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Contribution of the Right Hemisphere to the Processing of Concrete Words

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In spite of controversies, numerous studies have suggested that the right hemisphere (RH) of right-handers demonstrates some lexical–semantic abilities (see Joanette, Goulet, & Hannequin, 1990, for a review). For instance, the specificity of the RH lexicon has been investigated in divided visual-field studies in normal subjects, by manipulating word concreteness. A number of these studies showed a weak right visual-field (RVF) advantage or no asymmetry with concrete words, while abstract words gave rise to a large RVF advantage in lexical decisions (Bub & Lewine, 1988; Day, 1977, 1979; Mannhaupt, 1983; Rastatter, Dell, McGuire, & Loren, 1987), naming (Bradshaw & Gates, 1978; Bruyer & Racquez, 1985; Ellis & Shepherd, 1974; Hines, 1976, 1977; Lambert & Beaumont, 1983; Marcel & Patterson, 1978; Young & Ellis, 1985) and semantic judgment (Day, 1977). These observations were interpreted as reflecting lexical–semantic abilities of the RH specific to concrete words (e.g., Day, 1977).

Results of divided visual-field studies are informative with respect to the lexical–semantic potential of the RH, but cannot be taken as evidence of a necessary RH participation in normal processing (Joanette et al., 1990). The demonstration of a deficit in tasks requiring the participation of lexical–semantic processes after right hemisphere damage (RHD) would argue for such a RH contribution. For example, the ability of RHD patients to match a spoken word to a target picture is normal in the presence of phonologic distractors and impaired with semantic distractors (Gainotti, Caltagirone, Miceli, & Masulo, 1981; Lesser, 1974). Furthermore, Chiarello and Church (1986) observed a deficit following RHD in the detection of a semantic relation between two concrete words, but Goulet and Joanette (1988) observed normal performance by RHD adults matching two abstract synonyms in the presence of a semantic distractor. The results of several recent studies, taken together, are consistent with the hypothesis of a deficit after RHD that is specific to the lexical–semantic processing of concrete words.

The present study tested the hypothesis that concrete word lexical–semantic processing requires RH integrity. Thus, we investigated the lexical–semantic abilities of RHD patients by comparing their performance with that of non-brain-damaged controls in lexical decision and semantic judgment tasks using abstract and concrete words. A left hemisphere–damaged (LHD) group was also tested to evaluate the specificity of any observed RHD deficit. These conditions were developed to meet the requirements of a double dissociation (Jones, 1983; Teuber, 1955) or a reversed association (Dunn & Kirsner, 1988).

METHOD

Subjects

Twenty patients with single, unilateral, focal brain damage (vascular etiology) were included in one of two groups: 10 RHD and 10 LHD patients. Lesion sites were confirmed by computerized tomographic scans in 15 patients (7 RHD and 8 LHD). No clinical signs of bilateral brain damage were documented for the remaining 5 patients. The delay between stroke onset and testing varied from 56 to 266 days and was comparable for the two groups [$t(18) = 0.13$, $p > .05$] (see Table 1). All

Table 1. Characteristics of the Right Hemisphere–Damaged (RHD), Left Hemisphere–Damaged (LHD), and Control Subjects

	RHD	*LHD*	*Control*
n	10	10	20
Mean age (years)	61.2 (10.7)	61.8 (10.7)	61.3 (11.0)
Mean education (years)	10.7 (2.3)	10.0 (3.1)	10.0 (3.5)
Sex (F/M)	7/3	7/3	12/8
Mean days postonset	92 (30)	100 (62)	—

Note: Standard deviation is given in parentheses.

brain-damaged patients had intact central vision and did not show clinical signs of unilateral visual hemineglect. Eight LHD patients had aphasic symptoms and showed at least partly preserved written single word comprehension, assessed by the *Protocole Montréal–Toulouse d'Examen Linguistique de l'Aphasie* (Nespoulous et al., 1986). Two LHD subjects were nonaphasic, and none of the RHD patients showed aphasic symptoms.

Twenty neurologically normal hospitalized patients were individually matched to brain-damaged patients according to age and education to form a control group. The three groups were comparable in age, education, and sex (see Table 1). All subjects were right-handed, were native French speakers, and had normal or corrected-to-normal vision.

Stimuli and Procedure

Stimuli for the lexical decision task consisted of 60 French nouns and 60 nonwords of three to nine letters. Nouns consisted of 30 abstract (concreteness rating ≤ 3.56, $M = 2.98$, $SD = 0.29$) and 30 concrete (concreteness rating ≥ 5.41, $M = 5.91$, $SD = 0.25$) nouns according to the mean concreteness rating of their English equivalents (Toglia & Batig, 1978). Abstract and concrete nouns were individually matched for length (abstract: $M = 6.3$ letters, $SD = 1.6$; concrete: $M = 6.4$ letters, $SD = 1.3$) and word frequency (abstract: $M = 67$, $SD = 99$; concrete: $M = 67$, $SD = 100$) (Baudot, 1989). Phonologically acceptable nonwords were derived from the words by changing two or more letters. Stimuli were displayed horizontally and centrally for 100 msec following a fixation point. Subjects were asked to respond "yes" if the letter string was a word and "no" if otherwise.

For the semantic judgment task, nouns taken from 9 abstract and 8 concrete semantic categories were selected to constitute 23 abstract and 23 concrete related pairs. The nouns were also redistributed to create 23 abstract and 23 concrete unrelated pairs, for a total of 92 pairs. The English equivalents of the abstract nouns had a mean concreteness rating less than 4.85 ($M = 3.59$, $SD = 0.57$) and the concrete nouns' concreteness rating exceeded 4.96 ($M = 5.95$, $SD = 0.34$) (Toglia & Batig, 1978). Abstract and concrete pairs were matched on length (abstract: $M = 6.3$ letters, $SD = 2.0$; concrete: $M = 6.9$ letters, $SD = 2.3$) and word frequency (abstract: $M = 86$, $SD = 164$; concrete: $M = 85$, $SD = 157$) (Baudot, 1989). Each word pair was free of orthographic or phonetic similarity. Following a fixation point, the two words of each pair were presented simultaneously, horizontally and side-by-side in the center of the screen, and remained until the subject responded. Subjects were asked to respond "yes" to related and "no" to unrelated pairs.

In both tasks, subjects responded by moving a vertical lever on the sagittal plane with a movement of abduction ("yes") or adduction ("no") using their right hand (RHD and 10 matched control subjects) or left hand (LHD and 10 matched control subjects). Stimulus presentation was controlled and responses were recorded via a MacIntosh (Mac SE) using *PsychLab*, version 0.85 (Gum & Bub, 1988).

Performance was evaluated with nonparametric indexes for sensitivity (A') and bias (B") (Brown Grier, 1971) derived from the signal detection theory (McNichol, 1972). A mixed design analysis of variance (ANOVA) was conducted on A' in the lexical decision task and on A' and B" in the semantic judgment task. These analyses included group as the between-subject factor and concreteness as a within-subject factor. In the lexical decision task, there was one type of distractor, namely nonwords, so a global B" was computed for each subject and, consequently, the analysis of variance included only group as a between-subject factor.

RESULTS

In the semantic judgment task, A' was transformed to $2\text{Arcsin}\sqrt{A'}$ to equalize variances, as suggested by McNichol (1972). Transformations were not needed otherwise. The control group was first divided into two subgroups according to the laterality of the manual response and tested for differences on sensitivity or bias. No laterality effect or interaction between laterality and sensitivity or bias reached significance; thus, further analyses compared RHD and LHD groups to a single control group, using corrections for unequal sample sizes (Winer, 1971).

Lexical Decision Task

In the lexical decision task, group [$F(2, 37) = 3.76$, $p < .05$] and concreteness [$F(1, 37) = 32.81$, $p < .0001$] effects reached significance on sensitivity (Figure 1). Groups also showed different patterns of performance across the two levels of concreteness, as confirmed by the interaction between group and concreteness [$F(2, 37) = 3.82$, $p < .05$]. Simple effects analysis revealed a significant group effect with abstract words [$F(2, 37) = 4.07$, $p < .05$] and no significant group effect with concrete words [$F(2, 37) = 3.17$, $p > .05$]. Tukey A tests showed a significant difference only between LHD and control groups with abstract words. All groups presented a comparable negative bias, indicating that errors consisted mainly of false alarms [$F(2, 37) = 0.57$, $p > .05$] (Figure 2).

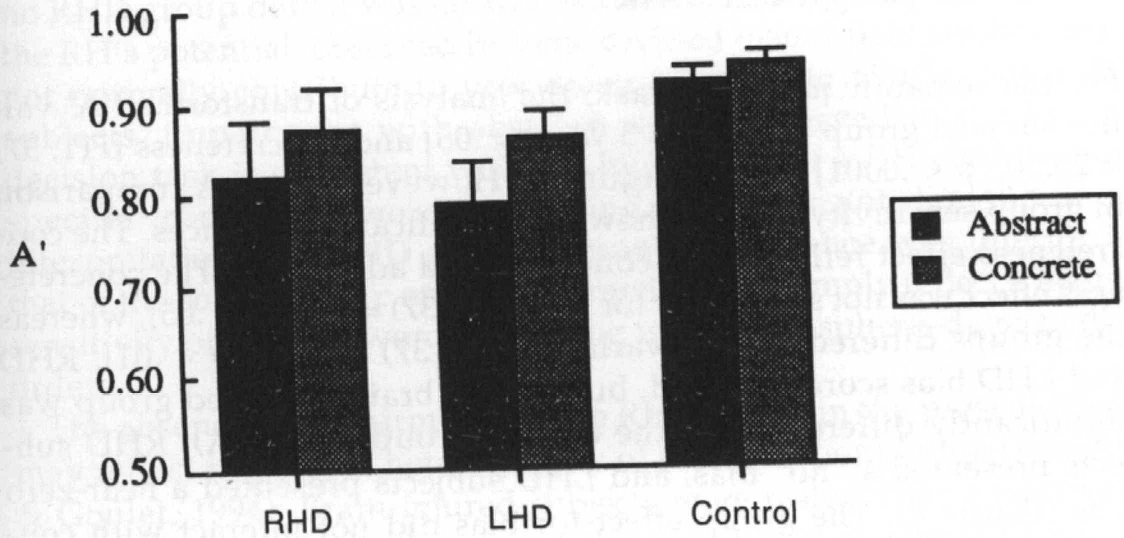

Figure 1. Mean sensitivity scores (A') and standard error for concrete and abstract words in the lexical decision task for RHD, LHD, and control subjects. Perfect performance corresponds to a sensitivity score of 1, and chance level is 0.5.

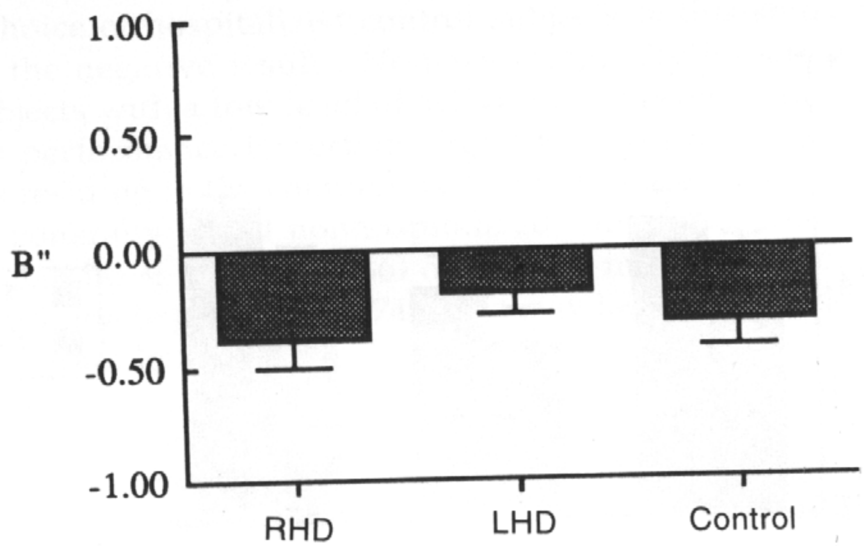

Figure 2. Mean bias scores (B") and standard error for RHD, LHD, and control subjects in the lexical decision task. A negative B" value indicates a loose criterion (a high rate of false positive responses), and a positive B" value corresponds to a strict criterion (a high rate of false negative responses).

Semantic Judgment Task

For the semantic judgment task, the analysis of transformed A' values showed group [$F(2, 37) = 3.98$, $p < .05$] and concreteness [$F(1, 37) = 25.50$, $p < .0001$] effects (Figure 3). However, Tukey A comparison of group sensitivity did not show any significant differences. The concreteness effect reflected the concrete word advantage. The concreteness effect was not significant for bias [$F(1, 37) = 2.99$, $p > .05$], whereas the groups differed on this variable [$F(2, 37) = 4.98$, $p < .01$]. RHD and LHD bias scores differed, but neither brain-damaged group was significantly different from the control group (Tukey A). RHD subjects presented a "no" bias, and LHD subjects presented a near-zero bias (Figure 4). The group effect for bias did not interact with concreteness [$F(2, 37) = 1.50$, $p > .05$].

DISCUSSION

The hypothesis that concrete word lexical–semantic processing requires the integrity of the RH was not supported by the data. In both tasks,

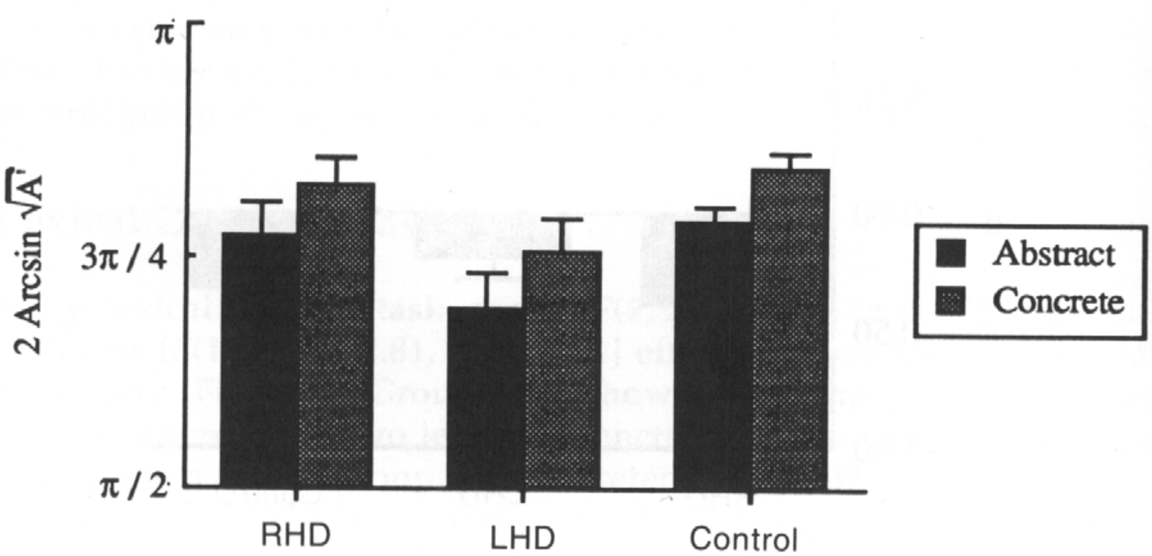

Figure 3. Mean transformed sensitivity scores ($2\text{Arcsin}\sqrt{A'}$) and standard error for concrete and abstract words in the semantic judgment task for RHD, LHD, and control subjects. Following the transformation, sensitivity varies from $\pi/2$ (chance level) to π (perfect performance).

no RHD group deficit was clearly evidenced. This result suggests that the RH's potential, observed in some divided visual-field studies, may not normally contribute to processing of concrete words. The LHD subjects' impairment with abstract words observed in the lexical decision task is consistent with the hypothesis of a RH contribution specific to concrete word processing, but does not demand such interpretation. The LHD group's mean performance was inferior to that of the control group and the interaction may simply reflect a higher sensitivity of abstract word processing to left hemisphere–damage disorders.

The absence of impairment for the RHD group in the present study may reflect in part the heterogeneity of the RHD population (Joanette & Goulet, 1994). Brain-injured subjects were tested after a relatively short postonset delay to prevent the possibility of effects of newly acquired abilities by the RH. However, this selection bias could have led to the exclusion of some RHD patients because of associated symptoms (e.g., hemianopia, hemineglect) that prevented them from performing at a higher than chance level. This short delay postonset contrasts with the relatively long delay in the study of Chiarello and Church (1986). It is probable that not all RHD patients demonstrate lexical–semantic impairments, and those who do may have exhibited other neuropsychological symptoms in the acute postonset period. It may be the case that these potentially more affected subjects have been excluded, thus biasing the subject sample.

The choice of hospitalized control subjects in this study may also explain the negative results. Non–neurologically impaired hospitalized subjects with a low level of activity have been reported to show a lower performance in certain cognitive tasks than active healthy subjects residing in the community (Klonoff & Kennedy, 1966). Other studies generally tested nonhospitalized subjects as control subjects (e.g., Chiarello & Church, 1986) or did not mention the control subjects' condition (e.g., Lesser, 1974). This may have amplified any apparent right brain lesion effect.

The difference in bias between brain-damaged groups confirms the importance of comparing sensitivity and not only percentage of hit responses. Chiarello, Nuding, and Pollock (1988) suggested that differences in bias may reflect postlexical operations involved in decisions and production of the response. The possibility of a general group difference in apprehension of the tasks is rendered less plausible by the selectivity of the bias difference to the semantic judgment task. One possible interpretation of this result might be that LHD subjects have a tendency to try to conceal their difficulty in relating words by producing a high rate of positive responses and, consequently, a high rate of false alarms and a low B" value.

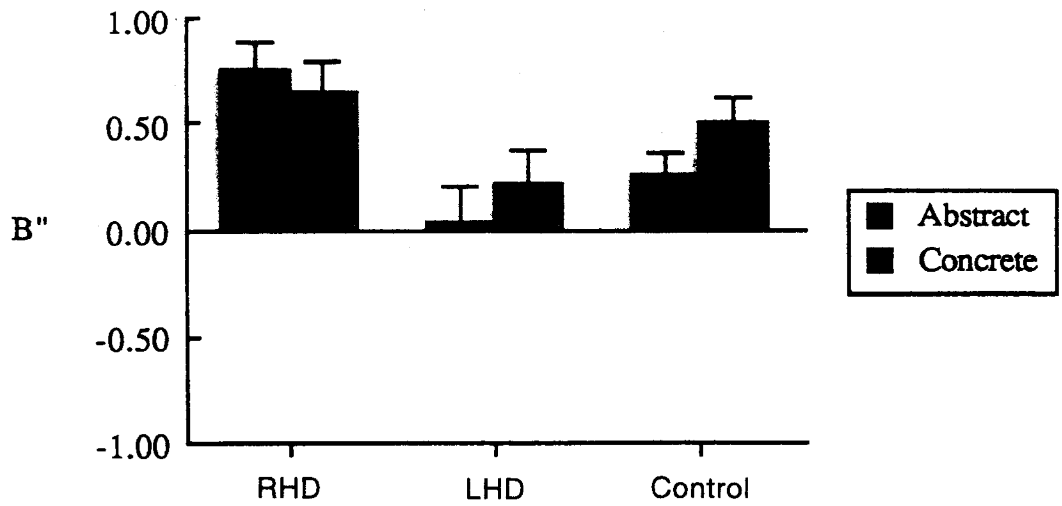

Figure 4. Mean bias scores (B") and standard error for concrete and abstract words for RHD, LHD, and control subjects in the semantic judgment task.

On the other hand, one may speculate that the exploitation of a qualitatively different semantic network in RHD and LHD patients could explain the observed difference in bias. RHD patients may rely on a more selectively organized semantic network with links between concepts having a high semantic relatedness, whereas LHD patients may rely on a more diffusely organized semantic network, as was suggested by Chiarello (1990). Relying on the former semantic network could result in positive responses only to highly related word pairs and consequently to a stringent decision criterion, whereas the latter network would permit less related concepts to be activated, and could lead to a more lenient criterion.

In conclusion, the present study did not find evidence of a RH contribution specific to the lexical–semantic processing of concrete words. The bias difference observed between RHD and LHD subjects could reflect a qualitative difference in semantic organization between the left hemisphere and right hemisphere, but this hypothesis needs further exploration. The meaning of the bias effect and its underlying processes should be investigated more extensively in different cognitive tasks and in different brain-damaged populations to examine its major theoretical and clinical significance.

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