain mostly intact general language skills (Thoma & Daum, 2006). This observation has lead to the idea that regions beyond classical, left hemisphere (LH) language areas are computing the figurative meaning of metaphors and idioms. To date it remains uncertain if they need a special kind of "extra-linguistic" processing, and if the right hemisphere (RH) is necessarily involved in their comprehension, as has been postulated by the RH theory of metaphor (e.g., Coulson & Van Petten, 2007).

Another core question is the serial or parallel availability of figurative meaning. According to the direct access view by Gibbs (1994), metaphors are comprehended easily in a supportive context, since the literal and figurative meanings are available in parallel. The category assertion view (Glucksberg, 2003; Glucksberg & Keysar, 1990) also suggests that the figurative meaning of metaphors (or at least nominal ones, such as "My lawyer is a shark") is readily accessible as a result of the dual reference of the figuratively used term ("shark") to a literal subordinate category (*marine creature*), and a metaphorical ad hoc superordinate category (*predatory creature*). Bowdle and Gentner (2005), in their career of metaphor hypothesis, propose that only conventional metaphors have such a dual reference, and novel metaphors are processed serially, as a kind of comparison, like similes, following a failed categorization attempt. Nevertheless, beside the question of lateralization, the temporal course of metaphor comprehension is not entirely clear either. The available empirical evidence is inconclusive as to whether metaphors are understood as quickly as literal expressions due to parallel processing, or if they are comprehended slower as a result of serial processing of their figurative meaning.

Thus the two key questions that remain unanswered are (1) what computational steps metaphors require and how these are reflected in the timing of processing, and (2) whether the RH of the brain is necessarily involved in their comprehension. In the following section we are going to review previous findings on the

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individual hemispheres′ contribution to the understanding of metaphors, which are often contradictory.

1.1. Metaphors and the right hemisphere

The RH had been regarded as the "mute" hemisphere for decades (e.g., Sperry, 1985). However, accumulating evidence suggests that it plays an important role in language comprehension, and it has been associated with a large variety of linguistic functions (Van Lancker Sidtis, 2006). The most notable of these are related to communicational pragmatics (Pléh, 2000; Van Lancker, 1997), such as comprehending jokes (Bihrle, Brownell, & Gardner, 1986; Brownell, Michel, Powelson, & Gardner, 1983; Coulson & Williams, 2005; Coulson & Wu, 2005; Marinkovic et al., 2011; Shammi & Stuss, 1999), sarcastic statements (Kaplan, Brownell, Jacobs, & Gardner, 1990), irony (Eviatar & Just, 2006), and indirect requests (Brownell & Stringfellow, 1999; Foldi, 1987; Stemmer, Giroux, & Joanette, 1994; Weylman, Brownell, Roman, & Gardner, 1989).

Metaphorical expressions were among the first linguistic materials whose processing was linked to the RH. In an early experiment performed on individuals with brain injury, Winner and Gardner (1977) found that patients with right hemisphere damage (RHD) preferred the literal depiction of figurative expressions relative to patients with left hemisphere damage (LHD). These findings were replicated in further picture naming experiments (Kempler, Van Lancker, Merchman, & Bates, 1999; Rinaldi, Marangolo, & Baldassari, 2004; the latter also controlled for the patients′ visuospatial deficits). Another study found that RHD patients also experienced difficulties with metaphors in purely language-based tasks (Brownell, Simpson, Bihrle, Potter, & Gardner, 1990). A landmark PET study with healthy individuals by Bottini and colleagues (1994) presented novel metaphors to avoid the automatic processing associated with fixed expressions. They found activation in the right middle temporal gyrus, right prefrontal regions, and right precuneus. Subsequent studies also found RH involvement in metaphor comprehension using neuroimaging techniques (Ahrens et al., 2007; Diaz, Barrett, & Hogstrom, 2011; Mashal, Faust, & Hendler, 2005; Mashal, Faust, Hendler, & Jung-Beeman, 2007; Schmidt & Seger, 2009; Stringaris et al. 2006; Yang, Edens, Simpson, & Krawczyk, 2009), event-related potentials (ERPs) with source localization (Arzouan, Goldstein, & Faust, 2007; Sotillo et al., 2005), TMS (Pobric, Mashal, Faust, & Lavidor, 2008), and the divided visual field (DVF) paradigm (Anaki, Faust, & Kravetz, 1998; Faust, Ben-Artzi, & Harel, 2008; Faust & Mashal, 2007; Mashal & Faust, 2008; Schmidt, DeBuse, & Seger, 2007).

Other groups have found no evidence for the RH′s involvement in understanding metaphors (Chen, Widick, & Chatterjee, 2008; Coulson & Van Petten, 2007; Eviatar & Just, 2006; Kacinik & Chiarello, 2007; Lee & Dapretto, 2006; Rapp, Leube, Erb, Grodd, & Kircher, 2004, 2007; Stringaris, Medford, Giampietro, Brammer, & David, 2007). One possible explanation for these contradictory findings is that novelty was not systematically controlled in these experiments (Schmidt & Seger, 2009). In support of this hypothesis a recent meta-analysis of fMRI studies on figurative language (Bohrn, Altamann, & Jacobs, 2012) showed that metaphors evoked LH activations, and only novel metaphors – relative to conventional ones – activated RH areas.

1.2. Lateralized language processing models

The most relevant models attribute the RH′s involvement in language comprehension to slightly different, but closely related linguistic factors. The RH′s participation is generally not attributed to figurativeness per se, but to its sensitivity to novel and unusual meanings (Beeman, 1998; Chiarello, 1991, 2003; Giora, 2003; St. George, Kutas, Martinez, & Sereno, 1999). The graded salience hypothesis (Giora, 1997, 1999, 2003) proposes that, regardless of figurativeness, salient meanings are processed by the LH, while non-salient meanings are processed by the RH. According to this view, the LH processes conventional metaphors, since they have a salient meaning, even if it is figurative. Novel metaphors, on the other hand, have no salient meaning and are processed by the RH in a slower, serial manner. Only after their salient literal meaning has been rejected can the non-salient, figurative meaning be selected (Giora, 1997, 1999; Giora & Fein, 1999). Saliency is determined by the meaning being coded in the mental lexicon, its prominence, conventionality, frequency, familiarity, and prototypicality. An interesting implication of the theory is that even conventional idiomatic expressions may evoke RH activations when they are interpreted in a non-salient, literal sense. Indeed, this prediction was born out in an fMRI study (Mashal, Faust, Hendler, & Jung-Beeman, 2008).

The coarse semantic coding theory (Beeman, 1998; Beeman et al., 1994) is a language processing model that emphasizes the neural differences of hemispheric organization. The asymmetry in the micro-circuitry of the two hemispheres creates narrow semantic fields in the LH, which code concepts in a fine-grained manner, and broad semantic fields in the RH, which code concepts in a coarse manner. Since elements of conventional expressions are strongly associated, the LH′s narrow semantic fields code them. The comprehension of novel expressions requires the activation of a wide range of meanings, because their constituents are weakly associated, therefore the broad (and hence overlapping) semantic fields of the RH code them. In other words, the lateralization of processing depends on the semantic-feature overlap between constituents. Two factors have been posited to contribute to semantic feature overlap: (1) category membership and (2) strength of association. The RH has been argued to process category members that are not associated (arm-nose), while the LH to exhibit a processing advantage for category members that are also associated (arm-leg) (Chiarello, 1991). As a consequence, the degree of lateralization during processing expressions that do not involve category membership and have no overlapping semantic features (e.g. adjective–noun expressions in the present study) shall be determined by the strength of association.

The Bilateral Activation, Integration, and Selection (BAIS) framework (Jung-Beeman, 2005) is an extended version of the coarse semantic coding theory, which is more flexible in terms of lateralization of language processing. Jung-Beeman proposes that three finely tuned semantic systems work together in a highly interactive manner: the posterior middle and superior temporal gyri activate, the inferior frontal gyrus selects, and the anterior middle and superior temporal gyri integrate semantic information, bilaterally. The fine coding systems of the LH settle on rapid and focused solutions via close links, while the coarse systems of the RH maintain broader interpretations via distant semantic links, in accordance with specific task demands. As a result, any given semantic task might partially place demands on the LH and on the RH – for example, it is possible that activation spreads in a coarse manner, but selection or integration requires fine coding.

Taken together, these models of lateralized language processing do not consider the figurativeness of expressions to be a relevant factor. At the same time empirical studies often fail to point out that the RH processing is not specific to metaphors. The formulation of the conclusion that novel metaphors require RH processing lends itself to the interpretation that the cause is not solely novelty, but also figurativeness. Because of these contradictions the issue needs more clarification.

1.3. Novelty and figurative language

Most metaphor researchers did not study figurativeness independent of novelty, even though a number of groups compared novel metaphors with conventional ones. This is only a partial solution, because such a design potentially confounds novelty and figurativeness. A right-hemisphere advantage could either be due to novelty, or figurativeness, or both. Another way to shed light on processes specific to metaphors is to keep the level of novelty constant, and compare novel metaphors with novel literal expressions.

A number of studies compared novel metaphorical and novel literal sentences, but the question of lateralization has not been settled. In their ERP study, Coulson and Van Petten (2007) found that the generators of a late positivity in the 600–1200 ms time window, evoked by novel sentences with similarly low probability sentence final words, are not identical for novel metaphorical and novel literal sentences. Therefore, novel metaphors might require unique computations. In a DVF experiment Schmidt et al. (2007) found RH advantage for unfamiliar metaphorical and unfamiliar literal sentences, but they failed to obtain any clear LH effects for familiar literal sentences, nor did they find any interaction between conditions and hemispheric presentation. When participants were familiarized with novel metaphors, activation decreased in bilateral and LH regions (Cardillo, Watson, Schmidt, Kranjec, & Chatterjee, 2012), suggesting that novelty processing does not necessarily depend upon the RH. In an experiment with patients with brain injury, interpreting familiar idiomatic expressions posed difficulties for RHD patients, while novel literal expressions were problematic for LHD patients (Van Lancker & Kempler, 1987). Diaz et al. (2011) asked healthy individuals to evaluate figurative and literal sentences, both familiar and novel, using fMRI, but found contradictory results. Group comparisons showed RH activations for all novel sentences, and for all figurative sentences. On the other hand, novel literal expressions, relative to familiar literals, elicited BOLD signal change only in the LH, and novel metaphors did not differ either from novel literals or from familiar metaphors. Neither of these results is in line with the predictions the graded salience hypothesis (Giora, 2003), or the original version of the coarse semantic coding theory (Beeman, 1998). And the above two experiments hint that it might be the LH that processes novel literal expressions. Forgács et al. (2012) tested the very same four conditions as Diaz et al. (2011), using noun–noun compound words without context. Novel words, in general, relative to conventional words, induced a stronger BOLD signal change in left inferior frontal gyrus (LIFG), perhaps reflecting both the selection of the appropriate meaning in a fine-coded manner and the semantic unification (Hagoort, 2005) of the two constituents. Novel metaphors, relative to novel literal expressions, evoked left anterior and posterior middle temporal activations. These areas, according to the BAIS model (Jung-Beeman, 2005), are responsible for fine-grained semantic integration and activation, respectively. The results suggest that the brain allocates its resources flexibly in a way that is finely tuned to the task at hand, and that RH areas might not be necessary for computing either figurativeness, or novelty.

1.4. Computational demands on the RH

One possible explanation for the contradictory findings with figurative and novel language is that the RH is sensitive to a number of linguistic variables, such as context (Ferstl, Neumann, Bogler, & von Cramon, 2008; St. George et al., 1999; Vigneau et al., 2011; Xu, Kemeny, Park, Frattali, & Braun, 2005). Contextual effects could have masked RH effects in fMRI studies. When metaphors are embedded in sentences, activations could cancel out each other across conditions. In one fMRI study context congruity exerted a stronger effect on the RH than figurativeness (Diaz & Hogstrom, 2011). Another possibility is that sentential processing places demands on the LH to an extent that overrides RH effects for novel items in sentences (cf. Mashal, Faust, Hendler, and Jung-Beeman 2009). One straightforward way to control for contextual and sentential effects is to present metaphors in isolation. Further on, emotions (Ferstl, Rinck, & Von Cramon, 2005) and visual imagery (Just, Newman, Keller, McEleny & Carpenter, 2004) are dimensions that are also potentially driving up the processing load on the RH, hence are necessary to control.

1.5. The rationale for the study

Motivated by contradictory findings in the literature, we designed the current study (1) to replicate a DVF experiment involving two word expressions by Faust and Mashal (2007); and (2) to extend it with a novel literal condition to directly control for the effect of processing novelty. More specifically, our goal was to test the predictions of the graded salience hypothesis (Giora, 2003), and determine whether the RH has a processing advantage in the comprehension of novel expressions irrespective of their figurativeness. In order to reduce potential hemispheric computational confounds, we presented word pairs in isolation, without sentential context, and controlled for a number of linguistic factors (emotional valence, arousal, and imageability) that could influence processing.

Comparing metaphorical and literal expressions matched according to novelty also offers a good opportunity to explore whether there are processes specific to metaphor comprehension. Particularly we could test whether the figurative meaning of novel metaphors is available only after a serial procedure, either as a result of a failed categorization, or the rejection of a salient literal meaning.

Our hypotheses were: (1) novel expressions, both metaphorical and literal, will be processed faster and more accurately when presented to the left visual field (LVF)–RH than to the right visual field (RVF)–LH, while conventional expressions, both metaphorical and literal, will be processed faster and more accurately when presented to the RVF–LH than to the LVF–RH. (2) There will be no processing differences in terms of response accuracy and reaction times between conventional metaphorical and literal expressions. However, novel metaphors will be processed slower than novel literal expressions – either because in the case of novel metaphors the salient literal meaning has to be rejected before arriving at the non-salient figurative meaning (Giora, 1997, 1999; Giora & Fein, 1999), or because of a lack of a failed categorization attempt, specific to novel metaphors (Bowdle & Gentner, 2005).

2. Methods

2.1. Participants

Thirty-seven undergraduate university students (18 female), aged 18–27 (M=20.29, SD=1.97), participated in the study for course credit. All participants were native speakers of Hungarian, had normal or corrected to normal vision, had no history of neurological or psychiatric disorders, and were right handed with a handedness quotient above or equal to 50 (M=76.53, SD=14.19) according to the Edinburgh Handedness Inventory (Oldfield, 1971). Ten additional participants were excluded because their handedness quotient was below 50, and another eight because of inaccurate eye-tracker calibration for more than 50% of the trials.

2.2. Stimuli

Stimuli consisted of 288 Hungarian adjective–noun word pairs. There were four experimental conditions, each with 36 word pairs. Conventional Metaphors (CM) (e.g., “warm heart”), Conventional Literal (CL) (e.g., “full stomach”), Novel Metaphors (NM) (e.g., “stinky deal”), and Novel Literal (NL) expressions (e.g., “boiled coke”). 144 semantically unrelated word pairs (e.g., “dilled zero”) served as fillers for the semantic decision task. We present examples in Table 1. Word length was controlled for with number of characters, and frequency for each target word was determined based on frequency counts in the Hungarian Webcorpus (http://mokk.bme.hu/en/resources/webcorpus/) by MOKK (Halácsy et al., 2004;

Table 1
Examples of the stimuli from the four experimental conditions and the filler condition (translated from Hungarian).

Conventional Metaphor	Conventional Literal	Novel Metaphor	Novel Literal	Unrelated
brilliant idea	famous painter	soft irony	adult ant	corrupt pump
blind love	deep water	silky sunset	canned radish	cooked mass
light meal	wilted flower	worn idea	funny donor	ticklish roller
warm heart	full stomach	sparkling party	kitschy bus	dilled zero
dark secret	straight line	smoky song	cycling chorus	angular dew
crude joke	narrow hips	stinky deal	elegant pimp	alert edge
sharp mind	frizzy hair	dusty poem	muddy train	drunk armor
bitter cold	knitted sweater	cruel building	boiled coke	thermal acacia

Kornai, Halácsy, Nagy, Trón, & Varga, 2006). Conventional word pairs were commonplace, fixed expressions, and part of everyday language. Novel word pairs were constructed from words that did not form a conventional or familiar expression, were not associated, but that were semantically compatible. In order to assign word pairs to categories in an objective manner, we entered pairs in a Google search. We included in the novel conditions only combinations that had zero word bigram frequencies; and in the conventional conditions we included only those that were frequent (at least 1000 hits). According to a Shapiro–Wilk test the distribution was not normal either for CMs, $W(36)=.6$, $p<.001$, or for CLs, $W(36)=.9$, $p<.01$, but according to a Mann–Whitney test there was no statistical difference between the two conditions, $U=785.5$, $p>.12$, $r=.18$; CM:*Mdn*=5255; CL:*Mdn*=10,070.

When selecting word pairs we controlled for a number of semantic factors that included meaningfulness, literalness, emotional valence, arousal, and imageability. First, 23 university students, who did not participate in the DVF experiment, rated the word pairs on a 7-point Likert scale for meaningfulness ("Please rate the word pairs according to how meaningful they seem to you." 1: "Completely" and 7: "Not at all"). Then participants engaged in a second task in which they rated the same words for literalness ("Please rate the word pairs according to how literally you interpreted them during your previous meaningfulness rating." 1: "Completely" and 7: "Not at all"). In a separate norming-study 30 university students (who also did not participate in the subsequent DVF experiment) rated the words according to the procedures of the Berlin Affective Word List, or BAWL (Võ, Jacobs, and Conrad 2006), on a 7-point Likert scale for emotional valence ("Please rate the word pairs according to their emotional valence." −3: "Highly negative", +3: "Highly positive"); arousal ("Please rate the word pairs according to how emotionally arousing they are." 1: "Not at all", 7: "Completely"); and imageability ("Please rate the word pairs according to how easily they evoke a mental image." 1: "Not at all", 7: "Completely").

We performed a one-way ANOVA on the norming data with word category as the differentiating factor. Experimental conditions did not differ in terms of target word frequency, $F(3, 140)=1.7$, $p=.17$, and length, $F(3, 140)=.6$, $p=.6$. As expected, literalness was significantly different across categories, $F(3, 140)=374.6$, $p<.001$, and Tamhane's post-hoc test revealed that except for conventional and novel metaphors all categories were significantly different ($p<.001$). It was not possible to make the experimental categories completely homogenous with regard to imageability, $F(3, 140)=49.3$, $p<.001$ (all categories being different according to Tamhane's post-hoc test, $p<.04$), and arousal, $F(3, 140)=2.8$, $p=.04$ (only CLs and NMs being different according to Tamhane's post-hoc test, $p<.04$), but we found no difference in valence, $F(3, 140)=1.9$, $p=.13$. We conducted a second one-way ANOVA, with unrelated word pairs also included, in order to test meaningfulness ratings. As expected, the effect was significant, $F(4, 283)=683.3$, $p<.001$. Tamhane's post-hoc test revealed that the meaningfulness of all categories were significantly different from each other ($p<.001$). Results of the norming are shown in Table 2. We included meaningfulness and all BAWL factors in the final statistical analysis as covariates.

2.3. Experimental procedure

After reading the instructions and completing 16 practice items (eight examples of the unrelated and two of each meaningful conditions, not included in the stimuli), participants viewed 288 word pairs. The first words of the expressions (the adjectives) that served as primes were presented centrally, while the second, target words (the nouns) appeared randomly either in the LVF or in the RVF. There were two stimulus sets, so that each target word was presented to both LVF–RH and RVF–LH across participants. Central fixation during the lateralized presentation was assured by an infrared eye-tracking system (IView X RED, SMI, Germany). If the subjects moved their gaze away from the central fixation-cross and towards the target, the word disappeared, and the trial ended. We presented stimuli, recorded responses, and controlled the eye-tracker with the Presentation 14.8 software (www.neurobs.com). Participants placed their head on a chinrest, at a viewing distance of 60 cm from the screen. All words appeared in white Arial letters (font size: 22) on a black background. After a fixation cross ("+") appeared centrally for 3000 ms, prime words appeared centrally for 400 ms. Following a central fixation-cross for 400 ms (SOA=800 ms), target words appeared for 180 ms, either to the left or to the right of the re-appearing central fixation-cross. Once the participant responded, the next trial began. We presented target words 1.6° to the left or to the right of the central fixation cross, since there is no strong evidence in favor of the bilateral representation of the fovea in the cortex, suggesting that it is split in humans (Brysbaert, 2004; Lavidor, Ellis, Shillcock, Bland, 2001; Lavidor & Walsh, 2004). According to participants' subjective account, words appeared in their visual periphery. Participants performed two blocks of trials, with a break in between. The eye-tracker's calibration was automatically checked at every 20 trials, and was re-established when necessary. We told participants to decide, as fast and accurately as possible, whether or not the two words constituted a meaningful combination. We instructed them to keep their right index finger above the right-arrow-key of the keyboard and to push it to indicate "yes", and to keep their left index finger above the left-arrow-key and push it to indicate "no".

3. Results

We excluded trials if eye-tracker calibration failed or if the target word appeared for less than 180 ms, indicating eye-movement (19.22%). We performed both subject (F1) and item (F2) based analyses on response accuracy and on the median of reaction times for correct responses. Meaningfully unrelated word pairs were not included in the analyses since they served as fillers.

For the F1 subject analysis we conducted a 2 × 2 × 2 (Visual Field × Figurativeness × Novelty) repeated measures analysis of variance (ANOVA). We found all main effects to be significant for response accuracy: visual field, $F_1(1, 36)=25$, $p<.001$, $\eta_p^2=.41$, figurativeness, $F_1(1, 36)=55.3$, $p<.001$, $\eta_p^2=.61$, and novelty, $F_1(1, 36)=422.7$, $p<.001$, $\eta_p^2=.92$. There was a significant three-way interaction between visual field, figurativeness, and novelty, $F_1(1, 36)=6.3$, $p=.02$, $\eta_p^2=.15$, a two-way interaction between novelty and figurativeness, $F_1(1, 36)=4.2$, $p=.049$, $\eta_p^2=.1$, and novelty and visual field, $F_1(1, 36)=4.5$, $p=.04$, $\eta_p^2=.11$. To break down the three-way interaction responses to conventional and novel conditions were entered into a 2 × 2 (Visual Field × Figurativeness) ANOVA separately, which yielded a significant interaction between the two within-subject variables for the conventional items, $F_1(1, 36)=5.4$, $p=.03$, $\eta_p^2=.13$, but not for the novel items, $F_1(1, 36)=1.9$, $p=.18$, observed power=.27. It was not possible to explain the interaction, since we found the one-way (visual field) ANOVA significant for CMs, $F_1(1, 36)=26.2$, $p<.001$, $\eta_p^2=.42$, and for CLs, $F_1(1, 36)=20.3$, $p<.001$, $\eta_p^2=.36$, both being processed more accurately in the RVF–LH. However, the effect sizes suggest that this former difference in accuracy was greater for CMs than for CLs. In the two-way ANOVAs there was a significant main effect of visual field for conventional items, $F_1(1, 36)=38.5$, $p<.001$, $\eta_p^2=.52$, and also for novel items, $F_1(1, 36)=4.4$, $p=.04$, $\eta_p^2=.11$. Based on the effect sizes, the difference in accuracy in the RVF–LH was greater for conventional items than for novel items. The main effect of figurativeness was significant again for both conventional, $F_1(1, 36)=24.2$, $p<.001$, $\eta_p^2=.40$, and novel expressions, $F_1(1, 36)=35$, $p<.001$, $\eta_p^2=.49$, where the effect sizes suggest that the higher accuracy of NLs relative to NMs was a greater difference than the higher accuracy of CLs relative to CMs. These latter main effects of the 2 × 2 ANOVAs were

Table 2
Mean (*SD*) values of psycholinguistic properties of the four experimental conditions and the filler condition.

	Conventional Metaphor	Conventional Literal	Novel Metaphor	Novel Literal	Unrelated
Frequency of target word	22378 (35420)	8402 (12895)	22246 (49636)	10290 (30552)	4332 (11605)
Length of target word	5.31 (1.79)	4.94 (1.09)	5 (1.07)	5.19 (1.04)	5.31 (1.01)
Meaningfulness (1 = highest)	1.54 (.35)	1.25 (.15)	3.4 (.85)	2.59 (.67)	5.39 (.53)
Literalness (1 = highest)	4.73 (.51)	1.95 (.21)	4.52 (.53)	2.41 (.44)	3.96 (.45)
Valence (−3 to +3)	.03 (1.26)	.14 (1.32)	−.45 (1.04)	−.16 (.84)	−.22 (.7)
Arousal (1 = none)	3.95 (1.2)	3.57 (1.21)	4.29 (.94)	3.99 (.76)	4.04 (.66)
Imageability (1 = none)	4.31 (.78)	5.56 (.58)	3.77 (.6)	4.78 (.61)	3.26 (.58)

equivalent with a brake down the two-way interactions of the three-way ANOVA (Novelty × Figurativeness and Novelty × Visual Field), however, because both subtests were significant in both cases, neither was possible to explain.

The median values of reaction times (F1) were entered also in a 2 × 2 × 2 (Visual Field × Figurativeness × Novelty) ANOVA, and all main effects proved significant: visual field, $F_1(1, 36)=12.1$, $p=.001$, $\eta_p^2=.25$, figurativeness, $F_1(1, 36)=11.8$, $p=.002$, $\eta_p^2=.25$, and novelty, $F_1(1, 36)=117.5$, $p<.001$, $\eta_p^2=.77$. The three-way interaction was not significant, $F_1(1, 36)=1.1$, $p=.29$, observed power = .18, but there was a significant two-way interaction between figurativeness and novelty, $F_1(1, 36)=17.7$, $p<.001$, $\eta_p^2=.33$. In order to break down the interaction, the data was collapsed across visual fields. Conventional and novel conditions were entered separately into a single level ANOVA with figurativeness being the only within-subject variable. CLs were processed significantly faster compared to CMs, $F_1(1, 36)=47.5$, $p<.001$, $\eta_p^2=.57$, but there was no difference between NLs and NMs, $F_1(1, 36)=.2$, $p=.66$, observed power = .07.

The F2 item analysis consisted of a two-level (visual field) repeated measures ANCOVA, with figurativeness and novelty as between-subject variables, and valence, arousal, imageability and meaningfulness as covariates. For response accuracy only the three-way interaction between visual field, figurativeness, and novelty, $F_2(1, 136)=4.9$, $p=.03$, $\eta_p^2=.04$, and the main effect of novelty, $F_2(1, 136)=13$, $p<.001$, $\eta_p^2=.09$, were significant. Meaningfulness was the only covariate that had a significant effect, $F_2(1, 136)=29.3$, $p<.001$, $\eta_p^2=.18$. When it was not included in the analysis, effects remained the same, except that the interaction between visual field and imageability became significant, $F_2(1, 137)=4.1$, $p=.04$, $\eta_p^2=.03$. When imageability was removed, the three-way interaction and the main effect of novelty remained, but also the between-subject effect of figurativeness proved significant, $F_2(1, 138)=15.7$, $p<.001$, $\eta_p^2=.1$. This suggests that the main effect of figurativeness in the F1 accuracy analysis could be due to the higher meaningfulness and imageability of literal expressions. To break down the three-way interaction, conventional and novel items were introduced separately to an ANCOVA identical to the one above except that only figurativeness was included as a between-subject variable. For conventional expressions there was no interaction between visual field and figurativeness, $F_2(1, 66)=.2$, $p=.66$, observed power = .07. Visual field had a significant main effect, $F_2(1, 66)=4.6$, $p=.04$, $\eta_p^2=.07$, and it was in interaction with meaningfulness, $F_2(1, 66)=8.9$, $p=.004$, $\eta_p^2=.12$, which latter also had a significant covariate effect, $F_2(1, 66)=19.6$, $p<.001$, $\eta_p^2=.23$. When we removed meaningfulness from the analysis, only figurativeness had a significant effect, $F_2(1, 67)=7.7$, $p=.01$, $\eta_p^2=.1$ (and visual field not). This suggests that the higher accuracy in the F1 analysis for conventional expressions in the RVF–LH relative to LVF–RH is reliable, even though modulated by meaningfulness, while the higher accuracy of CLs relative to CMs could be due to the higher meaningfulness of CLs. In the case of novel expressions, only meaningfulness had a significant effect, $F_2(1, 66)=13$, $p=.001$, $\eta_p^2=.17$, and when it was omitted, imageability marginally covaried with visual field, $F_2(1, 67)=3.8$, $p=.054$, $\eta_p^2=.05$. When both of the latter covariates were omitted, the effect of figurativeness become significant, $F_2(1, 68)=7.5$, $p=.01$, $\eta_p^2=.1$, suggesting that the more accurate processing of NLs compared to NMs in the F1 analysis, could be due to their higher meaningfulness and imageability.

Finally, median reaction times for the F2 analysis were included in an ANCOVA whose design was identical to the one above. There was no significant three-way interaction between visual field, figurativeness, and novelty, $F_2(1, 136)=1.9$, $p=.18$, observed power = .27. We found a significant main effect for novelty, $F_2(1, 136)=28.2$, $p<.001$, $\eta_p^2=.17$, but neither figurativeness, nor visual field was significant. Arousal was in interaction with visual field, $F_2(1, 136)=5.6$, $p=.02$, $\eta_p^2=.04$, and imageability marginally covaried, $F_2(1, 136)=3.9$, $p=.050$, $\eta_p^2=.03$. Emotionally more arousing word pairs were processed slower only in the LVF–RH. When arousal was not included in the model, the effect of visual field was still not significant, while the main effect of novelty and a trend for imageability remained, $F_2(1, 137)=3.8$, $p=.052$, $\eta_p^2=.03$. When only imageability was omitted, the main effect of visual field turned out to be significant, $F_2(1, 137)=4.5$, $p=.04$, $\eta_p^2=.03$, and figurativeness as well, $F_2(1, 137)=7.2$, $p=.01$, $\eta_p^2=.05$, otherwise all effects remained the same. Only in the RVF–LH were more imageable expressions processed faster, and was figurativeness in an interaction with novelty. These results suggest that in the F1 analysis the main effect of faster responses in the RVF–LH could be due to imageability and modulated by arousal, and the main effect of faster responses to literal expressions could be due to imageability. In a separate analysis, bigram frequency was also included in the relevant comparisons, but the pattern of results did not change. No other statistical tests were significant (all values of $F<3.8$, and $p>.058$).

In summary, our analyses revealed no RH processing advantage for novel items, either for metaphorical or literal. Both novel and conventional expressions were processed more accurately in the RVF–LH than in the LVF–RH (where meaningfulness contributed to the latter advantage), and all word pairs were processed faster in the RVF–LH (which was influenced by imageability, and in interaction with arousal). Irrespective of lateralization, CLs were processed more accurately than CMs, but it could be due to meaningfulness; NLs were processed more accurately than NMs, but meaningfulness and imageability could have contributed to

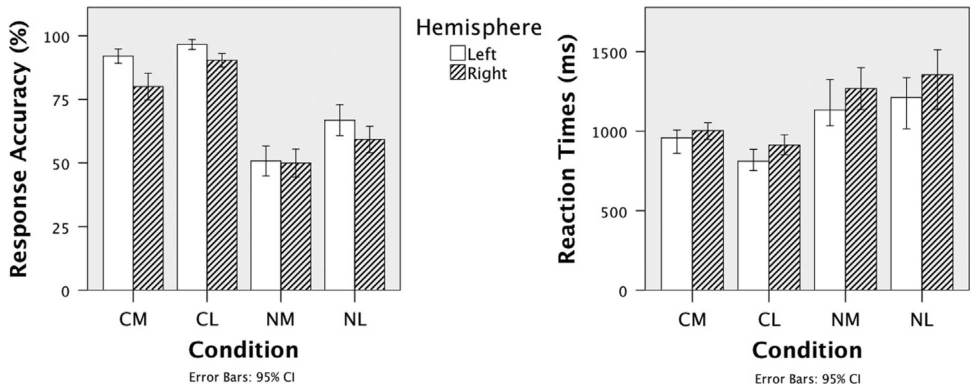

Fig. 1. Response accuracy (%), and median reaction times (ms) according to the F1 analysis. CM: conventional metaphor, CL: conventional literal, NM: novel metaphor, NL: novel literal expressions. All conventional and novel literal word pairs were processed more accurately, and all word pairs faster in the RVF–LH. NMs were processed just as fast as NLs, while CMs were processed slower than CLs.

this effect. CL word pairs were processed faster than CMs, but NMs did not need more processing time than NLs. We present the results of the F1 analyses in Fig. 1.

4. Discussion

The goal of the present study was to clarify the RH′s role in the comprehension of novel expressions, especially novel metaphors. In order to separate the effects of figurativeness and novelty, we introduced an experimental condition in which we presented novel literal word pairs. In contrast to most DVF experiments on figurative language (except when ERPs are recorded), we ensured lateralized presentation by using an eye-tracker. Additionally, we controlled for a number of factors that could activate the RH and act as confounds. We presented stimuli without context, and in the statistical analysis we included emotional valence, arousal, imageability, and meaningfulness as covariates.

4.1. *Novel expressions*

The LVF–RH processing advantage for two word novel metaphorical expressions was not evident in our results, either in response accuracy or reaction times, which we attribute to our careful control for potential confounds. Thus, our findings do not support the RH theory of metaphor processing. This observation is in line with earlier studies that did not identify RH processes during NM comprehension (Faust & Weisper, 2000; Mashal & Faust, 2010; Mashal et al., 2009; Shibata, Abe, Terao, & Miyamoto, 2007), although these research groups presented metaphors in sentences that could have affected their results. We presented novel metaphors without context, similarly to experimenters who used word pairs only (e.g., Anaki et al., 1998; Faust & Mashal, 2007; Mashal & Faust, 2008; Mashal et al., 2005, 2007; Pobric et al., 2008). The latter studies reported RH involvement that contradicts our findings. A possible resolution lies in the fact that we controlled for potential confounds such as imageability, emotional valence, and arousal. It is possible that novel metaphors, especially those taken from poetry (e.g., Faust & Mashal, 2007), differed from literal expressions in ways beyond those related to metaphoric value or novelty. Poetic effects often evoke pragmatic processes that are known to require RH resources (e.g., Pléh, 2000; Van Lancker, 1997). Our controlling for the aforementioned factors could explain why we did not replicate the previously reported LVF–RH processing advantage.

The finding that novel literals were processed more accurately, and that all novel word pairs were processed faster in the RVF–LH was not predicted by the graded salience hypothesis (Giora, 2003) or by the first version of the coarse semantic coding theory (Beeman, 1998); however, the BAIS framework (Jung-Beeman, 2005) can provide an explanation. According to this model there are two kinds of semantic activations, integrations, and selections: a finely coded one, and a coarsely coded one. The various sub-processes of language comprehension can tax either of the two hemispheres depending on the specific task. Selecting a relevant meaning, or integrating the word pairs into novel meaningful expressions could have required fine coding, even though they were not related semantically. Forgács et al. (2012) found that literal and metaphorical novel noun–noun compound words activated the LIFG. The inhibition of irrelevant, and the selection of appropriate senses seem to be LH weighted tasks, especially when conditions encourage strategic and post-access processing (Chiarello, 1988, 1991; Chiarello, Senehi, & Nuding, 1987). Alternatively, semantic integration of lexical items might be primarily a LH procedure (while contextual integration still could be carried out by the RH). Importantly, the paradigmatic summation priming task in the experiment of Beeman et al. (1994) did not require the integration of words into novel units. In that experiment subjects read three prime words (“foot”, “cry”, “glass”), each distantly related to the target word (“cut”) that had to be named following lateralized presentation. Furthermore, priming studies show that RH activations could be explained solely by spreading activation, but the LH dominance in semantic processing is not merely the result of automatic activation or focused lexical access (Chiarello et al., 1987). When one′s task is to arrive at coherence, rather than predictive inferences, the LH clearly shows a priming advantage (Beeman, Bowden, & Gernsbacher, 2000).

The comparable reaction times for NMs and NLs indicate that contrary to predictions of the graded salience hypothesis, there was no serial processing of salience. If the salient (i.e. literal) meaning of a NM had been processed first, and the non-salient figurative meaning inferred only afterwards (Giora, 1997, 1999, 2003), NMs should have taken longer to process than NLs. Even though the graded salience hypothesis proposes that unlike conventional expressions, novel expressions have no salient meaning, it is not clear why NLs required as much processing time as NMs. Does any kind of salient (literal) meaning have to be dropped in order to reach another, non-salient (but again literal) meaning? Thus, a saliency based explanation seems unsupported by our results. A more plausible explanation is that the meaning of novel expressions is not computed serially, but instead it is directly accessible once a semantic analysis has taken place. After the possible meanings of the constituents are activated, the most plausible candidates are selected, and then integrated. The processing of potential meanings seems to be carried out directly both for literal and metaphorical expressions. Blasko & Connine (1993) provided evidence that figurative meaning could be quickly available for apt NMs.

Similarly, the career of metaphor hypothesis (Bowdle & Gentner, 2005), as much as it can be generalized from nominal metaphors, proposes that NMs are processed serially. They should be comprehended as a comparison only after a failed categorization attempt (that is evoked by their grammatical concordance with literal comparisons). Since NLs do not require this extra step, NMs are expected to take longer to process. This was not apparent in our experiment, thus the theory is not supported by our results. Glucksberg (2003) proposes in his category assertion view that even novel (nominal) metaphors are comprehended via a categorization. Metaphorical terms are understood because they have a dual reference to a literal subordinate, and to a figurative ad hoc superordinate category, both of which are available. Whether or not this is the case, our results do not contradict his theory. During the processing course of novel expressions probably several potential meanings are activated and a figurative or a literal meaning is equally accessible, within a comparable time.

4.2. Conventional expressions

In line with the graded salience hypothesis (Giora, 2003) all conventional items were processed faster and more accurately in the RVF–LH than in the LVF–RH (although accuracy was modulated by meaningfulness, the RVF–LH advantage was consistent). Fixed expressions may be stored as lexical units, and it could be easier for the LH to retrieve and evaluate them.

Irrespective of lateralized processing, we found that CMs were processed slower and less accurately than CLs (the slower reaction times to metaphors appeared to be influenced by their lower imageability, and the lower accuracy by their lower meaningfulness). This is an important result, since the graded salience hypothesis (Giora, 2003) predicts no processing difference between conventional items in terms of figurativeness. Since we did not find evidence for serial processing of NMs, the processing delay is unlikely to indicate serial processing of CMs either. However, compared to CLs, CMs have not one, but two possible meanings, a literal and a figurative, both of which could be readily available. This dual activation is predicted by both the parallel access view (Gibbs, 1994) and the graded salience hypothesis (Giora, 2003). Contrary to novel expressions, the figurative and literal meanings are not just directly accessible, but both of them are accessed – and both of them are accessed faster than the meaning of any kind of novel expression. The activation of two possible meanings could explain the overall slower processing time, since one of them has to be selected. Semantic selection is probably taking place primarily in the LH (Burgess & Simpson, 1988), imposing extra processing load on that hemisphere. Forgács et al. (2012) found that conventional metaphors (relative to conventional literal expressions) activated the LIFG; the BAIS framework (Jung-Beeman, 2005) suggests that this area is responsible for fine-coded selection. Based on our results Gibbs' (1994) parallel access view could be extended to CMs not presented in a supportive context. The modulating effect of the closely related imageability and meaningfulness is an issue that should be explored in future studies, even though it might be an inherent feature of metaphorical language. Most metaphors refer to abstract concepts, which are more difficult to experience with the senses, thus are less imageable – and as a consequence less meaningful. Across all categories of word pairs the latter two factors correlated strongly: $r(288) = -.77$, $p < .001$.

4.3. Conclusions

In the present divided visual field study we employed an eye-tracker to ensure hemifield presentation of adjective-noun word pairs, without sentential context, to study the lateralized processing of novel metaphors. With our experiment we attempted to both replicate that of Faust and Mashal (2007) and, at the same time, extend it by an additional condition of novel literal expressions. With the new condition we controlled for processing novelty, and with including in the statistical analysis a number of potentially confounding variables (such as emotional valence, arousal, imageability, and meaningfulness) we were able to control for their influence on RH processing.

With this design, we found that all categories of word pairs were processed faster in the RVF–LH, and accuracy was also higher in the RVF–LH. Our results contradict studies in which researchers argued for a LVF–RH processing advantage for novel metaphors, and raise the possibility that other uncontrolled variables were responsible for previous results. Reaction times data indicated that the degree of lateralization of processing is influenced by how arousing the expressions are – even though only CLs and NMs were significantly different. Controlling for emotional factors, such as arousal, might be crucial for future studies examining hemispheric differences in figurative language comprehension. Responses to novel word pairs were faster in the RVF–LH, and were slower than those for conventional expressions, which together suggest that primarily a left hemisphere weighted semantic integration is responsible for their processing costs. The lack of reaction time differences between novel metaphors and novel literal expressions call into question the theories that posit a serial processing, either of salience (Giora, 1997, 1999), or as a consequence of a failed categorization attempt (Bowdle & Gentner, 2005). Both conventional categories of word pairs were processed faster and more accurately in the RVF–LH, while conventional metaphors were processed slower than conventional literal expressions, perhaps as a result of a parallel access to their literal and figurative senses. The results highlight the task sensitivity of the division of labor for language comprehension between the two cerebral hemispheres, and indicate that the role of the RH might not be as specific to metaphors, or even to non-salient language, as it has been proposed. Previous studies could have reported pragmatic effects stemming from the experimental situation and task. Further empirical studies are required to elucidate the language specific processes of the RH.

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References

Ahrens, K., Liu, H., Lee, C., Gong, S., Fang, S., & Hsu, Y. (2007). Functional MRI of conventional and anomalous metaphors in Mandarin Chinese. *Brain and Language*, *100*, 163–171.
Anaki, D., Faust, M., & Kravetz, S. (1998). Cerebral hemispheric asymmetries in processing lexical metaphors. *Neuropsychologia*, *36*, 691–700.
Arzouan, Y., Goldstein, A., & Faust, M. (2007). Dynamics of hemispheric activity during metaphor comprehension: Electrophysiological measures. *Neuroimage*, *36*, 222–231.
Beeman, M., Friedman, R. B., Grafman, J., Perez, E., Diamond, S., & Lindsay, M. B. (1994). Summation priming and coarse semantic coding in the right hemisphere. *Journal of Cognitive Neuroscience*, *6*(1), 26–45.
Beeman, M. J. (1998). Coarse semantic coding and discourse comprehension. In: M. Beeman, & C. Chiarello (Eds.), *Right hemisphere language comprehension: Perspectives from cognitive neuroscience* (pp. 255–284). Mahwah, NJ: Erlbaum.
Beeman, M. J., Bowden, E. M., & Gernsbacher, M. A. (2000). Right and left hemisphere cooperation for drawing predictive and coherence inferences during normal story comprehension. *Brain and Language*, *71*(2), 310–336.

Bihrle, A., Brownell, H., & Gardner, H. (1986). Comprehension of humorous and nonhumorous materials by left- and right-brain damaged patients. *Brain and Cognition*, *5*, 399–411.
Blasko, D., & Connine, C. M. (1993). Effects of familiarity and aptness on metaphor processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*(2), 295–308.
Bohrn, I. C., Altmann, U., & Jacobs, A. M. (2012). Looking at the brains behind figurative language – A quantitative meta-analysis of neuroimaging studies on metaphor, idiom, and irony processing. *Neuropsychologia*, *50*(11), 2669–2683.
Bottini, G., Corcoran, R., Sterzi, R., Paulesu, E. S. P., Scarpa, P., & Frackoviak, R. S. J. (1994). The role of the right hemisphere in the interpretation of the figurative aspects of language: A positron emission tomography activation study. *Brain*, *117*1241–1253.
Bowdle, B. F., & Gentner, D. (2005). The career of metaphor. *Psychological Review*, *112*(1), 193–216.
Brownell, H., & Stringfellow, A. (1999). Making requests: Illustrations of how right-hemisphere brain damage can affect discourse production. *Brain and Language*, *68*(3), 442–465.
Brownell, H. H., Michel, D., Powelson, J., & Gardner, H. (1983). Surprise but not coherence: Sensitivity to verbal humor in right-hemisphere patients. *Brain and Language*, *18*(1), 20–27.
Brownell, H. H., Simpson, T. L., Bihrle, A. M., Potter, H. H., & Gardner, H. (1990). Appreciation of metaphoric alternative word meanings by left and right brain damaged patients. *Neuropsychologia*, *28*(4), 375–383.
Brysbaert, M. (2004). The importance of interhemispheric transfer for foveal vision: A factor that has been overlooked in theories of visual word recognition and object perception. *Brain and Language*, *88*, 259–267.
Burgess, C., & Simpson, G. (1988). Cerebral hemispheric mechanisms in the retrieval of ambiguous word meanings. *Brain and Language*, *3*, 86–103.
Cardillo, E. R., Watson, C. E., Schmidt, G. L., Kranjec, A., & Chatterjee, A. (2012). From novel to familiar: Tuning the brain for metaphors. *NeuroImage*, *59*, 3212–3221.
Chen, E., Widick, P., & Chatterjee, A. (2008). Functional–anatomical organization of predicate metaphor processing. *Brain and Language*, *107*, 194–202.
Chiarello, C. (1988). Lateralization of lexical processes in the normal brain: a review of visual half-field research. In: H. H. Whitaker (Ed.), *Contemporary reviews in neuropsychology* (pp. 59–69). New York: Springer-Verlag.
Chiarello, C. (1991). Interpretation of word meanings in the cerebral hemispheres: One is not enough. In: P. J. Schwanenflugel (Ed.), *The psychology of word meanings* (pp. 251–275). Hillsdale, NJ: Erlbaum.
Chiarello, C. (2003). Parallel systems for processing language: Hemispheric complementarity in the normal brain. In: M. T. Banich, & M. Mack (Eds.), *Mind, brain and language* (pp. 229–247). Mahwah, NJ: Erlbaum.
Chiarello, C., Senehi, J., & Nuding, S. (1987). Semantic priming with abstract and concrete words: Differential asymmetry may be postlexical. *Brain and Language*, *31*, 43–60.
Coulson, S., & Van Petten, C. (2007). A special role for the right hemisphere in metaphor comprehension? ERP evidence from hemifield presentation. *Brain Research*, *1146*, 128–145.
Coulson, S., & Williams, R. F. (2005). Hemispheric asymmetries and joke comprehension. *Neuropsychologia*, *43*(1), 128–141.
Coulson, S., & Wu, Y. C. (2005). Right hemisphere activation of joke-related information: An event-related brain potential study. *Journal of Cognitive Neuroscience*, *17*(3), 494–506.
Diaz, M. T., Barrett, K. T., & Hogstrom, L. J. (2011). The influence of sentence novelty and figurativeness on brain activity. *Neuropsychologia*, *49*, 320–330.
Diaz, M. T., & Hogstrom, L. J. (2011). The influence of context on hemispheric recruitment during metaphor processing. *Journal of Cognitive Neuroscience*, *23* (11), 3586–3597.
Eviatar, Z., & Just, M. A. (2006). Brain correlates of discourse processing: An fMRI investigation of irony and conventional metaphor comprehension. *Neuropsychologia*, *44*, 2348–2359.
Faust, M., Ben-Artzi, E., & Harel, I. (2008). Hemispheric asymmetries in semantic processing: Evidence from false memories for ambiguous words. *Brain and Language*, *105*, 220–228.
Faust, M., & Mashal, N. (2007). The role of the right cerebral hemisphere in processing novel metaphoric expressions taken from poetry: A divided visual field study. *Neuropsychologia*, *45*(4), 860–870.
Faust, M., & Weisper, S. (2000). Understanding metaphors in the two cerebral hemispheres. *Brain and Cognition*, *43*, 186–191.
Ferstl, E. C., Neumann, J., Bogler, C., & von Cramon, D. Y. (2008). The extended language network: A meta-analysis of neuroimaging studies on text comprehension. *Human Brain Mapping*, *29*, 581–593.
Ferstl, E. C., Rinck, M., & Von Cramon, D. Y. (2005). Emotional and temporal aspects of situation model processing during text comprehension: An event-related fMRI study. *Journal of Cognitive Neuroscience*, *17*(5), 724–739.
Foldi, N. (1987). Appreciation of pragmatic interpretation of indirect commands: comparison of right and left hemisphere brain damaged patients. *Brain and Language*, *31*, 88–108.
Forgács, B., Bohrn, I., Baudewig, J., Hofmann, M. J., Pléh, C., & Jacobs, A. M. (2012). Neural correlates of combinatorial semantic processing of literal and figurative noun noun compound words. *Neuroimage*, *63*, 1432–1442.
Gibbs, R. W. (1994). *The poetics of mind: figurative thought. Language, and understanding*. Cambridge, UK: Cambridge University Press.
Giora, R. (1997). Understanding figurative and literal language: The graded salience hypothesis. *Cognitive Linguistics*, *8*, 183–206.
Giora, R. (1999). On the priority of salient meanings: Studies of literal and figurative language. *Journal of Pragmatics*, *31*, 919–929.
Giora, R. (2003). *On our mind: Salience, context and figurative language*. New York: Oxford University Press.
Giora, R., & Fein, O. (1999). On understanding familiar and less-familiar figurative language. *Journal of Pragmatics*, *31*, 1601–1618.
Glucksberg, S. (2003). The psycholinguistics of metaphor. *Trends in Cognitive Sciences*, *7*(2), 92–96.
Glucksberg, S., & Keysar, B. (1990). Understanding metaphorical comparisons: Beyond similarity. *Psychological Review*, *97*(1), 3–18.
Hagoort, P. (2005). On Broca, brain, and binding: A new framework. *Trends in Cognitive Sciences*, *9*(9), 416–423.
Halácsy, P., Kornai, A., Németh, L., Rung, A., Szakadát, I., & Trón, V. (2004). Creating open language resources for Hungarian. In Proceedings of language resources and evaluation conference (LREC04), LREC (pp. 203–210).
Jung-Beeman, M. (2005). Bilateral brain processes for comprehending natural language. *Trends in Cognitive Sciences*, *9*(11), 512–518.
Just, M. A., Newman, S., Keller, T. A., McEleny, A., & Carpenter, P. A. (2004). Imagery in sentence comprehension: An fMRI study. *NeuroImage*, *21*, 112–124.
Kacinik, N. A., & Chiarello, C. (2007). Understanding metaphors: Is the right hemisphere uniquely involved? *Brain and Language*, *100*, 188–207.
Kaplan, A., Brownell, H., Jacobs, R., & Gardner, H. (1990). The effects of right hemisphere damage on the pragmatic interpretation of conversational remarks. *Brain and Language*, *38*, 315–333.
Kempler, D., Van Lancker, D., Merchman, V., & Bates, E. (1999). Idiom comprehension in children and adults with unilateral brain damage. *Developmental Neuropsychology*, *15*, 327–349.
Kornai, A., Halácsy, P., Nagy, V., Trón, V., & Varga, D. (2006). Web-based frequency dictionaries for medium density languages. In Kilgarriff, A., & Baroni, M. (Eds). *Proceedings of the 2nd International Workshop on Web as Corpus, ACL-06* (pp. 1–9).
Lavidor, M., Ellis, A. W., Shillcock, R., & Bland, T. (2001). Evaluating a split processing model of visual word recognition: Effects of word length. *Cognitive Brain Research*, *12*, 265–272.
Lavidor, M., & Walsh, V. (2004). The nature of foveal representation. *Nature Reviews: Neuroscience*, *5*, 729–735.
Lee, S. S., & Dapretto, M. (2006). Metaphorical vs. literal word meanings: fMRI evidence against a selective role of the right hemisphere. *NeuroImage*, *29*, 536–544.
Marinkovic, K., Baldwin, S., Courtney, M. G., Witzel, T., Dale, A. M., & Halgren, E. (2011). Right hemisphere has the last laugh: Neural dynamics of joke appreciation. *Cognitive, Affective, & Behavioral Neuroscience*, *11*, 113–130.
Mashal, N., & Faust, M. (2008). Right hemisphere sensitivity to novel metaphoric relations: Application of the signal detection theory. *Brain and Language*, *104*, 103–112.
Mashal, N., & Faust, M. (2010). The effects of metaphoricity and presentation style on brain activation during text comprehension. *Metaphor and Symbol*, *25*, 19–33.
Mashal, N., Faust, M., & Hendler, T. (2005). The role of the right hemisphere in processing nonsalient metaphorical meanings: Application of principal components analysis to fMRI data. *Neuropsychologia*, *43*, 2084–2100.
Mashal, N., Faust, M., Hendler, T., & Jung-Beeman, M. (2007). An fMRI investigation of the neural correlates underlying the processing of novel metaphoric expressions. *Brain and Language*, *100*, 115–126.
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.
Mashal, N., Faust, M., Hendler, T., & Jung-Beeman, M. (2009). An fMRI study of processing novel metaphoric sentences. *Laterality*, *14*, 30–54.
Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, *9*, 97–113.
Pléh, Cs. (2000). Modularity and pragmatics: Some simple and some complicated ways. *Pragmatics*, *10*, 415–438.
Pobric, G., Mashal, N., Faust, M., & Lavidor, M. (2008). The role of the right cerebral hemisphere in processing novel metaphoric expressions: A transcranial magnetic stimulation study. *Journal of Cognitive Neuroscience*, *20*, 170–181.
Rapp, A. M., Leube, D. T., Erb, M., Grodd, W., & Kircher, T. T. J. (2004). Neural correlates of metaphor processing. *Cognitive Brain Research*, *20*, 395–402.
Rapp, A. M., Leube, D. T., Erb, M., Grodd, W., & Kircher, T. T. J. (2007). Laterality in metaphor processing: Lack of evidence from functional magnetic resonance imaging for the right hemisphere theory. *Brain and Language*, *100*, 142–149.
Rinaldi, M. C., Marangolo, P., & Baldassari, F. (2004). Metaphor processing in right brain-damaged patients with visuo-verbal and verbal material: A dissociation (re)considered. *Cortex*, *40*, 479–490.
Schmidt, G. L., DeBuse, C. J., & Seger, C. A. (2007). Right hemisphere metaphor processing? characterizing the lateralization of semantic processes. *Brain and Language*, *100*, 127–141.
Schmidt, G. L., & Seger, C. A. (2009). Neural correlates of metaphor processing: The roles of figurativeness, familiarity and difficulty. *Brain and Cognition*, *71*(3), 375–386.
Shammi, P., & Stuss, D. T. (1999). Humour appreciation: a role of the right frontal lobe. *Brain*, *122*, 657–666.
Shibata, M., Abe, J., Terao, A., & Miyamoto, T. (2007). Neural mechanisms involved in the comprehension of metaphoric and literal sentences: An fMRI study. *Brain Research*, *1166*, 92–102.
Sotillo, M., Carretié, L., Hinojosa, J. A., Manuel, M., Mercado, F., López- Martín, S., et al. (2005). Neural activity associated with metaphor processing: Spatial analysis. *Neuroscience Letters*, *373*, 5–9.
Sperry, R. W. (1985). Consciousness, personal identity, and the divided brain. In: D. F. Benson, & E. Zaidel (Eds.), *The dual brain: hemispheric specialization in humans* (pp. 11–26). New York: Guilford Press.

St. George, M., Kutas, M., Martinez, A., & Sereno, M. I. (1999). Semantic integration in reading: Engagement of the right hemisphere during discourse processing. *Brain*, *122*, 1317–1325.

Stemmer, B., Giroux, F., & Joanette, Y. (1994). Production and evaluation of requests by right hemisphere brain damaged individuals. *Brain and Language*, *47*, 1–31.

Stringaris, A. K., Medford, N. C., Giampietro, V. C., Brammer, M. J., & David, A. S. (2007). Deriving meaning: Distinct neural mechanisms for metaphoric, literal, and nonmeaningful sentences. *Brain and Language*, *100*, 150–162.

Stringaris, A. K., Medford, N. C., Giora, R., Giampietro, V. C., Brammer, M. J., & David, A. S. (2006). How metaphors influence semantic relatedness judgments: The role of the right frontal cortex. *NeuroImage*, *33*, 784–793.

Thoma, P., & Daum, I. (2006). Neurocognitive mechanisms of figurative language processing—Evidence from clinical dysfunctions. *Neuroscience & Biobehavioral Reviews*, *30*(8), 1182–1205.

Van Lancker, D. (1997). Rags to riches: Our increasing appreciation of cognitive and communicative abilities of the human right cerebral hemisphere. *Brain and Language*, *57*, 1–11.

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

Van Lancker Sidtis, D. (2006). Does functional neuroimaging solve the questions of neurolinguistics? *Brain and Language*, *98*, 276–290.

Vigneau, M., Beaucousin, V., Hervé, P. -Y., Jobard, G., Petit, L., Crivello, F., et al. (2011). What is right-hemisphere contribution to phonological, lexico-semantic, and sentence processing? Insights from a meta-analysis. *NeuroImage*, *54*, 577–593.

Võ, M. L. -H., Jacobs, A. M., & Conrad, M. (2006). Cross-validating the berlin affective word list. *Behavior Research Methods*, *38*, 606–609.

Weylman, S. T., Brownell, H. H., Roman, M., & Gardner, H. (1989). Appreciation of indirect requests by left and right damaged patients. The effects of verbal context and conventionality of wording. *Brain and Language*, *36*, 580–591.

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

Xu, J., Kemeny, S., Park, G., Frattali, C., & Braun, A. (2005). Language in context: Emergent features of word, sentence, and narrative comprehension. *NeuroImage*, *25*, 1002–1015.

Yang, F. G., Edens, J., Simpson, C., & Krawczyk, D. C. (2009). Differences in task demands influence the hemispheric lateralization and neural correlates of metaphor. *Brain and Language*, *111*, 114–124.