Fine-coarse semantic processing in schizophrenia: A reversed pattern of hemispheric dominance

Maor Zeev-Wolf\textsuperscript{a}, Abraham Goldstein\textsuperscript{a,}\textsuperscript{*}, Yechiel Levkovitz\textsuperscript{b}, Miriam Faust\textsuperscript{a}

\textsuperscript{a} Department of Psychology and Gonda Brain Research Center, Bar-Ilan University, Ramat Gan 52900, Israel
\textsuperscript{b} Emotion-Cognition Research Center, The Shalvata Mental Health Care Center and Sackler Faculty of Medicine, Tel-Aviv University, Tel-Aviv, Israel

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\textbf{A B S T R A C T}

Left lateralization for language processing is a feature of neurotypical brains. In individuals with schizophrenia, lack of left lateralization is associated with the language impairments manifested in this population. Beeman’s fine-coarse semantic coding model asserts left hemisphere specialization in fine (i.e., conventionalized) semantic coding and right hemisphere specialization in coarse (i.e., non-conventionalized) semantic coding. Applying this model to schizophrenia would suggest that language impairments in this population are a result of greater reliance on coarse semantic coding. We investigated this hypothesis and examined whether a reversed pattern of hemispheric involvement in fine-coarse semantic coding along the time course of activation could be detected in individuals with schizophrenia.

Seventeen individuals with schizophrenia and 30 neurotypical participants were presented with two word expressions of four types: literal, conventional metaphoric, unrelated (an exemplar of fine semantic coding) and novel metaphoric (an exemplar of coarse semantic coding). Expressions were separated by either a short (250 ms) or long (750 ms) delay.

Findings indicate that whereas during novel metaphor processing, controls displayed a left hemisphere advantage at 250 ms delay and right hemisphere advantage at 750 ms, individuals with schizophrenia displayed the opposite. For conventional metaphoric and unrelated expressions, controls showed left hemisphere advantage across times, while individuals with schizophrenia showed a right hemisphere advantage. Furthermore, whereas individuals with schizophrenia were less accurate than control at judging literal, conventional metaphoric and unrelated expressions they were more accurate when judging novel metaphors.

Results suggest that individuals with schizophrenia display a reversed pattern of lateralization for semantic coding which causes them to rely more heavily on coarse semantic coding. Thus, for individuals with schizophrenia, speech situation are always non-conventional, compelling them to constantly seek for meanings and prejudicing them toward novel or atypical speech acts. This, in turn, may disadvantage them in conventionalized communication and result in language impairment.

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1. Introduction

If it is language, above all else, which makes us truly human, Crow (1997) argues that schizophrenia may be the price that we pay for it. According to Crow’s theory, language is what separates man from other species, and hemispheric specialization (lateralization) is the mechanism by which the capability for language has developed. Crow asserts that the failure to establish left hemisphere (LH) dominance for language is crucial for understanding both the anomalies in asymmetry observed in individuals with schizophrenia and the nuclear symptoms of the disease. This research focused on the consequences of such a failure to establish LH dominance for language on the processing of novel metaphors.

Unlike the pattern of LH dominance for language processing characterizing neurotypical individuals, there is much constitutional and functional evidence for a lack of LH lateralization for language in individuals with schizophrenia, indicating a bilateral or even a reversed pattern of language lateralization (e.g., Bleich-Cohen, Hendler, Kotler, and Strous (2009), Crow et al. (1989), Dollfus et al. (2005), Falkai et al. (1995a), Falkai, Schneider, Greve, Klieser, and Bogerts (1995b), Kubicki et al. (2002), McCleary et al. (2002), McDonald et al. (2000), Rockstroh et al. (2001), Sommer, Ramsey, and Kahn (2001), Sommer, Aleman, Ramsey, Bouma, and Kahn (2001), Sommer, Ramsey, Mandl, and Kahn (2003), Vistoli, Passerieux, Houze, Hardy-Baylé, and Brunet-Gouet (2011), Weiss et al. (2004, 2006)). Crow (1997) postulated that the lack of
language lateralization in schizophrenia is not a consequence of the disease, but rather the essence of it. According to Crow’s etiological theory, schizophrenia is a by-product of the evolution of a language specialization in the brain which has resulted in an asymmetric brain in neurotypical individuals where the LH is dominant for language. Crow asserts that when the language lateralization process is distorted schizophrenia may result.

The most obvious consequence of a lack of lateralization for language processing is disturbance in language usage. Indeed, findings indicate that almost every aspect of language is impaired in individuals with schizophrenia (for a review see, Covington et al. (2005)). Recognition of the importance of impairments in language usage to the phenomenology of schizophrenia dates back to the initial formalization of the disorder. Bleuler (1911) observed that the speech acts of patients diagnosed with schizophrenia were marked by “loose associations”, a term he coined to describe their tendency to make incongruous verbal associations, resulting in incoherent speech. Today, after much investigation, it is widely believed that at the root of this phenomenon lies the lack of proper mechanisms of inhibition and activation in the automatic spread of activation in the semantic networks (e.g., Goldberg et al. (1998), Kumar and Debruille (2004), Maher (1983), Manschreck et al. (1988), Mathalon, Roach, and Ford (2010), Niznikiewicz, Mittal, Nestor, and McCarely (2010), Soriano, Jimenez, Roman, and Bajo (2008)).

The priming paradigm is the most widely used method for investigating the automatic spread of activation in semantic networks. In this paradigm a priming word is presented for a very short period of time and a target word is then presented for a fixed period of time following prime presentation (stimulus onset asynchrony—SOA). Subsequently, participants usually perform a lexical (e.g., word/non-word) or semantic (e.g., meaningful/meaningless) decision task (e.g., to decide whether the two words are related). The priming effect is considered positive when reaction time and/or error rate for the target word is improved as a result of the preceding priming word.

Priming studies comparing semantic processes in individuals with schizophrenia and neurotypical individuals have yielded inconsistent results. In a meta-analysis conducted by Pomarol-Clotet, Oh, Laws, and McKenna (2008) evidence for indirect semantic priming was found across nine studies on individuals with schizophrenia. In the version of the semantic priming paradigm employed in these studies the target word was indirectly semantically related to the prime word via a mediating word (e.g., as “sour” mediates between “lemon” and “sweet”). As opposed to other studies examined in the meta-analysis, these mediated priming studies were specifically designed to investigate whether the spread of activation among individuals with schizophrenia is overextended to encompass remote associations. All nine studies found an increased priming effect for remote associations among individuals with schizophrenia in comparison with neurotypical individuals (pooled effect size = 0.19). When findings from individuals with schizophrenia with thought disorder were analyzed separately, this effect was even larger (pooled effect size = 0.56).

Taken as a whole, these findings suggest that individuals with schizophrenia, those also manifesting thought disorders in particular, are characterized by overactivation in their semantic networks. Interpreting these findings in the light of Crow’s hypothesis, it could be argued that this overactivation is a result of a lack of lateralization for language in individuals with schizophrenia. This overactivation in semantic networks, in turn, may result in the ability to connect semantically indirect concepts that individuals with schizophrenia manifest, as evidenced in the phenomenon of loose associations.

One of the models for natural language processing which can provide a theoretical framework for the relationship between the ability to bring together two remote concepts and a bilateral or reversed pattern of language lateralization is Beeman’s Fine-Coarse Semantic Coding model (Beeman et al., 1994; Jung-Beeman et al., 2004; Jung-Beeman, 2005; Mirous & Beeman, 2012). According to Beeman’s model, in neurotypical brains each hemisphere specializes in a different type of semantic processing; the LH specializes in fine semantic coding, whereas the right hemisphere (RH) specializes in coarse semantic coding. In response to encountering any word, a broad semantic field (which includes multiple meanings, semantic features and associations) is initially strongly activated in the LH and weakly activated in the RH. However, after approximately 400 ms the LH suppresses all distantly related, irrelevant, non-salient and unrelated meanings, strongly focusing on a few closely related, salient word meanings or semantic features, i.e., fine semantic coding, while the RH weakly maintains a diffused semantic field for a long time (> 400 ms), i.e., coarse semantic coding. This unique ability of the RH enables it to bring together distant concepts; the larger the semantic fields surrounding two given words, the more likely they are to overlap with one another. For example, the concept of “sourness” is more likely to overlap in the two semantic fields of “lemon” and “sweet” generated in the RH than in the ultimately narrower semantic fields generated in the LH.

Based on empirical evidence from neurologically intact, split-brain and brain-injured participants, Beeman’s model indicates that when a word is processed by the LH only the most strongly related meanings remain activated, whereas in the RH subordinate, non-salient, distant and unusual meanings remain available (Beeman et al., 1994; Jung-Beeman et al., 2004; Jung-Beeman, 2005). Since its introduction the model has received much empirical support, suggesting higher involvement of the RH in the processing of indirect associations (e.g., Beeman et al. (1994)), in accessing subordinate meanings of ambiguous words in semantic memory (e.g., Faust and Kahana (2002)) and in the comprehension of novel metaphors (e.g., Bottini et al. (1994), Faust and Mashal (2007), Schmidt, DeBuse, and Seger (2007)). By explaining the unique role played by each hemisphere in language processing, Beeman’s model can point to the implications of the atypical pattern of brain lateralization for language found in individuals with schizophrenia. Furthermore, the distinction it postulates between RH and LH semantic coding specialization offers an explanation for the robust finding of excessive indirect priming in individuals with schizophrenia who manifest thought disorders.

Of all the linguistic stimuli used to investigate the dynamic interplay between RH and LH involvement in fine-coarse semantic coding, novel metaphoric expressions are of particular value. Unlike other linguistic phenomena, comprehension of novel metaphors requires the ability to make sense of linguistic expressions that are completely new and literally meaningless (e.g., consider the novel metaphor “mercy blanket” as opposed to the meaningless expression “boycott bucket”). This is as opposed to conventional metaphors, whose conventional nature may, according to the Graded Salience model, turn them into “dead” metaphors, i.e., their figurative meaning will be more salient and dominant than their literal one (Giora, 1997, 2007; Giora et al., 2004; Giora and Fein, 1999; Giora, Zaidel, Soroker, & Kasher, 2000; Peleg & Giora, 2011). As such, the processing of conventional metaphors is likely to be based on fine rather than coarse semantic coding.

Given the absence of a context that serves as a linguistic anchor, it is of great interest to discover just how the brain manages to differentiate between meaningful novel metaphors and meaningless unrelated word-pairs. According to Beeman’s model, this process requires a fine but flexible balance between the two hemispheres. In neurotypical brains this complex hemispheric interplay is characterized by LH dominance for language, with the RH becoming involved when coarse semantic coding is necessary (Jung-Beeman, 2005). This process can be conceptualized as a complex “negotiation” between
the two hemispheres wherein, after a short period of time, the LH restrains the RH from becoming overactivated. However, when a novel metaphor is encountered, the RH’s unique semantic coding ability is crucial for understanding and hence it becomes more involved, working to find a meaning by integrating seemingly unrelated concepts into a meaningful linguistic expression. The LH, meanwhile, acts as the gatekeeper, suppressing irrelevant and unrelated meaning combinations. Thus, by working together, the two hemispheres may demarcate the line between meaningfulness and meaninglessness.

One of the behavioural methods for testing the unique role of each hemisphere in fine-coarse semantic coding is to use the split visual field paradigm in a semantic priming experiment, based on the natural division between the right visual field (RVF) and the left visual field (LVF). For example, in one version of this paradigm, priming words are presented centrally to both hemispheres for a very short period of time. A target stimulus is then presented to either the RVF or the LVF providing a relative advantage in processing a two-word linguistic expression to the hemisphere opposite the visual field to which the target word was presented (RVF to LH and LVF to RH).

Faust and Mashal (2007) combined the split visual field paradigm with the semantic priming paradigm in order to examine the roles of the RH and LH in novel metaphor processing in light of Beeman’s model. Four types of two-word linguistic expressions were used: novel metaphors (e.g., dead words), conventional metaphors (e.g., cold war), literal expressions (e.g., back seat) and unrelated expressions (e.g., coat dance). A RH advantage was found for novel metaphor processing, but not for literal expression or conventional metaphor processing, for both reaction time and accuracy rate, indicating that RH involvement is crucial for novel metaphor comprehension. This finding appears to support Beeman’s model, according to which the neurotypical brain is characterized by LH dominance for language with the RH becoming more involved when coarse semantic coding is required.

One study has addressed novel metaphor processing in individuals with schizophrenia (Kircher, Leube, Erb, Grodd, & Rapp, 2007). The study found evidence for reduced activation in the RH and greater activation in the LH amongst individuals with schizophrenia when processing metaphors. However, there are three main limitations to this study: first, the study made no distinction between novel and conventional metaphors; second, fMRI was used in the study and the low temporal resolution of this technology prevented sufficiently granular monitoring of the time course of activation; third, the study used linguistic stimuli at the sentence level, exposing metaphor processing to contextual effects and higher level integrative processes. Since previous research has shown that the RH has a clear disadvantage in processing sentence-level linguistic information (e.g., Faust (2012)), the use of metaphoric sentences in this study may have affected the pattern of hemispheric processing.

Previous research has, however, employed the split visual field paradigm to investigate other language components in individuals with schizophrenia; yielding contradictory results. Some studies have found evidence for divergent patterns of lateralization, for example, in a syllable-matching task, Gur (1978) found a marked LVF/RH advantage in individuals with schizophrenia and an RVF/LH advantage in the control group; other studies found normal LVF/RH function but RVF/LH disadvantage in individuals with schizophrenia compared to neurotypical individuals in a consonant detection task (Kemali, Galderisi, Maj, Mucci, & Di Gregorio, 1991) and in a phonetic letter recognition task (Min and Oh, 1992).

Weisbrod, Maier, Harig, Himmelsbach, and Spitzer (1998) found a LVF/RH advantage for indirectly semantically related words in neurotypical individuals and individuals with schizophrenia with or without thought disorders. In addition, individuals with schizophrenia with thought disorders also demonstrated an enhanced overall indirect semantic priming effect in comparison with both neurotypical individuals and individuals with schizophrenia without thought disorders. However, other studies have failed to find any differences in lateralization patterns between individuals with schizophrenia and neurotypical individuals using the split visual field paradigm (e.g., Colborn and Lishman (1979), Magaro and Chamrad (1983)). All the above studies used low level linguistic stimuli (all studies were aimed mainly at investigating orthographic or phonological processing), and not high level linguistic stimuli designed to investigate fine-coarse semantic coding. The present study aimed to fill this gap by investigating the implications of a bilateral or even reversed pattern of lateralization on the time course of meaning activation during fine and coarse semantic coding in individuals with schizophrenia by focusing on novel metaphor comprehension.

Thus, using the divided visual field technique combined with the priming paradigm in a semantic judgement task, the present study investigated the relative involvement of each hemisphere in the comprehension of novel metaphors (coarse semantic coding) in comparison with the comprehension of conventional metaphors and literal expressions (fine semantic coding) at two different SOAs: a short SOA (250 ms), for detecting automatic activation processes, and a long SOA (650 ms), for detecting the activation/inhibition dynamics between the two hemispheres. Furthermore, following Pomarol-Clotet et al.’s (2008) meta-analysis finding that the most robust positive priming effect was found among individuals with schizophrenia with thought disorders, we chose to include in our study only patients with schizophrenia that at the time of the study manifested evidence of thought disorders.

Following previous studies (e.g., Faust and Mashal (2007), Gold and Faust (2010), Mashal, Faust, Hendler, and Jung-Beeman (2007)), two-word unfamiliar Hebrew metaphoric expressions taken from modern poetry were used in this study to facilitate coarse semantic coding (novel metaphor condition). In addition, two-word well-known Hebrew literal and conventional metaphoric expressions pre-tested for familiarity were used to represent fine semantic coding (see, Gold and Faust (2010)). Unrelated word pairs were also used as a control condition, representing meaningless, unfamiliar or nonsensical linguistic expressions. The grammatical form employed, in which two words are considered as a single unit, is commonly used in Hebrew and is a popular form of language usage in spoken and written language due to its economy and elegance.

Our main hypothesis was that, in comparison with neurotypical individuals and due to their bilateral, or even reversed, pattern of hemispheric lateralization for language, individuals with schizophrenia who manifest thought disorders would show a different pattern of processing (i.e., reaction times and accuracy rates) for novel metaphoric, conventional metaphoric, literal and unrelated expressions presented to the two visual fields at two SOAs (short vs. long). Specifically, we hypothesized that they would show an overall LVF/RH advantage (faster reaction times and lower error rates), across semantic expressions and SOAs, when compared with neurotypical individuals. We further hypothesized that when compared to neurotypical individuals, individuals with schizophrenia who manifest thought disorders would perform worse for conventional metaphors, literal and unrelated expressions (expressions which require fine semantic coding) but better for novel metaphors (coarse semantic coding).

For neurotypical individuals, we hypothesized that, for the short SOA, responses to novel metaphors presented to the RVF/LH would be faster and more accurate than to the LVF/RH, whereas for the long SOA an opposite pattern would be found (LVF/RH advantage for novel metaphors). For conventional metaphors, however, we hypothesized that neurotypical individuals would show a RVF/LH advantage at both SOAs.
2. Participants

2.1. Participants

Twenty one participants who met DSM-IV-TR criteria for schizophrenia (American Psychiatric Association, 2000) and 32 non-psychiatric participants were recruited for the experiment. Thought disorders were evaluated using the P2 item in the Positive and Negative Syndromes Scale (PANSS, scaled from 1 to 7; Kay, Fiszbein, and Opfer (1987)). Two patients did not meet the thought disorders criteria because they had a score of 1 (i.e., absent), as evaluated by their psychiatrists. Remaining patients had a mean score of 4.41 (SD = 2.7) with all patients scoring above 2 (i.e., minimal: questionable pathology). One patient with schizophrenia did not complete the experimental procedure. In addition, one schizophrenia and two non-schizophrenia participants were excluded because of a deviant pattern of responses (no correct responses in one or more of the experimental conditions), resulting in a total of 47 participants: 17 patients with schizophrenia who manifested thought disorders (SZT) and 30 neurotypical individuals in the control group.

The decision to use the PANSS to evaluate thought disorders was based on the familiarity and regularity of its use among the psychiatrists evaluating participants in the study. Despite the fact that the PANSS is not a specific scale for thought disorder and contains only one item referring to thought disorders, behind this item stands a thorough inventory of thought disorder symptoms collected in a semi-structured interview with the patient (e.g., circumstantiality, loose associations, disconnection, tangentiality, gross illogicity, thought block, paralogicality, difficulty in directing thoughts towards a goal, “word salad”, mutism and more), and its use in evaluating thought disorders is widespread (e.g., Becker et al., 2010; Kiefer, Martens, Weiskord, Herrle, and Spitzer, 2009; Peled, Netzer, and Modai (2005)). Moreover, thorough examination reveals substantial overlap between the list of thought disorders symptoms in the P2 item in the PANSS and other thought disorders scales, such as the clinical Language Disorder Rating Scale (Chen et al., 1996) or the Thought, Language, and Communication Scale (Andreasen, 1986), which was found to be highly correlated (r = .73) to some items in the PANSS including the P2 (Stirling, Hellewell, Blakey, & Deakin, 2006).

All participants with schizophrenia were recruited from Shalvata Mental Health Center in Israel and were diagnosed by a trained psychiatrist. The patient group had average full scale intelligence, as assessed by the Similarities subtest from the Hebrew adaptation of the Wechsler Adult Intelligence Scale, Third Edition (Wechsler, 1997) as well as normal reading capabilities (assessed using the Psychological Assessment of Language Processing in Aphasia Tool; Kay, Coltheart, and Lesser (1992)). The control group participants were recruited at the Psychology Department at Bar-Ilan University and received course credit or money for their participation. All participants were native Hebrew speakers aged above 18, had normal or corrected-to-normal vision and were right handed (Edinburgh handedness inventory; Oldfield, 1971), for demographic details, see Table 1. As can be seen in Table 1, the groups were balanced for all variables apart from age. However, when age was entered as a covariate it had a non-significant effect, with the results pattern remaining the same, thus the results presented below disregard age.

The research was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans, and was approved by the ethical boards of both Shalvata hospital and Bar-Ilan University.

2.2. Stimuli

The stimulus pool, which was taken from previous research (for a detailed description see Gold and Faust (2010)), consisted of 240 Hebrew word pairs (prime and target words) forming four types of semantic relations (60 pairs for each expression type): literal—LIT (e.g. soft blanket), conventional metaphoric—CM (e.g. juicy salad), novel metaphoric, evoked from non-NM (e.g. writing tape) or unrelated—UR (e.g. picturesque concern). The stimulus pool was subjected to extensive pre-testing in order to control for several relevant linguistic variables, including frequency, familiarity, meaningfulness, concreteness and syntactic structure (Gold and Faust, 2010). As a result of the pre-test, only novel expressions that were rare (e.g., Becker et al., 2010; Kiefer, Martens, Weiskord, Herrle, and Spitzer, 2009) were included in the final stimulus pool.

2.3. Procedure

The experiment consisted of 16 conditions: four types of semantic relations (NM, CM, LIT and UR) × 2 visual fields (left and right) × 2 SOAs (short and long). A total of 240 expressions were presented (15 per condition). Stimuli were presented using E-Prime 2.0. All participants were initially in the presence of the researcher, who documented any unusual behavior.

The word pairs were presented in a random order. In half of the word-pair presentations the first word was centrally presented for 150 ms and in the other half for 650 ms. The first word was followed by a centered fixation sign (“+”) for 100 ms, forming two different SOAs: short SOA (250 ms) and long SOA (750 ms). The target word was then presented for 180 ms with its center positioned 2.8° to the left or the right of the fixation sign and subtended, on average, 1.9° of horizontal and 0.7° of vertical visual angle. After receiving a response from the participant, a centered fixation sign was presented for 1500 ms before the beginning of the next trial. The order of the trials, comprising both short and long SOAs, was quasi-randomized in four fixed lists, counterbalanced over participants. Participants sat 60 cm away from the center of the screen with their heads located in a chinrest to ensure they remained in the same place during the experiment. With their right index finger placed between two keyboard keys, participants were asked to focus on the fixation sign at the center of the screen and not to shift their gaze from it. Participants were instructed to read the two words silently and to decide whether they formed a meaningful expression or not, and to respond by pressing with their index finger on either the right or left key (responses were counterbalanced over participants), as rapidly and as accurately as possible. Before the beginning of the experiment participants were given a practice session consisting of 20 word pairs which were not included in the results analysis. Participants were informed that some of the expressions in the experiment were taken from poetry and were given an illustrative example (e.g. “mercy blanket”). It was emphasized that some expressions might be unfamiliar but nevertheless meaningful.

3. Results

Mean reaction times in milliseconds (RTs) and error rates (ERs) were calculated for each participant for each condition, after excluding deviant trials. Only correct responses were included when calculating RTs. Sixty three trials (17 from the SZT group and 46 from the control group) where RT was longer or shorter than three standard deviations, for each condition, for each participant, were excluded from the data. Overall, the deviant trials rate was 0.39%, SD = 1, for the SZT group and 0.64%, SD = 1.28, for the control group. The overall ER was 29.12%, SD = 3.46. ERs covaried positively across conditions with RTs. Thus, no indications for trade-off between response speed and accuracy across either the whole sample, or separately within each group, were found. Furthermore, in an item analysis no expressions with deviant mean ER or RT were found.

A 2 × 2 × 2 × 4 repeated measures ANOVA was conducted for RT and ER separately, with GROUP (SZT or control) as a between-subjects factor. SOA (short or long), Visual Field (LVF or RVF) and TYPE (NM, CM, LIT or UR) were all within-subjects factors. For the purpose of this analysis Greenhouse-Geisser correction was applied when needed and the p-values reported reflect this correction.
The analysis revealed that, overall, SZT responded more slowly and made more errors than the control participants [1570.69 (542.57) vs. 878.12 (204.32), \( F(1,46) = 39.56, p < .001 \) and 31.8% (7.67) vs. 17.87% (5.73), \( F(1,46) = 50.04, p < .001 \) for the two groups, respectively]. However, for NM only, SZT had lower ERs than controls [37.47% (11.8) vs. 47.83% (23.47)], yielding a significant interaction, \( F(3,46) = 3.41, p < .05 \) (see Fig. 1).

More importantly for our hypothesis, a four-way (SOA × VF × TYPE × GROUP) interaction was found for both RT and ER, \( F(3,46) = 6.34, p < .001 \), and \( F(3,46) = 3.01, p < .05 \), respectively. In order to further examine the four-way interactions we calculated the difference between the LVF and RVF (LVF–RVF) for RT and ER for each subject in every condition, resulting in positive scores for RVF/LH advantage and negative scores for LVF/RH advantage. Difference scores were then entered into repeated measures ANOVAs.

For RT difference scores, a two-way (SOA × GROUP) interaction was found for both NM and LIT (see Fig. 2), \( F(1,46) = 12.64, p < .01 \) and \( F(1,46) = 10.98, p < .01 \) (for NM and LIT, respectively). For NM the groups showed opposite patterns: SZT showed LVF/RH advantage (\( M = −210.71 \)) at the short SOA and RVF/LH advantage (\( M = 213.25 \)) at the long SOA, \( t(16) = −2.15, p < .05 \), whereas controls showed RVF/LH advantage (\( M = 50.51 \)) at the short SOA and LVF/RH advantage (\( M = −159.17 \)) at the long SOA, \( t(29) = 2.79, p < .001 \). For LIT, SZT had RVF/LH advantage (\( M = 240.96 \)) at the short SOA and LVF/RH advantage (\( M = −272.34 \)) at the long SOA condition, \( t(16) = 2.6, p < .05 \), but controls showed no significant differences. In addition, for CM, a main effect for GROUP was found, \( F(1,46) = 4.78, p > .05 \), showing LVF/RH advantage for SZT and a RVF/LH advantage for controls. A similar pattern was found for UR but it did not reach statistical significance [\( F(1,46) = 3.36, p = .07 \)].

For difference scores in ERs, a two-way (SOA × GROUP) interaction was found for UR (see Fig. 3), \( F=4.69, p < .05 \). Whereas SZT displayed LVF/RH advantage (\( M = −1 \)) at the short SOA and RVF/LH advantage (\( M = −0.94 \)) at the long SOA, \( t(16) = −3.29, p < .01 \), no difference was found for controls.

In order to address the hypothesis that, overall, SZT would show more LVF/RH advantage than control participants, we calculated for each subject the average RT and ER difference between the LVF/RH and RVF/LH across conditions. An independent t-test revealed a significant difference between the two groups for RT, \( t(45) = 1.93, p < .05 \), indicating that, whereas SZT showed an overall LVF/RH advantage (\( M = −60.8 \)), the control group showed a RVF/LH advantage (\( M = 22.72 \)).

Finally, we investigated whether SZT’s performance was related to either the severity of their positive symptoms or the duration of their illness. Two series of correlation analyses for RT and ER, separately, were performed: (1) between the average RT and ER score and the total score of the positive sub-scale of the PANSS and the duration of illness; (2) between RT and ER for each of the 16 experimental conditions and the total score of the positive sub-scale of the PANSS and the duration of illness. In addition, a correlation analysis for RT and ER between the difference score RVF–LVF and the total score of the positive sub-scale of the PANSS and the duration of illness was performed. All the above correlation analyses with PANSS scores were calculated twice, once including the P2 item and once excluding it. The correlation coefficient was not significant (\( p > .05 \)) throughout the analysis, indicating that neither the severity of the positive symptoms nor the duration of illness did influence SZT’s performance, or their LVF advantage. Investigation of whether RH advantage in SZT was related to the severity of thought disorders was also conducted.

**Fig. 1.** Error rates by condition for the two groups (error bars show standard errors).

**Fig. 2.** Reaction times difference scores (LVF–RVF) for all conditions in the two groups (error bars show standard errors). Positive scores depict LH advantage and negative scores depict RH advantage. (*) Significant main effect for group. (**) Significant SOA × GROUP interaction.

**Fig. 3.** Error rates difference (LVF–RVF) for UR in the two groups (error bars show standard errors). Positive scores depict LH advantage and negative scores depict RH advantage.
Correlation analyses for RT and ER, separately, were performed between P2 item scores from the PANSS and RVF–LVF scores. No significant correlation coefficient was found ($p > .05$).

4. Discussion

As anticipated, SZT’s overall responses were slower and less accurate than controls. This result is similar to previous findings which have indicated a general tendency among individuals with schizophrenia to respond more slowly and make more errors in priming experiments in comparison with controls, (e.g., Mathalon et al. (2010), Niznikiewicz et al. (2010), Vistoli et al. (2011)).

Nevertheless, for NM processing, which relies mainly on coarse semantic coding, SZT outperformed the neurotypical individuals, i.e., making fewer errors. It should be noted that rejecting a NM as meaningful is not an “error” in the conventional sense of the term, in that the meaningfulness of such a stimulus is not established by convention, rather it is the overlooking of potential new meanings. Thus, low ER for NM reflects a tendency to discern potential new meanings while high ER for NM reflects a more conservative approach. For the purposes of this study, and following previous work (e.g., Gold and Faust (2010)), we have referred to the overlooking of such stimuli as an error.

In addition, qualitative differences between the two groups were found for each type of expression. The pattern of results was highly complex and did not always emerge in-line with our predictions. Intriguingly, however, when taken together, these results may offer an explanation for some of the difficulties in communication characterizing individuals with schizophrenia.

For LIT, the control group showed no differences between the RH and the LH during the time course of activation, presumably because of a ceiling effect due to the highly familiar nature of the stimuli and the ease of processing them. This finding replicates findings from similar experiments with neurotypical participants that used the same stimulus pool and that also failed to detect differences between the RH and the LH for LIT (Faust & Mashal, 2007; Gold & Faust, 2010). By contrast, SZT displayed an atypical pattern of semantic processing for LIT, such that at the short SOA they showed a LH advantage but at the long SOA they showed a RH advantage. This surprising pattern of results may indicate that even for the simplest and most familiar form of linguistic expression – LIT – SZT have a different and unique pattern of semantic processing which involves coarse semantic coding where it is normally not required. We speculate that for SZT, literal expressions are initially processed in the LH, however, because this hemisphere does not inhibit the RH, a broad semantic field is eventually activated in the RH, and thus even the most literal, familiar and common linguistic expressions activate a wide array of possible meanings, extending the range of meaning far beyond the conventional. For example, when one of the participants with schizophrenia was asked in a retrospective qualitative analysis of responses to explain the literal expression “an independent student” he initially focused on the conventional literal meaning before adding that such a student must be very lonely because he/she is studying alone (an unconventional non-literal interpretation).

The two groups also showed opposing result patterns for CM. Controls were found to have a LH advantage at both SOAs. Because it is the figurative meaning of such expressions which is conventional and thus more salient, it is expected that the LH, which is highly involved in the processing of salient meanings (fine semantic coding), would show better performance for conventional metaphor processing. The findings for the control group are thus consistent with the Graded Salience model (Giora, 2007), which asserts that the figurative meanings of conventional metaphors are more salient than their literal meanings, rely mainly on fine semantic coding and are thus processed mainly by the LH.

This result is consistent with previous findings (e.g., Faust and Mashal (2007), Gold and Faust (2010)).

SZT, by contrast, were found to have a RH advantage for CM comprehension at both SOAs. According to the Fine-Coarse Semantic Coding model (Jung-Beeman, 2005), these findings would appear to indicate that, when individuals with schizophrenia who manifest thought disorders encounter conventional metaphors, their comprehension is more reliant on coarse than on fine semantic coding. Thus, according to the Graded Salience model, this finding implies that the ordinarily non-salient meanings of such expressions, their literal meanings, should be more strongly activated than their salient, figurative meanings. This might imply that the conventional thought patterns of individuals with schizophrenia who manifest thought disorders are different than those of neurotypical persons, in the sense that the RH emphasizes the non-salient, literal meanings instead of the salient, conventional metaphorical meanings of conventional metaphors.

This finding may further provide an explanation for one of the canonical findings in the literature regarding figurative thinking in individuals with schizophrenia, i.e., their tendency for concreteness, which may actually be explained by their comprehension of conventional metaphors in terms of their literal rather than their figurative meanings. This may in turn be related to the different hemispheric dynamics during the processing of fine and coarse meanings that SZT display. According to the Graded Salience model, the literal meanings of conventional metaphors are non-salient, and it may be the case that as a consequence of the tendency to rely more heavily on coarse semantic coding, individuals with schizophrenia who manifest thought disorders will gravitate towards the literal meanings of conventional metaphors. In other words, it seems that when SZT encountered a conventional metaphor the RH took control and, as a consequence, literal, non-salient meanings were activated. Indeed, when one of the SZT participants was asked to interpret the conventional metaphor “blue blood”, he explained it in the following way: “it is when somebody’s blood color is blue instead of red so he is different, like me, because I have schizophrenia so, as far as I know, it might be because my blood is blue.”

The findings regarding processing of the two types of familiar linguistic expressions, LIT and CM thus indicate that SZT may manifest an atypical pattern of fine-coarse semantic coding for both expression types. Both are convention-governed forms of linguistic expressions that may require LH fine semantic coding mechanisms. These two types of expressions constitute the majority of daily communication and thus SZT’s over-reliance on the RH, instead of on LH processing, may go a long way towards accounting for the well documented impairments in everyday communication (Oltmanns, Murphy, Berenbaum, & Dunlop, 1985) found in individuals with schizophrenia who manifest thought disorders.

For the two types of unfamiliar expressions, NM and UR, we also found different patterns of hemispheric activity for the two groups. NM was the only expression type in the experiment which required mainly coarse semantic coding (RH) and as such the only expression that could benefit from an excessive reliance on the RH. Indeed, RH advantage for NM was found for both groups, but it occurred with a different time course in each group. In the neurotypical group, the RH advantage was found at the long SOA, with a LH advantage occurring at the short SOA. This is in line with the Fine-Coarse Semantic Coding model (Jung-Beeman, 2005) which asserts that an initially broad semantic field is strongly activated in the LH and weakly in the RH. However, after a short period of time the LH inhibits all irrelevant meanings while the RH maintains them. Indeed, the RH advantage found in the present study for NM processing at the long SOA is congruent with previous studies finding a RH advantage for NM at both 400 ms SOA and 1100 ms SOA (Faust and Mashal, 2007; Gold and Faust,
However, as far as we know, this is the first time that this results pattern – initial LH advantage for NM processing followed by subsequent RH advantage for NM – has received empirical support.

In contrast to the neurotypical group, SZT showed RH advantage at the short SOA and LH advantage at the long SOA. This finding may indicate that in individuals with schizophrenia who manifest thought disorders, primary, more automatic processing occurs in the RH with the LH becoming more dominant during later stages of activation. Nevertheless, SZT made fewer errors than the control group in both SOAs (more readily accepting NM as meaningful). In other words, even when the LH was more involved than the RH (long SOA), SZT processed NM more easily than a control group which, at the same time, showed a RH advantage. This result raises the possibility that in individuals with schizophrenia who manifest thought disorders the LH may not be involved in inhibiting remote and non-salient meanings activated in the LH and/or the RH as is the case in neurotypical individuals.

Results show that the differences for ER between NM and UR were relatively small in the SZT group (50.73% and 37.47%, for UR and NM respectively), with more mistakes made for UR, while in the control group there was a much larger difference between these two expression types (10.78% and 47.83%, for UR and NM respectively), with more mistakes made for NM. In comparison with the control group, it seems that SZT showed a greater tendency to accept NM expressions as meaningful. This tendency was evident for NM only, hence at the same time SZT made more mistakes for LIIT and CM, judging them as meaningless. Thus the effects reported here are not due to a simple positive response bias.

A potential problem with the above results is raised by the low accuracy rates for NM among the control group (47.83%) and for UR among SZT (50.73%) which appear to be at chance level performance. However, chance level performance would imply that whenever participants encountered an unfamiliar expression they would guess whether it was meaningful. Thus, the same performance should be replicated across both NM and UR, whereas in practice accuracy rates for NM and UR differ in each group. For the control group lower accuracy rates were found for NM whereas, for SZT lower accuracy rates were found for UR. Moreover, when NM and UR are taken together ER was found to be significantly lower than chance level in each group (t(29) = 16.33, p < .001; t(16) = 25.6, p < .001; for control group and SZT respectively).

Low accuracy rates for NM in neurotypical individuals is evident from previous studies (e.g., Mashal et al. (2007)). Meanwhile, Arzouan, Goldstein, and Faust (2007), in a study which utilized the same NM stimulus pool as the present study, found differing ERP patterns in neurotypical individuals when accepting versus rejecting NM, despite overall NM performance close to chance level. Taken as a whole we thus have substantial grounds for believing that our results are not the result of simple guesswork.

Findings for UR were only marginally significant. Nevertheless, it is interesting to note that controls displayed LH advantage at both SOAs. The capacity of the LH to inhibit meaning is crucial for demarcating the boundary between meaningfulness and meaninglessness (Faust, 2012). Thus, when encountering a novel linguistic stimulus which has no potential meaning, the LH's inhibitory function becomes central. Indeed, this finding corresponds with controls' high success rate in correctly identifying such expressions as meaningless. This LH advantage, coupled with the RH advantage found for NM processing, suggests that neurotypical individuals possess an optimal interplay between the two hemispheres which allows them to reject nonsensical expressions, and at the same time accept potentially meaningful novel expressions (e.g., NM).

By contrast, SZT showed a RH advantage at both SOAs for UR. This finding implies that the inhibitory function performed by the LH in neurotypical individuals may have been less effective in SZT. Given that according to the Fine-Coarse Semantic Coding model the RH specializes in coarse semantic coding – wherein semantic fields are more likely to overlap – it would seem reasonable to anticipate that increased RH activation would result in an increased tendency to find meanings for UR—meaningless expressions. This explanation is supported by findings showing that SZT made more errors for UR (were more likely to decide that UR expressions were meaningful; M = 50.73%).

It seems, in light of these findings, that SZT lack the optimal interplay between LH fine and RH coarse semantic coding found in neurotypical individuals. SZT appear to over-rely on coarse semantic coding, which may disrupt their ability to balance between finding new meanings to novel, potentially meaningful linguistic stimuli (e.g., NM), on the one hand, and rejecting meaningless linguistic stimuli (e.g., UR), on the other hand. For example, when asked to explain the UR expression “failure pocket” used in the experiment, one SZT participants said: ‘It means that I’m poor because I don’t have any pocket money’. Another SZT participant employed a clang association, based on the sound of the word, to form a meaning to the UR expression “flowerbed of hopes”. In Hebrew, the sound of the word “flowerbed” resembles the sound of the word “dead”. Based on this near-homophone, the interpretation the participant made was that ‘there is always hope, even when you are dead there is hope, for example, after life’.

Thus far, the results discussed indicate that in neurotypical individuals the interplay between the two hemispheres enables them to cope successfully with every type of expression. We would argue that this is because they rely mainly on LH fine semantic coding mechanisms for processing meaningful, conventional language (e.g., LIIT and CM) and for rejecting nonsense expressions (e.g., UR), while relying mainly on RH coarse semantic processing mechanisms for processing potentially meaningful novel expressions (e.g., NM). The ability to identify meaningfulness, meaninglessness and to efficiently differentiate one from the other is what makes the communication of linguistic meanings possible. By contrast, in SZT the general results pattern implies the dominance of coarse semantic coding even when it is not required, i.e., for the processing of conventional language (e.g., LIIT and CM) or for the processing of meaningless expressions (UR); this may result in unconventional semantic processing, including loose associations. The phenomenon of loose associations breaches the premise that people share the same associational world for conventional expressions and may thus serve as an explanation for the difficulties in communication experienced by SZT.

According to the present findings, it would appear that even the meanings of literal expressions are processed in an unconventional manner as a result of the wide semantic field containing remote and thus unconventional associations activated in the RH. Similarly, our findings suggest that the natural process of the conventionalization of the meaning of metaphors through repeated use, which creates conventional metaphors and in which figurative meanings become more salient than literal meanings, does not take place in SZT. Thus, it may be that in individuals with schizophrenia the non-salient meanings of such metaphors (their literal meanings) are activated during communication. Since the accurate use of literal expressions and conventional metaphors is essential in our daily communicational language, this finding may shed new light on the language and communication difficulties experienced by individuals with schizophrenia who manifest thought disorders.

While an over-reliance on coarse semantic coding is disruptive for LIIT and CM comprehension, it becomes an advantage where NM comprehension is required. This suggests that the tendency...
of individuals with schizophrenia who manifest thought disorders to understand conventional metaphors in their literal sense is not because of an inability to understand figurative language, but is an impairment in thinking conventionally (in this case by choosing salient meanings). However, the advantage in processing NM, which SZT appear to have, is not a real advantage. This is because SZT are apparently unable to differentiate between NM and UR, attributing meaning to both types of unfamiliar expressions. By contrast, it seems that in the neurotypical brain, the flexible interaction between the two hemispheres enables it to identify potentially meaningful novel expressions while rejecting novel meaningless expressions.

Language is akin to a living organism, constantly evolving and growing, as exemplified in poetry and humor. Nevertheless, poetry and humor are meaningful only in so far as they are coupled with the ability to demarcate between linguistic meaningfulness and meaninglessness, constraining communication to meanings that can be grounded in conventional thought and are not purely idiosyncratic. The findings of the present study suggest that the ability to comprehend potentially meaningful novel linguistic expressions and to differentiate between them and meaningless ones may be deficient in individuals with schizophrenia who manifest thought disorders.

To sum up, the present study may shed some light on the neurolinguistic basis of semantic processing in individuals with schizophrenia who manifest thought disorders, offering an explanation for the phenomenon of loose associations characterizing schizophrenic thought and language. In this experiment we found a complicated pattern of results that was not consistent with all of our predictions. However, we did find an overall reversed pattern of hemispheric involvement in fine and coarse semantic processing between the two groups, with controls showing a flexible and optimal interplay between the two hemispheres along the time course of meaning activation which allowed them to accept potentially meaningful expressions and reject meaningless ones. By contrast, SZT showed an over-reliance on RH coarse semantic coding which, as has been discussed above, may offer an explanation both for loose associations and for comprehending conventional metaphors in their literal sense (concreteness).

There are some limitations to this study that future research should account for. First, in the split visual field paradigm employed in this study only the target word was lateralized, while the prime word was centrally presented. In an alternative paradigm both prime and target words are lateralized. It is thus important to understand the relative limitations of these two different methods. Chiarello, Burgess, Richards and Pollock (1990) compared the two priming methods. They found differences in priming between the RVF and the LVF only when both prime and target words were lateralized and concluded that central presentation of the prime word induces interhemispheric sharing of prime activation and thus biases target processing. They further claimed that, in order to assess hemispheric specific spread in activation processes, the lateralization of both the prime and target words is required.

However, interhemispheric sharing occurs already after approximately 150 ms, regardless of whether stimuli are presented centrally or laterally (e.g., Khateb et al. (2001)). Consequently, whether or not the prime word is lateralized, information reaches the other hemisphere by the time the target word is presented, making it impossible to isolate intrahemispheric processing of the prime word. In the paradigm we used, we controlled for the transfer of information of the prime word by priming both hemispheres equally and thus reading both for processing the target word, each in its own unique way. There is a substantial amount of data on NM processing in neurotypical individuals collected in our lab using the split visual field paradigm, in which the prime word is presented to the center of the screen. Thus an additional reason why we utilized this method was to enable comparison between our results and previous findings.

Another reason for centrally presenting the prime word was due to the difficulty that individuals with schizophrenia display with inhibiting reflexive eye shifts to lateralized stimuli. Thus, lateralizing both the prime and target words would have resulted in the target word falling on both visual fields. Indeed, in our study we noticed that participants with schizophrenia shifted their eyes to the lateralized target word but by the time their eyes reached the location of the target word it had already disappeared. Nevertheless, in a future study it would be worthwhile to replicate the experiment with both the prime and target words lateralized in order to compare results.

Furthermore, in order to specifically examine the interplay between the two hemispheres a bilateral presentation condition should be added to the paradigm. Such presentation would make it possible to assess the communication between the two hemispheres in addition to the relative involvement of each one. As was suggested, the impairment manifested by SZT in the present experiment may be due to the lack of sufficient LH inhibition mechanisms affecting RH overactivation. An additional bilateral presentation could test this explanation. In addition, we assumed that the LH is responsible for fine semantic coding and that in individuals with schizophrenia who manifest thought disorders this hemisphere is not sufficiently dominant during semantic processing. In light of our findings, we concluded that the LH does not perform its anticipated role (fine semantic coding) in individuals with schizophrenia who manifest thought disorders even when it was found to be more involved than the RH. Further experiments should address this issue by designing specific paradigms to assess LH function during semantic processing in individuals with schizophrenia who manifest thought disorders.

A further limitation to the study is the lack of findings regarding the relationship between severity of symptoms or duration of illness and SZT’s performance. We believe that this is due to the low number of individuals with schizophrenia who participated in the experiment, coupled with the high standard deviation this group displayed. In future studies a larger group sample should be taken if possible.

In addition, and in order to assess the appropriateness (level of conventionality) of the interpretations made by SZT participants to the expressions used in the experiment, a systematic qualitative analysis of these interpretations is required. Finally, the experiment should be replicated with individuals with schizophrenia without thought disorders in order to determine if the findings are applicable across the disorder or limited to a specific subgroup within it.

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