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Activation and maintenance of peripheral semantic features of unambiguous words after right hemisphere brain damage in adults

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Abstract

Background—The right cerebral hemisphere (RH) sustains activation of subordinate, secondary, less common, and/or distantly related meanings of words. Much of the pertinent data come from studies of homonyms, but some evidence also suggests that the RH has a unique maintenance function in relation to unambiguous nouns. In a divided visual field priming study, Atchley, Burgess, and Keeney (1999) reported that only left visual field/RH presentation yielded evidence of continuing activation of peripheral semantic features that were incompatible with the most common image or representation of their corresponding nouns (e.g., *rotten* for “apple”). Activation for weakly related features that were compatible with the dominant representation (e.g., *crunchy*) was sustained over time regardless of the visual field/hemisphere of initial stimulus input. Several studies report that unilateral right hemisphere brain damage (RHD) in adults affects the RH’s meaning maintenance function, but this work also has centred on homonyms, and/or more recently metonymic and metaphoric polysemous words.

Aims—The current investigation examined whether RHD deficits in processing secondary and/or distantly related meanings of words, typically observed in studies of homonyms, would extend to peripheral, weakly related semantic features of unambiguous nouns.

Methods & Procedures—Participants were 28 adults with unilateral RHD from cerebrovascular accident, and 38 adults without brain damage. Participants listened to spoken sentences that ended with an unambiguous noun. Each sentence was followed by a spoken target phoneme string. Targets included peripheral semantic features of the sentence-final noun that were either compatible or incompatible with the dominant mental images of the noun, and were presented at two intervals after that noun. A lexical decision task was used to gauge both the early activation and maintenance of activation for these weakly related semantic features.

Outcomes & Results—Accuracy data demonstrated activation (priming) for both types of peripheral features, in both groups, shortly after presentation of the corresponding noun. Neither group evidenced continuing activation for either type of feature at a longer interval. These results are interpreted as reflecting rapid decay/poor maintenance of activation for distantly related features for both groups. The lack of a biasing context, however, did not provide an appropriate test for

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previously reported suppression deficits after RHD. Fast decay of activation of compatible semantic features was unexpected for the control group. Adults with RHD were less accurate than the control group at both test intervals for the features that are semantically more distant from their associated nouns (Related-incompatible features). Accordingly, it is argued that the RHD group's poor maintenance of activation for these features reflects a deficit, rather than normal performance. The interpretation of results from this study is complicated by the lack of RT priming for either type of semantic feature, and for either participant group.

Conclusions—The right cerebral hemisphere appears to be necessary for activating semantic features that are particularly distantly related to their corresponding lexical items, and for sustaining activation of these features in the absence of a biasing context. Because lexical processing has been linked with discourse comprehension for adults with RHD, more work in this area should enhance clinical management in the future.

Damage to the right cerebral hemisphere (RHD) in adults has been linked with deficits of activation and/or deactivation for the subordinate and context-alternative meanings of ambiguous words (Fassbinder & Tompkins, 2001; Grindrod & Baum, 2003, Klepousniotou & Baum, 2005a, 2005b; Tompkins, Baumgaertner, Lehman, & Fassbinder, 2000). As noted recently by Klepousniotou and Baum, the relevant investigations have typically centred on homonyms, or lexical ambiguities with two distinct and unrelated meanings (e.g., “bank”).

Most research on lexical-semantic processing in the intact right hemisphere (RH) also has focused on homonyms. Burgess and Simpson (1988) performed seminal work in this area, using divided visual field presentation methods to evaluate the time course of activation for dominant and subordinate meanings of polarised ambiguous words like “bank”. Each ambiguity served as a prime in a lexical decision task in which the critical target words were related to either meaning of the ambiguity (e.g., bank – money; bank – river). When the onsets of primes and target words were separated by only a brief time interval, the ambiguities activated the target concepts in both visual fields. At a longer time interval, however, the subordinate meaning (“river”) was primed only when stimuli were presented to the left visual field (RH). Burgess and Simpson concluded that right hemisphere processing is important for keeping available the subordinate meanings of words, in case they are needed for later meaning elaboration or reinterpretation.

Since that time, numerous studies have substantiated and built on the notion that the intact right cerebral hemisphere provides a critical maintenance function for weakly related, secondary, or less common word meanings (e.g., Abdullaev & Posner, 1997; Faust & Gernsbacher, 1996; Federmeier & Kutas, 1999; Richards & Chiarello, 1995; Titone, 1998). Recently this finding has extended to less frequent verbs (Chiarello, Kacinik, Shears, Arambel, Halderman & Robinson, 2006), indirectly connected words (e.g., lion – stripes [connected through “tiger”]; Yochim, Kender, Abeare, Gustafson, & Whitman, 2005), and “punch words” that reflect the endings of jokes (Coulson & Williams, 2005). While there is evidence to the contrary (Coney, 2002, Koivisto, 1998) this “right hemisphere meaning maintenance” hypothesis predominates in the literature.

Atchley, Burgess, and Keeney (1999) reported distinctions in hemispheric meaning maintenance even among peripheral, weakly related features of ostensibly *unambiguous* nouns (e.g., “apple”). Both (relatively) strongly and weakly related features were gleaned from a semantic feature generation task, and were used as target words in a priming study. The unambiguous nouns served as primes. The weakly related semantic features were subdivided into two types by expert judges, who generated a mental image of each noun and then rated whether the target features were compatible (“crunchy”) or incompatible (“rotten”) with that mental image. Results of the study indicated that initial activation was sustained over time for the compatible features that were part of the dominant meaning, regardless of the visual field/

hemisphere of initial stimulus presentation. But only with left visual field/ RH presentation was there evidence for continuing activation of the distantly related features that were incompatible with the most common image or representation of the prime words, and as such were part of a distinct and competing, subordinate representation.¹

The current study was conducted primarily to determine if RHD adults' previously predicted or reported deficits in maintaining activation for lexical alternative meanings would extend to weakly related semantic feature representations of the "unambiguous" lexical items examined by Atchley and colleagues (1999). Possible outcomes were generated from Atchley and colleagues' findings, the literature on hemispheric contributions to homonym processing, and the potential modifying effect of the method of prime presentation. With regard to this last issue, studies that have used split visual field presentation of prime words provide most of the evidence that has been used to propose that adults with RHD should have deficits in sustaining subordinate/weakly related/secondary/alternative meanings. But investigations in which primes are presented in typical reading conditions can yield different results (Fassbinder & Tompkins, 2006). For instance, when primes are presented in the centre of the visual fields, in standard reading conditions, subordinate meanings are no longer active at a long interval post-prime presentation, even for adults without brain damage (Hino, Lupker & Sears, 1997; Simpson & Burgess, 1985). Weakly related meanings remain active, however (Becker, 1980; McRae & Boisvert, 1998). With each of these factors in mind, the following three outcomes were deemed possible for RHD adults' maintenance of activation for weakly related semantic features of unambiguous words.

First, a direct extrapolation from Atchley et al. (1999) might suggest that adults with RHD would have difficulty *sustaining* activation of only the *incompatible* (subordinate) features. Activation for semantic features that are weakly related but *compatible* with the most common representations of the lexical items in question would be maintained over time by adults with RHD, because both cerebral hemispheres support continuing activation of these features. Second, other results, also primarily from split visual field studies, suggest that the intact right hemisphere is important for maintaining subordinate or distantly related meanings of words without reference to the "compatibility" dimension (e.g., Abdullaev & Posner, 1997; Faust & Gernsbacher, 1996; Federmeier & Kutas, 1999; Richards & Chiarello, 1995; Titone, 1998, Yochim et al., 2005). In this case, RHD may diminish activation maintenance for both types of semantic features. A third possible outcome is that adults with RHD would show prolonged activation of the incompatible features at a time when these features were no longer primed in non-brain-damaged individuals (as per the evidence from studies with central prime presentation, cited above). This result would be consistent with evidence that adults with RHD have difficulty *suppressing* the context-inappropriate meanings of homonyms (Fassbinder & Tompkins, 2001; Klepousniotou & Baum, 2005b; Tompkins et al., 2000) and metonyms (but not metaphors; Klepousniotou & Baum, 2005b). It is important to note that the "poor maintenance" vs "prolonged maintenance" (suppression deficit) possibilities for adults with RHD may not be mutually incompatible, being associated, for instance, with differences in initial activation and/or in within-hemisphere lesion site.

A control group of adults without brain damage would be expected to show sustained activation of *compatible* semantic features, because they are a part of the dominant meaning of the concept

¹Some confusion is created by Atchley and colleagues' (1999) use of the term "subordinate" to refer to the "compatible" semantic features that were actually part of a dominant meaning representation, but that nonetheless had a weak semantic relationship to their parent concept (as determined by production frequency). Meaning dominance and semantic relatedness are distinct concepts with distinct results in studies of hemispheric processing of words (Chiarello, Liu, Shears, Quan, & Kacinik, 2003; Fassbinder & Tompkins, 2006). We refer to both compatible and incompatible semantic features as weakly related, distantly related, or peripheral features, and emphasise that compatible features are part of the "dominant" meaning and incompatible features part of a distinct, "subordinate" meaning.

in question. Prolonged activation of *incompatible* features by control participants would be unlikely, however, because these features are part of a distinct, subordinate meaning.

A secondary purpose of this study was to determine whether RHD affects the earlier activation of the types of features studied by Atchley and colleagues (1999). Postulating a deficit in the maintenance of activation for secondary/alternative features or meanings assumes adequate initial activation of those meanings or features. This has been demonstrated in several prior studies of homonym processing (Fassbinder & Tompkins, 2001; Klepousniotou & Baum, 2005b; Tompkins et al., 2000). But it is also possible that earlier activation of the *incompatible* features may be disrupted by RHD. Some evidence in line with this possibility is that adults with RHD did not prime for the secondary (subordinate) senses of metaphoric polysemous words, whether in the absence (Klepousniotou & Baum, 2005a) or presence (Klepousniotou & Baum, 2005b) of a biasing context. In addition, adults with RHD may activate distinct senses of homonyms based on meaning frequency (Grindrod & Baum, 2003). Thus the early activation of *compatible* semantic features, which conform to the dominant representation of their associated concepts, may be unaffected by RHD, but early activation of the *incompatible* features would more likely be affected, because these features reflect characteristics of a secondary (subordinate) representation.

METHOD

Participants

A total of 66 adults participated in this study. Of these, 28 had unilateral RHD due to cerebrovascular accident, and 38 had no known brain damage or neurological impairment. Table 1 provides biographical and clinical information for each participant group. The groups did not differ on demographic variables or vocabulary recognition scores, but differed reliably on various clinical/neuropsychological measures, as would be expected.

Participants with RHD were recruited from eight acute care hospitals and rehabilitation facilities. All potential participants with RHD met the following inclusion criteria: unilateral hemispheric lesion(s) confirmed by CT or MRI scan report; at least 4 months post-onset of CVA; age between 40 and 85 years; and a minimum of 8 years of formal education. Exclusions were based on medically documented evidence of bilateral lesions, brainstem or cerebellar damage, premorbid seizure disorders, head injuries requiring hospitalisation, problems with drugs and/or alcohol, a potentially cognitively deteriorating condition such as Alzheimer's or Parkinson's disease, or psychiatric illness. Clinical CT or MRI reports showed a range of within-hemisphere lesion sites (see Table 1).

Potential participants were interviewed and tested for several other selection criteria. By self-report they were right-handed, monolingual American English speakers (see Tompkins, Bloise, Timko & Baumgaertner, 1994, for operationalisations). They also passed a pure-tone air conduction hearing screening (35dB HL at 500, 1000, and 2000 Hz; values within 0.5 standard deviation of Harford & Dodds' 1982 means for ambulatory, non-institutionalised older men). Those who passed the hearing screening in only one ear were also asked to repeat 12 words, each of which was loaded with fricative consonants. More than one repetition error was grounds for exclusion from the study.

Individuals in the non-brain-damaged (NBD) control group were recruited from the laboratory's research registry, and also through media advertisements, senior citizen groups, hospital volunteer departments, a University website on clinical research, and control participants' referrals of family members or friends. These individuals met the same biographical and behavioural inclusion criteria as participants with RHD. Before being enrolled in the study, they were interviewed to rule out previous neurological episodes or conditions or

problems with drugs and/ or alcohol. In addition, as a cognitive screen, all control group participants passed the Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975) with at least 28 out of 30 possible points.

Overview

In the experimental task, participants listened to spoken sentences that each culminated in an unambiguous noun (e.g., He has an *apple*). Each sentence was followed by a spoken target phoneme string at two interstimulus intervals (175 and 1000 ms from sentence-final noun offset). Targets included three types of real words: semantic features of the sentence-final nouns that were either (a) compatible (Related-compatible; e.g., “*crunchy*”) or (b) incompatible (Related-incompatible; e.g., “*rotten*”) with the dominant mental image of the noun; and (c) unrelated words (e.g., “*mermaid*”). Activation/deactivation for these weakly related semantic features was gauged implicitly with a lexical decision task, in which participants indicated as quickly as possible whether each target phoneme string was or was not a real word. Nonword targets were paired with other sentences.

Stimuli and tasks

Lexical decision task—Except as otherwise noted, the stimulus validation results reported below reflect data from a minimum of 10 sociodemographically appropriate respondents per validation task. More detail on stimulus validation is available on request.

Two types of stimulus sentences were created for this task, experimental and filler. Experimental stimulus sentences were built around 16 critical one- to two-syllable nouns (e.g., *apple*) that raters had judged to be unambiguous (Atchley et al., 1999). The nouns were the final words in brief S-V-O sentence frames that were designed to be semantically neutral (e.g., He has an *apple*). Raters verified that each sentence frame biased neither the compatible nor incompatible features of the sentence-final nouns. The Appendix provides a list of all experimental stimuli. Filler sentence stimuli were also simple declarative sentences that were similar to the experimental sentences in length (four to seven words). Filler sentences were actually the experimental stimuli from another lexical decision experiment, and the two stimulus sets were combined into one task, to balance critical stimulus features. The combined stimulus sets yielded 168 total trials, that included equal numbers of ambiguous and unambiguous sentence-final nouns, and equal numbers of verbs that (1) biased neither “image” of the unambiguous nouns that are the focus of this study; (2) strongly biased the (filler) ambiguous nouns towards one of their meanings; (3) biased neither interpretation of another set of (filler) ambiguous nouns; and (4) were highly consistent with another set of (filler) unambiguous nouns.

The experimental sentences were paired with the three types of real-word lexical decision targets described above (see Appendix). Both Related-compatible and Related-incompatible targets were from the stimulus set validated by Atchley et al. (1999). Related targets and their corresponding sentence-final nouns were not associated (Nelson, McEvoy, & Schreiber, 1998). Raters for this study verified the intended degree of semantic fit between the sentence-final nouns and real-word targets to be equally high for both types of semantic feature targets and essentially nonexistent for unrelated word targets. Data from e-lexicon (Balota et al., 2002) were used to match the three types of real-word targets for lexical properties, including log frequency, prosodic features, abstractness, and mean reaction time. Filler sentences were also paired with two types of related word targets (representing the dominant and subordinate meanings of ambiguous nouns) and unrelated word targets. Nonword targets were used exclusively with filler sentences. Nonword targets were formed by changing one or two phonemes of a real-word target in a way that made the “nonword” decision impossible until the final third of each phoneme string.

Word-monitoring task—An incidental component of this study was a simple auditory word-monitoring task, to keep participants' attention focused on the entire stimulus sentence. This was important for the stimuli from the other experiment (the filler stimuli for this study, described above), in which the sentence biased a particular interpretation. Each word to be listened for was a common noun or verb, one to three syllables in length (e.g., “gave”, “animal”).

Task construction

Lexical decision task—A practised female speaker audio recorded the sentence stimuli, and a practised male speaker the probe words, all at an average speaking rate of about four syllables/second. Stimuli were produced without undue emphasis on any lexical element. All recordings were made with an Audio-Technica ATR20 vocal/instrument microphone with a constant microphone-to-mouth distance (~4 inches). Recording was done in a double-walled, sound-treated booth. Stimuli were recorded onto a Dell Optiplex GX260 with a Creative SB Live! Value (WDM) sound card using Sound Forge v4.5 software at a sampling rate of 22.05 KHz with 16-bit resolution. The first author and several assistants collaborated with the speakers to achieve recording consistency.

Stimuli were then assembled using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002). A single trial consisted of a trial number followed by a 500-ms pause, the stimulus sentence, another interval of either 175 ms or 1000 ms, and then the spoken target. Each experimental stimulus for this task occurred three times, once with each of its three real-word targets (total of 48 experimental trials). Thus, several design features were included to minimise expectancies about stimulus repetition. First, none of the filler sentences was repeated verbatim within either ISI condition; second, different types of filler sentences were created by systematically varying their elements (sentence length, sentence complexity, verb bias, final-noun ambiguity); and third, each nonword target also occurred three times, each time with a different stimulus sentence. For the entire task, sentences and target words were combined to achieve an overall relatedness proportion of .59 and a nonword ratio of .55.

The 168 trials for this task were pseudorandomly arranged into 14 blocks of 23–24 trials each. Each block of trials was checked to assure the following: (1) there were no exact sentence repetitions in the same block; (2) there were no more than three of each type of filler sentence in each block; (3) each repeated experimental sentence was separated by at least nine items across blocks; (4) there were no more than three sequential “yes” or “no” responses in each block; and (5) each block began with at least two filler trials and ended with at least one filler.

Experimental apparatus and procedures

Lexical decision task—All stimuli were delivered via a Dell Inspiron 5150 notebook computer, through high-quality supra-aural earphones (Beyerdynamic DT150) at a comfortable loudness level selected by the participant (via Quick Mixer v1.7.2). Participants responded to each target word by pressing one of two labelled buttons (Yes/No) on a manual response box. E-Prime software generated and stored accuracy data and millisecond RTs.

Word-monitoring task—Before each block of trials for the lexical decision task, participants were shown an index card. The card contained the word for which participants were asked to listen, printed in half-inch block letters. The word was read out loud to the participant and then the card was placed on the response box. At the end of the block of trials, participants were asked to indicate whether they heard the word. Eight blocks of trials contained the word in question, while six did not. When the word occurred, it only occurred once, in a filler trial, in the latter two thirds of the stimulus block.

General procedures—Testing required four to five sessions, lasting up to 90 minutes, over a period of about 3–7 weeks. Order of stimulus block presentation within and across sessions was counterbalanced for each participant. Stimulus blocks were interspersed with screening and clinical measures, and with experimental tasks for other studies, to maximally separate presentations of repeated stimuli.

Participants were tested in a quiet room, either in their homes or in the first author's laboratory. Five examiners were trained to perform the testing, and only one examiner worked with each participant. Each examiner tested people from both groups. Participants received extensive orientation, instruction, and practice in performing the lexical decision task, first without the word-monitoring component and later with it. Participants were trained to indicate their lexical decision for each trial with a single finger of the right hand, and to return that finger between trials to a designated location equidistant from the labelled response buttons. They were instructed to respond as quickly and accurately as possible, and both spoken and gestural reminders about speed and consistency were provided throughout the training. Training and practice continued until participants responded with assurance and RTs had stabilised. In each new session, participants received additional practice items before presentation of the first block of stimuli. Spoken and gestural reminders about response speed and consistency were provided prior to each block of trials. Participants used the same response buttons to respond to the word-monitoring task.

To encourage rapid responding on the lexical decision task, a response deadline (standard Windows bell) was presented on 50% of filler trials. Response deadlines were individually determined, by averaging RTs for correct responses during practice trials.

RESULTS

This study assessed activation/deactivation of targets that reflect two types of weakly related semantic features of unambiguous nouns (e.g., *apple*). Related-compatible targets are compatible with the dominant mental representations of these nouns (e.g., *crunchy*). By contrast, Related-incompatible targets are compatible with a distinct, subordinate mental image (e.g., *rotten*).

Preliminary data analysis

Independent *t*-tests were computed separately for each group, to evaluate accuracy and RT performance for gender differences. None of these analyses was significant (all $p > .09$). Both groups' data were also assessed for speed–accuracy trade-offs, using Pearson correlation analysis. All correlations but one were smaller than $r = .22$. The exception, for RHD Short ISI Unrelated trials, was not consistent with a speed–accuracy trade-off. Rather, the direction of association indicated faster RTs with higher accuracy, $r(25) = -.47$; $p < .05$.

RT data were further evaluated for outlying values ($> \pm 3 SD$ from the relevant condition mean for each group), and these outlying data points were coded as errors. As a result, one participant with RHD had only one pair of accurate data points in each condition, and was excluded from RT analyses. This participant's demographic and clinical characteristics were well within the range of those for the full group with RHD. Outlying RT values totalled 7.5% of all trials for the group with RHD, and 8% for the NBD group.

Primary data analysis

Table 2 provides group accuracy and RT data for Related-incompatible (e.g., *rotten*) and Related-compatible (e.g., *crunchy*) semantic feature targets and for Unrelated target words (e.g., *mermaid* for *apple*). All data were submitted to mixed two-way Analyses of Variance

(ANOVA; Group by ISI [short, long]), with repeated measures on ISI, as specified below. Alpha was set at .05 for all analyses. Table 3 provides statistics and effect sizes for each analysis.

Related-compatible semantic feature targets

Accuracy analysis—Two accuracy analyses were conducted. First, total accuracy scores were assessed. The only significant result was the main effect of ISI (see Table 3). Both participant groups were nearly at ceiling at the Short ISI, and both groups made more lexical decision errors at the Long ISI.

Second, an accuracy proportion measure (Related-compatible accuracy/Unrelated accuracy) was calculated to assess priming of Related-compatible semantic features. Proportions were used rather than the more common difference scores, to take into account absolute differences in response speed between groups and individuals. A proportion greater than 1 represents priming, or better performance for Related than Unrelated targets. Priming would indicate that an unambiguous noun like “apple” activates even weakly related features that are compatible with the dominant mental representation or image of that noun. One participant with RHD was excluded from this analysis due to a high error rate on the Unrelated targets (less than 33% correct). As determined with the semi-Automated Labelling Pathway procedure for lesion localization (Wu, Carmichael, Carter et al., 2006) this individual had an extensive anterior lesion involving Brodmann’s areas 12, 25, and 47 along with small portions of 10 and 11.

This analysis again yielded only an ISI effect (see Table 3). Related-compatible feature targets were primed at the Short ISI, but not at the Long ISI.

RT analysis—RT data were analysed only for accurate trials. Two RT analyses paralleled those for accuracy. The first assessed raw RTs in ms, and was included to illustrate a fully anticipated Group difference, as well as for completeness. In this analysis, only the main effect of Group was significant (Table 3). As would be expected, participants in the NBD group responded faster to the Related-compatible feature targets than did those in the RHD group, regardless of ISI.

RT priming was also evaluated, using a proportion measure calculated for each trial (Related-compatible RT/Unrelated RT) and then averaged across trials, to adjust for inter-individual differences in basic response speed. A proportion between 0 and 1 would indicate an RT *advantage* for the Related-compatible feature targets, in relation to Unrelated word targets. In addition to the participant from the RHD group noted above, who had such low accuracy on Unrelated trials, one NBD participant was excluded from this analysis because his Long ISI RT proportion scores were 3 *SD* higher than their respective group mean. Of all study participants, this individual had the lowest vocabulary recognition score, per the *Peabody Picture Vocabulary Test-Revised* (Dunn & Dunn, 1981).

The RT proportion ANOVA yielded no significant effects. The data in Table 2 show that there was no RT advantage for Related-compatible trials as compared to Unrelated trials.

Analysis of Related-incompatible semantic feature targets

The same analyses were performed on Related-incompatible feature trials, in which lexical decision targets were semantic features that were incompatible with the dominant mental image of the unambiguous nouns (e.g., *rotten* for apple). This time, for total accuracy, both main effects were significant (see Table 3). The NBD group was more accurate overall regardless of ISI, and accuracy for both groups was higher overall at the shorter interstimulus interval.

The analysis of accuracy proportion measures again indicated only a significant effect of ISI (Table 3). Related-incompatible features were primed at the 175 ms ISI, but not at the 1000 ms ISI, irrespective of participant group.

For raw RTs, two-way ANOVA again indicated only the expected main effect of Group (Table 3) with NBD participants responding faster regardless of ISI. The RT proportion analysis yielded a significant effect of ISI. This result signifies smaller RT proportions at the Short ISI than at the Long ISI. Again, however, the data in Table 2 show that on average, neither group responded more quickly to Related-incompatible targets than to Unrelated lexical decision targets, at either ISI. Thus, no priming was evident in the RT data for the Related-incompatible semantic features.

Assessment of individual differences in performance

Several approaches were taken to evaluate variation between participants in processing weakly related features of unambiguous nouns. First, post hoc correlations of performance on each accuracy and RT dependent measure were performed separately with the continuous demographic and clinical variables listed in Table 1, and also with pure tone averages as an index of hearing sensitivity. Results were assessed against Cohen's (1988) rule of thumb for a large effect size in the behavioural sciences ($r > 0.5$). For accuracy performance, there were no correlations that met or approached this criterion for either group. NBD group data evidenced no such correlations for RT measures either. For the group with RHD, the established criterion was met for all correlations between raw (ms) RTs and test scores on standardised measures of visual perception (*Visual Form Discrimination*, Benton, Hamsher, Varney & Spreen, 1983) and neglect (*Behavioural Inattention Test*, Wilson, Cockburn, & Halligan, 1987), which were themselves moderately highly correlated; $r(28) = .69$. In addition, criterion was met for the associations between an estimate of Working Memory capacity for language (Lehman & Tompkins, 1998; Tompkins et al., 1994) and raw RTs to Related-compatible targets at both ISIs, and to Unrelated targets at the Long ISI only.

Differences in performance were also explored by within-hemisphere lesion site for the RHD group. Because sample sizes were small in each lesion subgroup, these results were not analysed statistically. Accuracy on Unrelated targets was disproportionately low for the subgroup with "cortical anterior" damage, but this was traceable to the single individual previously mentioned with the extreme error rate on these targets. Otherwise there were no obvious differences among lesion subgroups.

DISCUSSION

This investigation examined whether deficits in processing lexical alternative meanings after RHD, typically observed in studies of homonymous words, would extend to weakly related semantic features of unambiguous words. Lexical decision data were obtained to word targets that reflected two types of semantic features: those that were compatible with the most common mental image of the prime words in question (Related-compatible, e.g., "crunchy" for apple) or those that reflected alternatives to this most common representation (Related-incompatible, e.g., "rotten" for apple). Performance was evaluated at two ISIs, to address both sustained activation of peripheral semantic feature targets over time, and earlier feature activation.

As outlined in the introduction, the prediction based on Atchley and colleagues (1999) was that both types of feature representations would be primed soon after the presentation of their corresponding stimulus sentence and that adults with RHD would have difficulty sustaining activation of Related-incompatible features at the later processing point. A second possible outcome, assuming adequate initial activation, was that RHD would diminish the later processing of both types of features, because both are only weakly related to their parent

concept. A third possibility was that participants with RHD would have difficulty suppressing activation for Related-incompatible features at the Long ISI. Finally, a possible disruption in early activation of weakly related targets was considered as well: impairment only for Related-incompatible features, which are part of the subordinate meaning representations of the unambiguous nouns. The results of this study paint a somewhat mixed portrait, in that the RT findings do not mirror the accuracy data. The ensuing discussion considers accuracy and RT performance in turn, and finally addresses individual differences.

Accuracy performance

Both types of weakly related features were primed in the accuracy performance of both groups, but this priming occurred only at the Short ISI, close in time to the presentation of the stimulus sentence. In addition, there was a small but significant accuracy advantage at the Short ISI. The most straightforward interpretation of these results is that peripheral semantic features of words are activated, both by individuals with RHD and without brain damage, but then that activation quickly decays or is rapidly suppressed. These data thus raise doubt about Atchley and colleagues' (1999) differentiation of hemispheric function based on the "compatibility" of features with their associated conceptual representations.

This parallel group performance might be interpreted as a lack of deficit—strictly normal performance—in this sample of participants with RHD. Three pieces of evidence argue against this interpretation. The first, though indirect, is that the group with RHD had significant deficits on all of the clinical/neuropsychological measures summarised in Table 1. The second is that this group of adults with RHD is quite similar in demographic and clinical characteristics to RHD participants in studies that have documented lexical processing deficits (Fassbinder & Tompkins, 2001; Tompkins et al., 2000). The third and most important piece of evidence rests in the overall group accuracy difference for Related-incompatible semantic feature targets. This finding suggests that different processes were at work for the RHD and NBD groups.

As just noted, the participants with RHD did evidence initial activation for Related-incompatible feature trials. But they were less accurate than the control group on these trials, at both post-sentence intervals. There was no such group difference for Related-compatible trials. This selective disadvantage for Related-incompatible trials is consistent with the proposal that an intact right hemisphere is necessary for activating and further processing word meanings/features/senses that are semantically more distant from the concept to which they relate (e.g., Beeman, 1998; Jung-Beeman, 2005). The Related-incompatible features in this study appear to be intermediate on a semantic distance continuum between the Related-compatible features, which are primed for both groups, and the quite loosely related metaphoric senses of polysemous words (Klepousniotou & Baum, 2005a, 2005b). These metaphoric senses are not reliably activated by non-brain-damaged older adults without a biasing context (Klepousniotou & Baum, 2005a), and are not activated by individuals with RHD even with biasing context (Klepousniotou & Baum, 2005b). Coulson and Wu (2005) recently suggested that the intact right hemisphere's contribution to semantic activation reflects a preferential involvement in coding thematically related information rather than semantic distance per se. However, this hypothesis is not clearly applicable to the current findings, and as such requires further testing.

The finding of decay/poor maintenance of activation of both types of features for adults with RHD is potentially compatible with other evidence implicating the intact right hemisphere in sustaining activation of subordinate, secondary, weakly related, and/or context-incompatible meanings of words (Abdullaev & Posner, 1997; Faust, M. & Chiarello, 1998; Faust, M.E. & Gernsbacher, 1996; Federmeier & Kutas, 1999; Richards & Chiarello, 1995; Titone, 1998; with the potential exception of metaphoric polysemies, Klepousniotou & Baum, 2005a, 2005b). The lack of accuracy priming at the Long ISI appears to be inconsistent with an RHD

suppression deficit. However, the suppression deficit account may not be applicable in the current investigation. The sentence contexts in this study were designed and validated to be neutral with respect to the mental image or representation of the critical noun; this was done because the original Atchley et al. (1999) task was single word-pair priming. A difficulty suppressing contextually irrelevant or incompatible meanings may only be manifest when the preceding context biases interpretation away from an alternate, and unintended, meaning. All prior evidence for lexical-level suppression deficit has come from studies with contexts of this sort (Fassbinder & Tompkins, 2001; Klepousniotou & Baum, 2005b; Tompkins et al., 2000). Indeed, this is essentially inherent in Gernsbacher's (1990) original notion of the suppression mechanism: that it acts to dampen meanings that are superfluous to a given context. If this reasoning is correct, it may explain other reported failures to find suppression deficits in adults with RHD, such as that in Klepousniotou and Baum's (2005a) word-pair-priming study. It would also remain to be determined whether the extent or degree of contextual bias would influence suppression function in adults with RHD. In the studies reporting RHD suppression deficit, the biasing contexts can be considered very strong, in that they rule out the unbiased interpretations or meanings of words.

Fast decay/rapid suppression of activation for Related-compatible semantic features was unanticipated for the NBD group, because in divided visual field conditions young adults demonstrate sustained priming for these features regardless of the visual field/hemisphere of initial stimulus presentation (Atchley et al., 1999) and because with central prime presentation, weakly related meanings remain active at long prime-target intervals (Becker, 1980; McRae & Boisvert, 1998). This unexpected finding cannot be assimilated easily by either of the two main extant proposals about age-related changes in hemispheric function. The Hemispheric Asymmetry Reduction in Older Age proposal (HAROLD; Cabeza, 2002) suggests that functions ascribed primarily to one hemisphere in younger individuals—especially frontal regions and memorial functions—may be more bilaterally mediated in older adults. As such its predictions are not clearly relevant to already bilateral functions like the maintenance of meaning activation for Related-compatible semantic features. Similarly, the Right Hemisphere Aging Hypothesis (Goldstein & Shelly, 1981) resurrected in recent years (Harvey & Butler, 2004; Orbel, Testa, & Ross, 2003), would not obviously predict changes for bilaterally supported processes. Perhaps more precise predictions of the occurrence or extent of age-related changes in hemispheric function would result if such proposals addressed factors other than the mere presence of functional asymmetries in younger individuals, such as the degree of, or extent of variability in, such asymmetries. Tompkins and Scharp (2006) recently outlined several other general problems with each of these proposals and much work is needed to generate and test more specific and powerful neuropsychological and neurophysiological accounts of cognitive ageing.

In light of this unexpected finding, it would have been beneficial to include a younger participant group in this study, both to evaluate the applicability of the Atchley and colleagues (1999) results to older adults, and to assess their replicability when primes are presented in ecologically valid conditions. A younger participant group could also provide a control with respect to other factors that might account for results that diverge from expectations. For example, priming effects in the current study might have been reduced relative to those in Atchley et al. because of differences in the overall context of the stimulus lists. Both studies incorporated both strongly and weakly related items. However, the “strongly related” items in Atchley and colleagues' study, whose items all had very weak associations, were probably much less strongly related than the prime-target pairs in this investigation's filler trials. In studies of college students, priming effects for weakly related items are generally decreased when weakly and strongly related prime-target pairs are mixed, as was done in this study (Becker, 1980; Canas, 1990). No such list effect was demonstrated in Howard's (1983) work with older adults, but that was a small investigation. However, it is not known whether list

effects of this sort are an issue for measures of accuracy priming, having been previously demonstrated only for RT priming.

RT performance

The group difference in raw RT was fully expected. The lack of RT priming was not, although accuracy priming in the absence of RT priming has also been reported for a study of context-alternative inferences (Tompkins et al., 2004). A number of factors can reduce the sensitivity of RT measures, including low overall accuracy and high RT variances. Accuracy was high in the current study, and RT variation was proportionally no larger than in prior studies in which priming has been observed. But RT variance for older adults is higher than that of the college student population that participated in Atchley et al. (1999) and other similar studies (Deary & Der, 2005; Der & Deary, 2006). Thus, the range of RTs in this study may have been sufficient to swamp small but real effects that were detected in the accuracy data.

It is also possible that activation of peripheral features like those investigated in this study is slowed in older age, yielding a boost for accuracy without RT facilitation. Slowed semantic activation has not been ruled out for adults with RHD (Fassbinder & Tompkins, 2001). More work is needed to understand the occurrence and interpretation of accuracy priming without RT priming, for older and/or brain-damaged adults.

Individual differences in performance

The accuracy data in this investigation were the source of noteworthy effects. Unfortunately, little in the current dataset offers seeds for hypothesising about the bases of inter-individual variations in these data. Neither accuracy nor accuracy priming correlated meaningfully with demographic or clinical variables for either group. Additionally, while sample sizes were small, there were no obvious differences in accuracy performance in relation to within-hemisphere lesion site for the RHD group. One individual with an extensive right frontal lesion made an unusually large number of lexical decision errors in the unrelated-word condition, responding more than 66% of the time that a real but unrelated target word was not a real word. This individual may have had difficulty retaining the task goal in memory (Duncan, 2005; Duncan, Emslie, Williams, Johnson, & Freer, 1996), responding primarily on the basis of prime–target relatedness rather than lexicality. However, another individual with a purely frontal lesion experienced no such difficulty. More participants with right frontal damage need to be studied to address this possibility.

Although tangential to the issues of interest in this study, there were a few meaningful correlations with raw RTs for the group with RHD. Specifically, more severe visual-perceptual and attentional difficulties were associated with longer reaction times, as was a lower estimated working memory capacity for language. These correlations probably reflect general effects of lesion size on RTs and as such are uninteresting for the present purposes. There were no meaningful associations with the RT priming measure for participants with RHD, and no meaningful correlations for either RT dependent measure for the NBD group.

Conclusions and implications

Lexical decision accuracy data indicate that both participant groups activated (primed) two types of weakly related semantic features of unambiguous nouns shortly after those nouns were presented. Inconsistent with predictions based on Atchley et al. (1999), neither group evidenced continuing activation for either type of feature at a longer interval after presentation of the unambiguous noun. These results are interpreted as reflecting rapid decay/poor maintenance of activation for peripheral/distantly related features for both groups. It is suggested that the experimental conditions were probably not appropriate to test for previously reported

suppression deficits after RHD, in that the stimulus sentences were unbiased towards either type of feature.

Concerning the early activation of these peripheral features, the group with RHD was less accurate than the control group for only the features that could be considered semantically more distant from their associated nouns (Related-incompatible features). This result is potentially consistent with previous reports that adults with RHD do not activate particularly loosely-related meanings of words (Klepousniotou & Baum, 2005a, 2005b) and may initially activate meanings based on their frequency of occurrence, from higher to lower (Grindrod & Baum, 2003). It remains to be determined whether the current results would be replicated, amplified, or refuted with stimuli that represent other parameters postulated to reflect hemispheric differences in lexical-semantic processing.

The interpretation of results from this study is complicated by the lack of RT priming for either type of semantic feature, and for either participant group. This unexpected finding may reflect slower activation of peripheral features, increased performance variability, and/or differing processing algorithms in older age than in the typically studied college student population.

Lexical processing deficits after RHD in adults have been linked with discourse comprehension difficulties (e.g., Beeman, 1998; Tompkins et al., 2000). It is hoped that a better understanding of lexical processing in this group will eventually lead to better assessment and management of comprehension disorders in individuals with RHD.

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References

- Atchley RA, Burgess C, Keeney M. The effect of time course and context on the facilitation of semantic features in the cerebral hemispheres. *Neuropsychology* 1999;13:389–403. [PubMed: 10447300]
- Abdullaev YG, Posner MI. Time course of activating brain areas in generating verbal associations. *Psychological Science* 1997;8(1):56–59.
- Balota, DA.; Cortese, MJ.; Hutchison, KA.; Neely, JH.; Nelson, D.; Simpson, GB., et al. Washington University; 2002. The English Lexicon Project: A web-based repository of descriptive and behavioral measures for 40,481 English words and nonwords. <http://ellexicon.wustl.edu/>
- Becker CA. Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory and Cognition* 1980;8:493–512.
- Beeman, M. Coarse semantic coding and discourse comprehension. In: Beeman, M.; Chiarello, C., editors. *Right hemisphere language comprehension: Perspectives from cognitive neuroscience*. Hillsdale NJ: Lawrence Erlbaum Associates Inc; 1998. p. 255-284.
- Benton, AL.; Hamsher, K.; Varney, NR.; Spreen, O. *Visual form discrimination*. New York: Oxford University Press; 1983.
- Burgess C, Simpson GB. Cerebral hemispheric mechanisms in the retrieval of ambiguous word meanings. *Brain and Language* 1988;33:86–103. [PubMed: 3342321]
- Cabeza R. Hemispheric asymmetry reduction in older adults: The HAROLD model. *Psychology & Aging* 2002;17(1):85–100. [PubMed: 11931290]
- Canas JJ. Associative strength effects in the lexical decision task. *Quarterly Journal of Experimental Psychology, A* 1990;42(1):121–145.
- Chiarello, C. Parallel systems for processing language: Hemispheric complementarity in the normal brain. In: Banich, MT.; Mack, M., editors. *Mind, brain, & language: Multidisciplinary perspectives*. Mahwah, NJ: Lawrence Erlbaum Associates Inc; 2003. p. 229-247.

- Chiarello C, Kacinik N, Shears C, Arambel S, Halderman L, Robinson C. Exploring cerebral asymmetries for the verb generation task. *Neuropsychology* 2006;20(1):88–104. [PubMed: 16460225]
- Chiarello C, Liu S, Shears C, Quan N, Kacinik N. Priming of strong semantic relations in the left and right visual fields: A time-course investigation. *Neuropsychologia* 2003;41(6):721–732. [PubMed: 12591029]
- Cohen, J. Statistical power analysis for the behavioral sciences. Vol. 2. Hillsdale, NJ: Lawrence Erlbaum Associates Inc; 1988.
- Coney J. The effect of associative strength on priming in the cerebral hemispheres. *Brain and Cognition* 2002;50(2):234–241. [PubMed: 12464192]
- Coulson S, Williams RF. Hemispheric asymmetries and joke comprehension. *Neuropsychologia* 2005;43(1):128–141. [PubMed: 15488912]
- Coulson S, Wu YC. Right hemisphere activation of joke-related information: An event-related brain potential study. *Journal of Cognitive Neuroscience* 2005;17(3):494–506. [PubMed: 15814008]
- Deary I, Der G. Reaction time, age, and cognitive ability: Longitudinal findings from age 16 to 63 years in representative population samples. *Aging, Neuropsychology, and Cognition* 2005;12(2):187–215.
- Der G, Deary I. Age and sex differences in reaction time in adulthood: Results from the United Kingdom Health and Lifestyle Survey. *Psychology & Aging* 2006;21(1):62–73. [PubMed: 16594792]
- Duncan, J. Task models in prefrontal cortex. In: Mayr, U.; Awh, E.; Keele, S., editors. *Developing individuality in the human brain: A tribute to Michael I. Posner*. Washington, DC: American Psychological Association; 2005. p. 87-108.p. xiiip. 273
- Duncan J, Emslie H, Williams P, Johnson R, Freer C. Intelligence and the frontal lobe: The organization of goal-directed behavior. *Cognitive Psychology* 1996;30(3):257–303. [PubMed: 8660786]
- Dunn, L.; Dunn, L. *Peabody Picture Vocabulary Test – Revised*. Circle Pines, MN: American Guidance Service; 1981.
- Fassbinder W, Tompkins C. Slowed lexical-semantic activation in individuals with right hemisphere brain damage? *Aphasiology* 2001;15(1011):1079–1090.
- Fassbinder W, Tompkins C. Hemispheric differences in word-meaning processing: Alternative interpretations of current evidence. *Aphasiology* 2006;20(234):110–122. [PubMed: 20054427]
- Faust M, Chiarello C. Sentence context and lexical ambiguity resolution by the two hemispheres. *Neuropsychologia* 1998;36:827–835. [PubMed: 9740356]
- Faust ME, Gernsbacher MA. Cerebral mechanisms for suppression of inappropriate information during sentence comprehension. *Brain and Language* 1996;53:234–259. [PubMed: 8726535]
- Federmeier KD, Kutas M. Right words and left words: Electrophysiological evidence for hemispheric differences in meaning processing. *Cognitive Brain Research* 1999;8:373–392. [PubMed: 10556614]
- Folstein MR, Folstein SE, McHugh PR. Mini-Mental State: A practical guide for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research* 1975;12:189–198. [PubMed: 1202204]
- Gernsbacher, MA. *Language comprehension as structure building*. Hillsdale, NJ: Lawrence Erlbaum Associates Inc; 1990.
- Goldstein G, Shelly C. Does the right hemisphere age more rapidly than the left? *Journal of Clinical Neurology* 1981;3(1):65–78.
- Grindrod CM, Baum SR. Sensitivity to local sentence context information in lexical ambiguity resolution: Evidence from left- and right-hemisphere-damaged individuals. *Brain and Language* 2003;85:5003–5023.
- Harford ER, Dodds E. Hearing status of ambulatory senior citizens. *Ear & Hearing* 1982;3(3):105–109. [PubMed: 7095317]
- Harvey, M.; Butler, SH. Aging affects perceptual and eye-movement biases apparent in chimeric face processing. 2004. Abstract retrieved 4 April 2005, from <http://www.perceptionweb.com/perception/ecvp04/0225.html>
- Hino Y, Lupker SJ, Sears CR. The effects of word association and meaning frequency in a cross-modal lexical decision task: Is the priming due to “semantic” activation? *Canadian Journal of Experimental Psychology* 1997;51:195–211.

- Howard DV. The effects of aging and degree of association on the semantic priming of lexical decisions. *Experimental Aging Research* 1983;9:145–151. [PubMed: 6641773]
- Jung-Beeman M. Bilateral brain processes for comprehending natural language. *Trends in Cognitive Science* 2005;9(11):512–518.
- Klepousniotou E, Baum SR. Unilateral brain damage effects on processing homonymous and polysemous words. *Brain & Language* 2005a;93(3):308–326. [PubMed: 15862856]
- Klepousniotou E, Baum SR. Processing homonymy and polysemy: Effects of sentential context and time-course following unilateral brain damage. *Brain & Language* 2005b;95(3):365–382. [PubMed: 16298667]
- Koivisto M. Categorical priming in the cerebral hemispheres: Automatic in the left hemisphere, postlexical in the right hemisphere? *Neuropsychologia* 1998;36(7):661–668. [PubMed: 9723937]
- Lehman M, Tompkins C. Reliability and validity of an auditory working memory measure: Data from elderly and right-hemisphere damaged adults. *Aphasiology* 1998;12(7–8):771–785.
- McRae K, Boisvert S. Automatic semantic similarity priming. *Journal of Experimental Psychology: Learning Memory and Cognition* 1998;24:558–572.
- Nelson, DL.; McEvoy, CL.; Schreiber, TA. The University of South Florida word association, rhyme, and word fragment norms. 1998. Retrieved 5 February 2004, from <http://www.usf.edu/FreeAssociation/>
- Orbela DM, Testa JA, Ross ED. Age-related impairments in comprehending affective prosody with comparison to brain-damaged subjects. *Journal of Geriatric Psychiatry and Neurology* 2003;16(1):44–52. [PubMed: 12641373]
- Richards L, Chiarello C. Depth of associated activation in the cerebral hemispheres: Mediated versus direct priming. *Neuropsychologia* 1995;33:171–179. [PubMed: 7746362]
- Schneider, W.; Eschman, A.; Zuccolotto, A. E-prime user's Guide. Pittsburgh, PA: Psychology Software Tools Inc; 2002.
- Simpson GB, Burgess C. Activation and selection processes in the recognition of ambiguous words. *Journal of Experimental Psychology: Human Perception & Performance* 1985;11:28–39.
- Titone D. Hemispheric differences in context sensitivity during lexical ambiguity resolution. *Brain and Language* 1998;65:361–394. [PubMed: 9843609]
- Tompkins CA, Baumgaertner A, Lehman MT, Fassbinder W. Mechanisms of discourse comprehension impairment after right hemisphere brain damage: Suppression in lexical ambiguity resolution. *Journal of Speech Language & Hearing Research* 2000;43(1):62–78.
- Tompkins CA, Bloise CGR, Timko ML, Baumgaertner A. Working memory and inference revision in brain-damaged and normally aging adults. *Journal of Speech and Hearing Research* 1994;37:896–912. [PubMed: 7967574]
- Tompkins CA, Fassbinder W, Lehman Blake M, Baumgaertner A, Jayaram N. Inference generation during text comprehension by adults with right hemisphere brain damage: Activation failure versus multiple activation. *Journal of Speech Language & Hearing Research* 2004;47(6):1380–1395.
- Tompkins, CA.; Scharp, VL. Hemispheric specialization. In: Schulz, R.; Noelker, L.; Rockwood, K., editors. *Encyclopedia of aging*. Vol. 4. New York: Springer Publishing Company; 2006.
- Wilson, B.; Cockburn, J.; Halligan, P. Behavioural Inattention Test. Titchfield, UK: Thames Valley Test Company; 1987.
- Wu M, Carmichael O, Carter CS, Figurski JL, Lopez-Garcia P, Aizenstein HJ. Quantitative comparison of neuroimage registration by AIR, SPM, and a fully deformable model. *Human Brain Mapping* 2006;27(9):747–754. [PubMed: 16463385]
- Yochim B, Kender R, Abeare C, Gustafson A, Whitman R. Semantic activation within and across the cerebral hemispheres: What's left isn't right. *Laterality* 2005;10(2):131–148. [PubMed: 15849028]

TABLE 1

Demographic and clinical characteristics of two participant groups

Characteristics	RHD (N = 28)	NBD (N = 38)
<i>Age (years)</i>		
Mean (SD)	64.4 (10.6)	60.0 (9.5)
Range	42–79	45–84
Gender		
Male	15	19
Female	13	19
<i>Education (years)</i>		
Mean (SD)	14.3 (3.1)	13.9 (2.2)
Range	9–22	12–20
<i>Lesion site (from CT/MRI report)</i>		<i>Not applicable</i>
Right cortical anterior	2	
Right cortical posterior	1	
Right cortical mixed	2	
Right subcortical	9	
Right cortical + subcortical	7	
Right MCA	7	
<i>Lesion type (from medical records)</i>		<i>Not applicable</i>
Thromboembolic	16	
Lacunar	2	
Haemorrhagic	10	
<i>Months post-onset</i>		<i>Not applicable</i>
Mean (SD)	59.1 (51.3)	
Range	4–167	
<i>Vocabulary Recognition (PPVT-R)^a</i>		
Mean (SD)	156.7 (11.7)	162.9 (11.1)
Range	132–173	115–174
<i>*Auditory Working Memory for Language^b</i>		
Word recall errors		
Mean (SD)	12.9 (6.8)	5.0 (4.6)
Range	1–25	0–16
<i>*Behavioural Inattention Test^c</i>		
Mean (SD)	137.8 (13.1)	144.0 (2.8)
Range	85–146	133–146
<i>*Visual Form Discrimination^d</i>		
Mean (SD)	28.5 (3.4)	30.3 (2.2)
Range	20–32	24–32
<i>*Judgement of Line Orientation^e</i>		
Mean (SD)	22.6 (5.4)	27.1 (4.2)

Characteristics	RHD (<i>N</i> = 28)	NBD (<i>N</i> = 38)
Range	9–30	16–33

RHD = right hemisphere brain damage; NBD = non-brain damaged.

* significant group difference ($p < .05$)

^a PPVT-R = Peabody Picture Vocabulary Test—Revised. Dunn & Dunn (1981; maximum = 175).

^b Tompkins et al. (1994; maximum errors = 42).

^c B. Wilson, Cockburn, and Halligan (1987; maximum = 146; neglect cut-off = 129).

^d Benton, Hamsher, Varney, and Spreen (1983; maximum = 32).

^e Benton et al. (1983; age and gender corrected score; maximum = 35).

TABLE 2

Accuracy and RT data (means, *SD*) for three types of lexical decision targets, by group and ISI

	RHD	NBD
Accuracy		
<i>Related-compatible semantic features^a</i>		
Short ISI	15.85 (0.46)	15.89 (0.31)
Long ISI	15.56 (0.89)	15.76 (0.633)
<i>Related-incompatible semantic features^b</i>		
Short ISI	15.59 (0.69)	15.82 (0.39)
Long ISI	15.26 (0.81)	15.76 (0.43)
<i>Unrelated words</i>		
Short ISI	14.69 (2.63)	15.39 (0.75)
Long ISI	15.04 (2.34)	15.58 (0.72)
Accuracy priming ^c		
<i>Related-Compatible/Unrelated</i>		
Short ISI	1.05 (.01)	1.04 (.10)
Long ISI	1.01 (.01)	1.01 (.01)
<i>Related-incompatible/Unrelated</i>		
Short ISI	1.04 (.01)	1.03 (.01)
Long ISI	0.99 (.01)	1.01 (.01)
RT (ms)		
<i>Related-compatible semantic features^a</i>		
Short ISI	693 (287)	417 (125)
Long ISI	701 (277)	387 (101)
<i>Related-incompatible semantic features^b</i>		
Short ISI	670 (265)	390 (124)
Long ISI	699 (297)	379 (119)
<i>Unrelated words</i>		
Short ISI	634 (264)	379 (110)
Long ISI	619 (276)	362 (130)
RT priming ^d		
<i>Related-compatible RT/Unrelated RT</i>		
Short ISI	1.11 (0.17)	1.11 (0.18)
Long ISI	1.16 (0.14)	1.12 (0.20)
<i>Related-incompatible RT/Unrelated RT</i>		
Short ISI	1.06 (0.13)	1.03 (0.13)
Long ISI	1.15 (0.15)	1.09 (0.21)

RT = Response time; RHD = Right-hemisphere-damaged; NBD = Non-brain-damaged; ISI = interstimulus interval.

^a e.g., *crunchy* (for apple).^b e.g., *rotten* (for apple).

^c priming = proportion >1.0.

^d priming = proportion <1.0.

TABLE 3

Statistics and effect-size results for two-way ANOVAs (Group by ISI)

	F(df)	p	Partial eta-squared
Accuracy			
<i>Related-compatible semantic features^a</i>			
Group main effect	0.78 (1, 64)	.380	.01
ISI main effect	8.96 (1, 64)	.004	.12
Group by ISI	1.22 (1, 64)	.273	.02
<i>Related-incompatible semantic features^b</i>			
Group main effect	8.10 (1, 64)	.000	.11
ISI main effect	5.55 (1, 64)	.022	.08
Group by ISI	2.87 (1, 64)	.095	.04
Accuracy priming ^c			
<i>Related-compatible/Unrelated</i>			
Group main effect	0.38 (1, 63)	.539	.01
ISI Main effect	11.79 (1, 63)	.001	.16
Group by ISI	1.36 (1, 63)	.249	.02
<i>Related-incompatible/Unrelated</i>			
Group main effect	0.62 (1, 63)	.435	.01
ISI main effect	10.29 (1, 63)	.002	.14
Group by ISI	2.40 (1, 63)	.126	.04
RT (ms)			
<i>Related-compatible semantic features^a</i>			
Group main effect	37.06 (1, 63)	.000	.37
ISI main effect	0.64 (1, 63)	.427	.01
Group by ISI	1.89 (1, 63)	.174	.03
<i>Related-incompatible semantic features^b</i>			
Group main effect	35.94 (1, 63)	.000	.36
ISI main effect	0.25 (1, 63)	.617	.00
Group by ISI	1.93 (1, 63)	.169	.03
RT priming ^d			
<i>Related-compatible RT/Unrelated RT</i>			
Group main effect	0.09 (1, 60)	.762	.00
ISI main effect	0.92 (1, 60)	.341	.02
Group by ISI	0.29 (1, 60)	.594	.01
<i>Related-incompatible RT/Unrelated RT</i>			
Group main effect	2.50 (1, 60)	.119	.04
ISI main effect	5.92 (1, 60)	.018	.09
Group by ISI	0.36 (1, 60)	.550	.01

RT = Response time; RHD = Right-hemisphere-damaged; NBD = Non-brain-damaged; ISI = interstimulus interval.

^a e.g., *crunchy* (for apple).

^b e.g., *rotten* (for apple).

^c priming = proportion >1.0.

^d priming = proportion <1.0.

APPENDIX

EXPERIMENTAL SENTENCES WITH CORRESPONDING TARGET WORDS

Experimental sentence	Related-compatible	Related-incompatible	Unrelated
He has an <i>apple</i>	crunchy	rotten	mermaid
He was concerned about the <i>airplane</i>	window	captain	simple
He has a <i>cabin</i>	chimney	cramped	teammate
He had a <i>car</i>	gas	hood	sweet
He visited the <i>castle</i>	dungeon	royal	powder
He drank some <i>coffee</i>	bitter	beans	needle
I saw the <i>cotton</i>	ball	field	wife
She used the <i>garlic</i>	bulb	powder	lamp
He liked the <i>milkshake</i>	smooth	calories	medicine
There is the <i>mustard</i>	spicy	plant	prison
He moved the <i>oak</i>	branches	furniture	calories
He ate the <i>potatoes</i>	skin	fluffy	shiny
She didn't like the <i>rice</i>	sticky	bland	glove
Here is a <i>shirt</i>	pocket	wrinkled	parsley
He inspected the <i>sofa</i>	leather	springs	rocket
She spit out the <i>milk</i>	warm	spoiled	knife