Is black always the opposite of white? The comprehension of antonyms in schizophrenia and in healthy participants

Cristina Cacciari
Univ. of Modena, Italy
cacciari.cristina@unimore.it

Francesca Pesciarelli
Univ. of Modena, Italy
francesca.pesciarelli@unimore.it

Tania Gamberoni
AUSL, Modena, Italy
t.gamberoni@ausl.mo.it

Fabio Ferlazzo
Sapienza Univ. Rome, Italy
fabio.ferlazzo@uniroma1.it

Abstract

In this study, we tested the online comprehension of antonyms in 39 Italian patients with paranoid schizophrenia and in an equal number of pairwise-matched healthy controls. Patients were rather accurate in identifying antonyms, but compared to controls, they showed longer response times and higher priming scores, suggesting an exaggerated contextual facilitation. Presumably, this reflects a deficient controlled semantic processing and an overreliance on stored semantic representations.

1 Introduction

In this study we investigated the recognition of antonym word pairs in patients with paranoid schizophrenia and in pairwise matched healthy participants.

Conceptual knowledge stored in semantic memory includes representations of many different types of lexico-semantic relationship, among which antonymy. Antonymy is thought to be the most robust of the lexico-semantic relations, relevant to both the mental organization of the lexicon and the organization of coherent discourse (Fellbaum, 1998; Willners, 2001; Jones, 2002; Murphy, 2003; Paradis and Wilners, 2006; van de Weijr et al., 2014). Antonymy is the label generically used to refer to any of two words that are semantically opposed and incompatible for at least one of their senses (e.g., *black/white*, *dead/alive*). Antonyms are recognized faster than any other words or non-words in word recognition, elicit each other in word association tests and are often mistaken in speech errors. Antonyms occur very frequently in written and oral language, presumably because binary contrast is a powerful organizing principle in perception and cognition (Bianchi et al., 2011). In sum, antonym word pairs represent an important phenomenon for elucidating the nature of the semantic dysfunction that characterizes schizophrenia (henceforth, SZ) and, on more general grounds, for establishing the neural and cognitive prerequisites of word comprehension. Studying the types of semantic relationship that patients with SZ can or cannot correctly understand may also yield further insights into the ways in which semantic knowledge is represented in the human brain, and into the mechanisms underlying its use.

SZ is a neurobiological disorder associated to several cognitive deficits that include mild to severe language comprehension and production abnormalities (at word and sentence levels) as well as attentional and information processing impairments (Harvey, 2010; Kuperberg, 2010ab, Kiang, 2010; Levy et al., 2010). The literature has shown that language comprehension impairment in SZ are not global and generalized but selectively involve abnormalities at a word and/or sentence level (Kuperberg, 2010ab). Studies on word processing in SZ have predominantly used the semantic priming paradigm obtaining mixed results (for overviews, Minzenberg et al., 2002; Pomarol-Clotet et al., 2008; Pesciarelli et al., 2014). Typically, studies have obtained greater than normal semantic priming (*hyper-priming*) at short intervals between the presentations of prime and target (SOA, stimulus onset asynchrony) especially, but not only, in thought-disordered patients. Hyper-priming is often accompanied by reduced or absent priming at long SOAs (more than 300 msec). These distorted priming effects have been interpreted in terms of abnormal neural processing of the relationships between concepts in long-term semantic memory and of functional abnormalities of semantic memory neural networks that produce abnormally fast and/or far-reaching spreading of activation among concepts (Kiang, 2010). Patients with SZ would also fail in suppressing or deactivating contextually inappropriate semantic associations because of the distorted use of context that characterize SZ. This deficit has been attributed to a more general deficit in constructing and maintaining an internal representation of context for control of action (Cohen et al., 1999), due to working memory deficit (Barch and Ceaser,

In Vito Pirrelli, Claudia Marzi, Marcello Ferro (eds.): *Word Structure and Word Usage*. Proceedings of the NetWordS Final Conference, Pisa, March 30-April 1, 2015, published at http://ceur-ws.org

2012). But, according to some authors, patients would fail in inhibiting contextually-irrelevant information, especially at long SOAs (Minzenberg et al., 2002), rather than in encoding contextually-relevant information. This impairment would be linked to a more global deficit in controlled semantic processing (Titone et al., 2000; Titone et al., 2002).

The importance of antonyms for elucidating the organization and retrieval of semantic knowledge is documented by the recent resurgence of interest on antonyms in normal comprehension (e.g., de Weijers et al., 2014; Paradis et al., 2009). In contrast, the vast literature on semantic processing deficit in SZ has almost ignored antonyms with the exception of a few paper-and-pencil studies of the 1960s (Blumberg and Giller, 1965; Burstein, 1961) that have documented impairment of SZ patients on antonyms. This underestimation of antonyms as a relevant test case of semantic organization can also be attributed to the fact that most neuropsychological studies on conceptual representations have primarily investigated semantic similarity rather than opposition (Crutch et al., 2012) at variance with the fact that semantic opposition, rather than similarity, is thought to be the axis around which the adjectival lexicon clusters (Murphy, 2003; Paradis and Willners, 2011).

2 Aims of the study

Shedding light on whether or not antonym identification is spared in a neurobiological disorder typically associated to semantic deficit may improve our understanding of the organization of word storage in the human brain (Jeon et al., 2009). Our general aim was therefore to expand the knowledge about the cognitive processes underlying the recognition of antonyms, and to evaluate whether these processes differed in SZ and in normal language comprehension. We tested whether the semantic dysfunction that often characterizes people with SZ necessarily leads to a loss of the capacity to recognize antonyms when antonyms are presented alone, rather than with homonyms and/or synonyms (Blumberg and Giller, 1965; Burstein, 1961), and when they are tested with a real-time task (for a more detailed version of this study, see Cacciari et al., 2015).

SZ patients tend to be less accurate and slower than healthy controls on most cognitive measures (Harvey, 2010; Vinogradov et al., 1998). Since response slowing is related to the disease, rather than necessarily reflecting semantic dysfunction (Niznikiewicz et al., 2010), this may lead to an artificial increase of the reaction time difference with healthy participants. To avoid this confound, often semantic priming studies have used a priming score (PRI; Spitzer et al., 1993), rather than the mere response times to the targets. The PRI reflects the amount of facilitation of prior context on the response time to a target and is calculated as follows: $(RT_{\text{unrelated targets}} - RT_{\text{related targets}})/ RT_{\text{unrelated targets}})*100$ (Spitzer et al., 1993). Here, we compared the individual PRI of patients to those of pairwise matched healthy controls.

Subjects read a definitional sentence fragment (*The opposite of word is*..) that, upon pressing the space bar, was followed by the antonym or an unrelated control word. This self-paced target verification task is suited to obtain information on real-time comprehension while placing little demand on the need to maintain and update information in working memory. We did not use similar, fixed time durations for patients and controls because SZ patients typically need longer presentation durations than healthy subjects to perceive a stimulus.

Healthy subjects should respond in a fast and accurate way, in line with the literature. Semantic priming studies often observed an exaggerated priming score of patients compared to controls (for an overview, see Kuperberg, 2010b; Pomerol-Clotet et al., 2008). This, as we mentioned, has been mostly attributed to faster than normal and far-reaching spread of activation in semantic memory. This larger semantic priming effect has been observed under the ‘automatic’ condition of word priming at short SOAs (Minzenberg et al., 2002). In this study, the priming effect elicited by the definitional sentence fragment on the target word, if any, would occur under strategically controlled conditions since the target presentation is self-paced, and the definitional sentence fragment strategically guides the semantic search toward the item that fulfills the antonymy definition. Notwithstanding, if indeed patients are characterized by an abnormal spread of activation, we should obtain larger priming scores in patients than in controls. This result would contribute to clarify the conditions under which hyper-priming effect can occur. The easy nature of the task, the high written frequency and bound lexical couplings of the antonym pairs of this study can minimize semantic processing demands. However, it is unlikely that an even *intact* ability to identify antonyms may eliminate any group difference, given the general cognitive deficits of people with SZ. To limit this potential confound, we carried out analyses of covariance on mean response times and accuracy to partial out the contribution of covariates (i.e., Verbal fluencies, Vocabulary, and Digit Span). Although we did not necessarily expect accuracy to be compromised in patients, given their mild-to-moderate form of SZ, the low demanding nature of the task and the high familiarity of the stimuli, we expect accuracy to be modulated by the severity of thought disorder and the clinical state of patients, as found in prior studies on semantic processing in SZ.

3 Method

3.1 Participants

Participants included 39 Italian chronic outpatients with paranoid SZ (14 female; mean age 31 years, age range 20-45, SD 6.2) and 39 healthy volunteers as control participants (see Table 1 for a characterization of patients and controls). The diagnosis of paranoid SZ is based on the *Positive and Negative Syndrome Scale* (PANSS; mean score: 46.69, range: 34-68) and was confirmed by the clinical consensus of staff psychiatrists. Participants gave their informed consent for inclusion before they participated in the study (approved by the Ethics Committee of Modena).

Table 1
Demographic characteristics of the study sample, and clinical characteristics of the schizophrenic patients

	Patients		Controls		
	Mean	SD	Mean	SD	p
Sex	M=25; F=14		M=25; F=14		
Age (years)	31.41	6.22	31.28	6.31	.93
Education (years)	12.56	1.33	12.51	1.48	.88
Drug	SG=33; FG=2; FSG=4				
Years of illness	8.97	5.94			
WAIS-R (Verbal Scale)	91.05	15.41			
WAIS-R (Performance Scale)	86.31	19.42			
WAIS-R (Total Score)	87.82	18.31			
Vocabulary (WAIS-R)	8.23	3.24	10.77	2.38	.0001
Phonemic Fluency	28.51	8.25	37.28	7.68	.0001
Semantic Fluency	38.44	8.44	44.10	7.74	.003
BADA (errors)	1.15	1.18	0.03	.16	.0001
Digit SPAN (Forward)	5.44	.74	5.85	.83	.04
Digit SPAN (Backward)	3.75	1.07	4.28	.97	.05
Digit SPAN (Total Score)	9.18	1.51	10.13	1.57	.02
BPRS			2	0	
PANSS (Positive Scale)	11.64	3.12			
PANSS (Negative Scale)	11.21	4.02			
PANSS (Gen Psyc Scale)	23.84	3.43			
PANSS (Total Score)	46.69	8.13			

M = male; F = female; FG = first-generation antipsychotics; SG = second-generation antipsychotics; FSG = combination of first- and second–generation antipsychotics.

3.2 Materials and Procedure

Participants were presented with a definitional sentence fragment containing the first word of the antonym pair (e.g., *The opposite of black is*) followed by the correct antonym (*WHITE*) or by a semantically unrelated word (*NICE*). Subjects had to decide whether or not the target was correct. We used 40 very familiar antonym word pairs (W1-W2; e.g., *black/white*, *dead*/*alive*; *long/short; optimistic/pessimistic*) in which the antonym had a cloze probability value of 0.98.

Each W1 was also paired with a semantically unrelated non-antonym target word (W3). Two lists were created each containing 40 sentences with the same format. The target word was an antonym in 20 sentences and a semantically unrelated, non-antonym word in the other 20 sentences. A spacebar press initiated the presentation of the definitional sentence fragments as *The opposite of word is*; a second spacebar press initiated the presentation of the target word that remained on the screen until response. Participants pressed a *YES* button to respond to correct targets and a *NO* button for incorrect targets.

4 Results

Significant group differences emerged in all the neuropsychological tests (see Table 1) administered to patients and controls. The priming scores revealed a statistically significant, enhanced contextual priming in patients compared to controls (16.04% vs. 9.6%). The ANCOVA on response times showed significant main effects of Group, with patients overall slower than controls (Ant.: 1273 ms; Unrel.: 1645 ms; Ant.: 984 ms; Unrel.: 1108 ms, for patients and controls respectively), and of Vocabulary. The ANCOVA on accuracy (Ant.: 96%; Unrel.: 98%; Ant.: 98%; Unrel.: 99%; for patients and controls respectively) showed a main effect of Vocabulary. In addition, the accuracy and response times of patients significantly correlated with Vocabulary scores (WAIS-R) in that patients scoring higher in the Vocabulary test also were overall faster in responding to antonyms and non-antonyms and more accurate in rejecting non-antonyms. Patients scoring higher on the Verbal Scale (WAIS-R) also had faster response times to antonyms, and patients scoring higher on the Positive Scale (PANSS) a lower accuracy on antonyms.

5 Conclusions

While antonym recognition was fast and accurate in heathy controls, the picture emerging for patients is more complex. Specifically, the preceding definitional fragment facilitated antonym recognition in both patients and healthy controls but the amount of facilitation indeed differed. In fact patients were helped more than controls by the previous definitional context, as shown by the larger reduction of response times to antonyms than to non-antonyms (on average, patients were 25.4% faster in responding to antonyms than to non-antonyms compared to 11.8% of controls), and by the exaggerated priming effect of patients (close to twice the effect of controls). This enhanced semantic priming was not associated to the clinical state and/or the thought disorder of patients. In sum, the patients group encoded contextually relevant target words (Titone et al., 2000; Titone et al., 2002) but to a much higher degree than controls. Interestingly, this larger semantic effect occurred under strategically controlled conditions rather than under the automatic condition typical of word priming at short SOAs (Minzenberg et al., 2002). This suggests a compromised ability of patients with SZ to engage in the controlled processing operations necessary to flexibly use semantic memory representations. At the same time the relatively high level of accuracy of patients (96.6% vs. 98.5% of healthy subjects) suggests a preserved semantic storage and access to semantic representations (Titone et al., 2002; Titone et al., 2007). High accuracy may reflect a ceiling effect as well as the fact that polarity information processing can be less demanding on executive resources than other types of semantic relationships (Crutch et al., 2012). Consistently with the reported effects of thought disorder on semantic processing (for overviews, see Kuperberg, 2010b; Pomarol-Clotet et al., 2008), patients with higher scores of positive thought disorder were also less accurate in identifying antonyms. Accuracy instead improved in patients scoring higher in both the Vocabulary sub-test and the Verbal scale of WAIS-R (these patients also had faster response times). These results are consistent with prior studies indicating that in SZ high Vocabulary scores are protective of semantic deterioration (Brébion et al., 2010) reflecting premorbid intelligence (Lezak et al., 2004). On more general grounds, these results provide further evidence of the already documented association of verbal intelligence to efficient language comprehension (Hunt, 1977). Overall, our results indicate that the state of residual SZ contributed to slower antonym recognition above and beyond the cognitive deficits that characterize SZ patients. In sum, it is not the case that patients comprehended antonyms as controls, but simply at a slower pace. In fact, compared to controls, patients not only had longer response times but also enhanced priming scores that presumably reflect deficient controlled semantic processing and overreliance on stored semantic representations. In conclusion, all other things being equal, antonym identification requires a preserved ability to appreciate the difference between *maximally similar* and *maxi-*

mally dissimilar meanings (Paradis and Willners, 2011). This ability to a large extent relies on preserved executive resources, integrity of the semantic processing system and size of the lexicon.

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