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Coarse coding and discourse comprehension in adults with right hemisphere brain damage

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Abstract

Background—Various investigators suggest that some discourse-level comprehension difficulties in adults with right hemisphere brain damage (RHD) have a lexical-semantic basis. As words are processed, the intact right hemisphere arouses and sustains activation of a wide-ranging network of secondary or peripheral meanings and features—a phenomenon dubbed “coarse coding”. Coarse coding impairment has been postulated to underpin some prototypical RHD comprehension deficits, such as difficulties with nonliteral language interpretation, discourse integration, some kinds of inference generation, and recovery when a reinterpretation is needed. To date, however, no studies have addressed the hypothesised link between coarse coding deficit and discourse comprehension in RHD.

Aims—The current investigation examined whether coarse coding was related to performance on two measures of narrative comprehension in adults with RHD.

Methods & Procedures—Participants were 32 adults with unilateral RHD from cerebrovascular accident, and 38 adults without brain damage. Coarse coding was operationalised as poor activation of peripheral/weakly related semantic features of words. For the coarse coding assessment, participants listened to spoken sentences that ended in a concrete noun. Each sentence was followed by a spoken target phoneme string. Targets were subordinate semantic features of the sentence-final nouns that were incompatible with their dominant mental representations (e.g., “rotten” for apple). Targets were presented at two post-noun intervals. A lexical decision task was used to gauge both early activation and maintenance of activation of these weakly related semantic features. One of the narrative tasks assessed comprehension of implied main ideas and details, while the other indexed high-level inferencing and integration. Both comprehension tasks were presented auditorily. For all tasks, accuracy of performance was the dependent measure. Correlations were computed within the RHD group between both the early and late coarse coding measures and the two discourse measures. Additionally, ANCOVA and independent *t*-tests were used to compare both early and sustained coarse coding in subgroups of good and poor RHD comprehenders.

Outcomes & Results—The group with RHD was less accurate than the control group on all measures. The finding of coarse coding impairment (difficulty activating/sustaining activation of a word’s peripheral features) may appear to contradict prior evidence of RHD suppression deficit (prolonged activation for context-inappropriate meanings of words). However, the sentence contexts in this study were unbiased and thus did not provide an appropriate test of suppression function. Correlations between coarse coding and the discourse measures were small and nonsignificant. There were no differences in coarse coding between RHD comprehension subgroups on the high-level inferencing task. There was also no distinction in early coarse coding for subgroups based on comprehension of implied main ideas and details. But for these same subgroups, there was a

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difference in sustained coarse coding. Poorer RHD comprehenders of implied information from discourse were also poorer at maintaining activation for semantically distant features of concrete nouns.

Conclusions—This study provides evidence of a variant of the postulated link between coarse coding and discourse comprehension in RHD. Specifically, adults with RHD who were particularly poor at *sustaining* activation for peripheral semantic features of nouns were also relatively poor comprehenders of implied information from narratives.

Right hemisphere brain damage (RHD) in adults can markedly impair discourse-level comprehension. Comprehension difficulties are especially evident when messages contain ostensible ambiguity or explicit conflict, and thus induce multiple competing inferences or interpretations (Joanette, Goulet, & Hannequin, 1990; Malloy, Brownell, & Gardner, 1990; Tompkins, 1995; Tompkins, Baumgaertner, Lehman, & Fassbinder, 2000; Tompkins, Fassbinder, Lehman-Blake, & Baumgaertner, 2002). Some bridging inferences that are necessary for discourse coherence may also be particularly difficult for adults with RHD (e.g., Beeman, 1993; but see also Tompkins, Fassbinder, Blake, Baumgaertner, & Jayaram, 2004).

A number of authors have postulated that such difficulties can be traced, at least in part, to underlying deficits in lexical-semantic processing (e.g., Beeman, 1993, 1998; Brownell & Martino, 1998; Richards & Chiarello, 1995). This view stems primarily from a large body of work indicating that the intact right cerebral hemisphere arouses and sustains a rather diffuse network of remote associates and secondary meanings of words as they are processed, while the intact left hemisphere quickly focuses initial meaning activation to a narrow range of dominant interpretations and/or strong associates (e.g., Atchley, Burgess, & Keeney 1999; Burgess & Lund, 1998; Burgess & Simpson, 1988; Chiarello, 1998; M.A. Faust & Chiarello, 1998; M.E. Faust & Gernsbacher, 1996; Nakagawa, 1991). This widespread right hemisphere lexical-semantic activation, or “coarse coding” (Beeman, 1993, 1998; Jung-Beeman, 2005), is hypothesised to underpin nonliteral language interpretation, discourse integration, some kinds of inference generation, and recovery when a reanalysis is required (Anaki, Faust, & Kravetz, 1998; Beeman et al., 1994; Beeman, Bowden, & Gernsbacher, 2000; Burgess & Chiarello, 1996; Richards & Chiarello, 1995; Titone, 1998). For instance, Beeman (1993, 1998) proposed that RHD renders individuals unable to compute inferences that support discourse coherence because these individuals do not activate the range of distant semantic relations that support such inferences (although see Tompkins et al., 2004, for competing evidence and interpretation).

The “coarse coding impairment” hypothesis quickly gained traction in the RHD comprehension literature, and a presumed deficiency in right hemisphere lexical-semantic processing activity has often been invoked post hoc to account for interpretive deficits exhibited by adults with RHD (e.g., Beeman, 1998; Beeman et al., 1994; Brownell, 2000; Hagoort, Brown, & Swaab, 1996; McDonald et al., 2005). Yet the relation of lexical-semantic processing to comprehension problems in adults with RHD has been investigated in only three studies (Tompkins et al., 2000, 2004; Tompkins, Lehman-Blake, Baumgaertner, & Fassbinder, 2001), and to date no research has addressed the postulated connection between “coarse coding impairment” and discourse comprehension in RHD. This study begins to fill that gap.

Some recent work has raised questions about whether RHD does indeed result in coarse coding deficits at the lexical-semantic level (e.g., Klepousniotou & Baum, 2005a, 2005b; Tompkins et al., 2000, 2004). However, results consistent with a coarse coding impairment have also been obtained. For example, adults with RHD did not prime for metaphoric interpretations of polysemous words (Klepousniotou & Baum, 2005a, 2005b), suggesting a difficulty in activating particularly peripheral meanings of lexical items. Hagoort et al. (1997) reported a trend towards impaired processing of distantly related word pairs (members of the same category that were unassociated) but not of closely related pairs (associated words) by adults with RHD. In addition, a reliable RHD group deficit was obtained on an index of activation of peripheral semantic features (Tompkins, Fassbinder, Scharp, & Meigh, 2008 this issue).

In the current investigation, performance on the Tompkins et al. (2008 this issue) measure of peripheral semantic feature activation is taken as an indicator of "coarse coding" facility in adults with RHD, and is related to two measures of discourse comprehension. The first is performance on the Implied questions of the Discourse Comprehension Test (Brookshire & Nicholas, 1993), a standardised and reliable test of narrative comprehension. The second is an index of narrative comprehension on texts that assess high-level inferencing (Winner, Brownell, Happe, Blum, & Pincus, 1998). These stimuli contain overt contradictions and support competing interpretations. As such, they require cognitive processes related to coherence inferencing, reanalysis, and discourse integration and could be postulated to be susceptible to coarse coding impairment. The hypothesis for this study is that for a group of adults with RHD, individual variation in "coarse coding" facility will predict comprehension performance on these two narrative measures.

METHOD

Participants

A total of 70 adults participated in this study, of whom 32 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, but the group with RHD was reliably poorer on vocabulary recognition, comprehension of cleft object sentences, and various clinical/neuropsychological measures.

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.

Experimental tasks and measures

Assessment of coarse coding—To generate a measure of coarse coding, participants performed a task derived from Atchley and colleagues (1999), as described in prior research on lexical processing by adults with RHD (Tompkins et al., 2008 this issue). In this task, participants listened to simple spoken sentences that each culminated in a concrete noun (e.g., He has an apple). Each sentence was followed by a spoken target phoneme string at a Short and Long interstimulus interval (ISI; 175 and 1000 ms from sentence-final noun offset, respectively). Rationales for the two ISIs are provided below. Targets included three categories 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 representation of the noun; and (c) unrelated words (e.g., "*mermaid*"). Activation for these features and words 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 filler sentences.

The two types of subordinate feature targets were generated in a task in which 100 undergraduate students were shown 56 nouns in sequence, and given 1.5 minutes per noun to list as many features of that noun as they could (Atchley et al., 1999). Cues were provided to encourage the students to list both perceptual and functional features. "Subordinate features" were those that were listed by 10–24% of this sample. To determine subordinate feature compatibility with the nouns, five graduate student raters completed two tasks. First, when provided with each noun and its dominant feature (the one the undergraduate sample listed most frequently for that noun), they were asked to form a representation or mental image of the noun. Second, these five raters were given four to eight words per noun that met the subordinate feature criterion, and asked to rate on a scale from 1–7 (7 = highlycompatible) how compatible each subordinate feature was with their mental of the noun. Inter-rater reliability was high. Atchley and colleagues defined "compatible" subordinate features as those that were rated 6 or 7 by all raters (e.g., "crunchy" for apple), and "incompatible" subordinate features as those that were rated 1 or 2 by all raters (e.g., "rotten" for apple).

Tompkins and colleagues (2008 this issue) inserted each noun into a brief sentence frame, as exemplified above. The sentences were developed to be neutral, i.e., without differential bias towards the compatible or incompatible subordinate features. The bias equivalence of these sentences was validated by as follows. Sociodemographically appropriate judges ($N = 25$) were presented with each sentence, and were told that it was "the beginning of a sentence" (e.g., "He has an apple ..."). In addition, they were provided with several possible phrases "that could complete the sentence". These raters judged on a 4-point scale how well each phrasal completion "makes sense" as an ending (0 = makes no sense at all; 4 = makes complete sense). The phrasal completions specified compatible subordinate features (e.g., "... that is crunchy"), incompatible subordinate features (e.g., "... that is rotten"), and various foils (e.g., "that is blue", "that is red"). A total of 16 sentence stimuli met the bias equivalence criterion (ratings for the paired "compatible" and "incompatible" completions were never more than 1 point apart for any rater; mean ratings for both feature types were within 0.25 of each other). This subset of Atchley and colleagues' stimulus words retained critical controls that characterised their larger stimulus set. Specifically, neither type of subordinate feature was associated with its sentence-final noun (Nelson, McEvoy & Schreiber, 1998) and real-word targets were equated on a range of lexical characteristics, across categories (related-compatible, related-incompatible, unrelated).

Performance on the 16 Related-incompatible feature trials provided the basis for generating a measure of coarse coding for Tompkins et al. (2008 this issue). As calculated from a large database of semantic distance norms (Maki, McKinley, & Thompson, 2004) the words representing these features are relatively semantically distant from their corresponding nouns (M = 15.6 vs M = 9.8 for the "related-compatible" subordinate features, where "0" = complete semantic overlap).

The Short ISI between sentence offset and target onset in Tompkins et al. (2008 this issue) was included to assess early, relatively automatic meaning activation of each noun's subordinate features. At this ISI, a group of 28 adults with RHD was less accurate than a NBD control group (the same control participants as in this study) in making lexical decisions to words that represent the semantically distant, Related-incompatible trials. No such difference was evident for the Related-compatible or Unrelated trials. This result suggests that adults with RHD may not activate particularly distantly related meanings of words (as reported for lexical metaphor, Klepousniotou & Baum, 2005a,2005b). Thus, in the current study, performance on Related-incompatible trials at the Short ISI will be used to capture the concept of coarse coding impairment in initial meaning activation.

At the Long ISI, the same measure was also used to gauge coarse coding, and the group with RHD was again less accurate than the NBD control group. This processing point is important because it may be the intact right hemisphere's preferential *maintenance* of activation for semantically distant features that underlies the ability to compute discourse coherence, draw inferences, resolve ambiguity, revise interpretations, and the like (Beeman, 1998; Brownell, 2000; McDonald et al., 2005). In addition, discourse comprehension difficulty in adults with RHD has been linked with meaning modulation deficits at this longer time interval (Tompkins et al., 2000, 2001, 2004), although poorer comprehension was related to abnormally prolonged maintenance of activation for contextually inappropriate alternatives, rather than lack of activation. Thus, in the current study, coarse coding will be evaluated for Long ISI trials, as well.

Assessment of discourse comprehension

DCT-implied questions: The first comprehension measure was derived from the Discourse Comprehension test (Brookshire & Nicholas, 1993), a standardised test of narrative comprehension with good psychometric properties. The five stimuli from Set A were administered (see Appendix A for an example). Audio recorded for this study, the story stimuli averaged 63.2 seconds in duration. The texts depict "humorous situations that would be familiar to most adults in America" (p. 6). Story stimuli are 14 sentences long and extensively controlled for other structural variables, including number of words (M = 205.6, range 197–210), number of subordinate clauses (M = 9, range = 8–10), and ratio of clauses to T-units (M = 1.6, range 1.5–1.7). On average only 1.8 words per passage (range 0–3) are designated "unfamiliar" (i.e., not among the 10,000 most frequent words in printed English—Carroll, Davies, & Richman, 1971—excluding proper names). The stories were relatively "easy" in listening difficulty, per the Easy Listening Formula (Fang, 1966) that tracks the number of syllables beyond one per sentence.

Each narrative was followed by eight spoken Yes/No questions about either directly stated or implied main ideas and details (see Appendix A). The questions range from 4 to 13 words in length (M = 7.8) and contain no unfamiliar words. They are controlled for ratio of clauses to T-Units (M = 1.0, range 1–2) and characterised for passage dependency, or the extent to which the questions rely on information from the text, rather than from world knowledge, to be answered correctly (Tuiman, 1974; M = 0.45, range = 0.35–0.59). The dependent measure for this study was total accuracy on the "implied" questions (4 per story, maximum = 20). These were considered most relevant for assessing the relation between coarse coding and comprehension in adults with RHD. Bridging inferences were required in order to answer the “implied” questions accurately.

High-level inference questions: The second comprehension measure was selected to gauge typical RHD difficulties with input that promotes or induces competing interpretations (Joanette et al., 1990; Malloy et al., 1990; Tompkins, 1995; Tompkins et al., 2000, 2002). Winner and colleagues (1998) developed a set of narratives that engender differing interpretations when a character’s comment contradicts an established fact. Adults with RHD had particular difficulty answering some high-level inference questions about these texts. The stimuli were intended to evaluate mental attributions or “theory of mind” processing. However, we agree with Brownell and Friedman (2001) that performance by the RHD group may be attributable to a more general high-level inference deficit, because the original study lacked an appropriate control condition to investigate non-theory-of-mind inferences. In any case, the stimuli contain overt contradictions and trigger competing interpretations. As such they require cognitive processes of interest in association to coarse coding in adults with RHD, including those related to coherence inferencing, reanalysis, and meaning integration.

The stimulus texts describe scenarios in which Character A, committing a transgression, is seen doing so by Character B (see Appendix B for a full example). For example, Jack, who is on a diet, is seen eating brownies by his wife Betty. The crucial manipulation in Winner and colleagues’ (1998) study was whether Jack knew he was seen. When confronted by his wife, the intent of Jack’s response depends on this knowledge. If unaware of being observed, his comment “I haven’t eaten anything fattening all day” is a white lie to avoid being caught. If he is aware, this same comment functions as an ironic joke, to mitigate his embarrassment. Two versions of each text (a Joke and a Lie version) differed only in the information that indicates Jack’s knowledge.

In the original study, the stories were presented in four segments, with a total of six Yes/No questions occurring both between segments and at the end of the story (see Appendix B). These questions were designed to probe comprehension at several levels of processing, and were identical across the two versions of a single text. They queried (1) stated facts (e.g., Did Jack eat some brownies?); (2) first-order beliefs (e.g., Did Betty realise Jack was eating a brownie?); (3) second-order beliefs (Jack’s friend asks: “Does Betty know you are breaking your diet?”); (4) second-order follow-ups (e.g., Did Jack think that what he told his friend was really true?); (5) second-order expectations (e.g., When Jack said that to Betty, did he think that Betty would believe him?); and (6) a final interpretation (e.g., was Jack “lying to avoid getting caught” or “joking to cover up his embarrassment”?).

Participants in this study listened to six of the original scenarios, each in a Joke and a Lie version. This subset of stimuli described only minor transgressions, like the example above. We modified the original interpretation question by splitting it into two parts, querying separately whether the character was joking or lying. To index High-level Inference in this study, two composite accuracy measures were generated, one each for Joke and Lie texts. These composite measures totalled accuracy on the second-order belief, second-order expectation, and follow-up questions. The composites (maximum score = 18) were constructed to provide a larger range of scores for correlation with the measures of coarse coding. Fact and first-order belief questions were excluded from these indices because participants with RHD in Winner et al. (1998) and in the current study had no difficulty with these questions, and interpretation questions were omitted due to an order effect in their presentation. The final dependent measure of High-level Inference was the composite accuracy measure for the Joke texts, because preliminary analysis indicated no group difference on the composite accuracy measure for the Lie stories.

Task construction—A practised female speaker audio recorded the sentence and text stimuli, and a practised male speaker the probe words, all at an average speaking rate of about 4 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). For the assessment of coarse coding, 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 lexical decision 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.

The 168 trials for the entire task were pseudorandomly arranged into 14 blocks of 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 “yes” or “no” responses in sequence within each block; and (5) each block began with at least two filler trials and ended with at least one filler.

For the DCT administration, a single trial consisted of a trial number followed by a 500-ms pause, the stimulus story, and 4 seconds between each of the eight comprehension questions. The questions were presented in the order prescribed in the text manual. The five stories were randomised by E-prime for presentation to each participant.

Finally, for the High-level Inference task, a single trial consisted of a trial number followed by a 500-ms pause, a portion of the stimulus story, a 500-ms pause, a comprehension question, and more of the story. This pattern continued until all four parts of the story had been played and the seven comprehension questions were answered. Durations between questions ranged from 2 seconds to 4.5 seconds, depending on question difficulty as inferred from the Winner et al. (1998) data. The six Joke and six Lie texts were combined with six filler stories, and pseudorandomly arranged into six blocks of three stories each, two experimental and one filler. One version of a text was maximally separated from its other version by at least one stimulus block (with a minimum of seven or more stories between versions) and at least one ancillary task from the clinical assessments listed in Table 1.

Experimental apparatus and procedures

All stimuli were delivered via a Dell Inspiron 5150 notebook computer, through high quality supraural earphones (Beyerdynamic DT150) at a comfortable loudness level selected by the participant via Quick Mixer v1.7.2. Participants responded to each target word or comprehension question 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, but only accuracy data are considered in the current study.

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 from which the coarse coding variables are derived. Participants were trained to indicate their 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. A response deadline (standard Windows bell) was included on a portion of the filler trials, to encourage rapid responding, but only the accuracy data are analysed for this study.

Participants also received practice on the discourse comprehension tasks. One example story stimulus with questions was administered live-voice, and one via E-Prime. Feedback was provided after all questions had been answered. On the High-level Inference task, the response deadline signal was included on one or two comprehension questions for each filler story. Again, for the current study, only the accuracy data are of interest.

Preliminary data analysis

A series of independent *t*-tests was computed separately for each group, to evaluate all demographic, clinical, and experimental variables for gender differences. None of these analyses was significant for the group with RHD. In the control group, males were more accurate than females on the DCT-Implied questions ($p < .05$), possibly due to the fact that in this group the males tended to be younger than the females ($p = .055$). But because this study focused on the link between lexical processing and discourse comprehension in adults with RHD, data were collapsed across males and females in the primary analyses, for both groups. To determine whether partial correlation or covariate analyses might be needed to assess the issues of principal interest, the experimental variables were also correlated with demographic and clinical variables for the group with RHD. The resulting univariate correlations were assessed against Cohen’s (1977) rule of thumb for a large effect size in the behavioural sciences ($\underline{r}$ > /0.5/). None of the correlations with the High-level Inference measure met this criterion. However, the correlation between DCT-Implied question accuracy and estimated working memory capacity for language (Tompkins et al., 1994; see Table 1) exceeded the effect size criterion, $r(32) = -.52$. This correlation indicates that better comprehenders in the RHD group made fewer word recall errors on the working memory measure, and as such had better estimated working memory capacity than poorer comprehenders.

RESULTS

Primary data analysis

Table 2 provides (a) group data on the coarse coding variables (accuracy, at Short and Long probe intervals, of lexical decisions to words representing semantic features that were incompatible with the dominant mental image of a noun, e.g., *rotten* for apple); (b) group data on both discourse comprehension measures; and (c) the results of independent *t*-tests assessing group differences on each of these variables. Alpha was set at .05 for all analyses. The group with RHD performed less well than the control group on all measures, confirming an overall group impairment in coarse coding and in the comprehension measures of interest.

Coarse coding and DCT-Implied question comprehension in adults with RHD

For the RHD data, Pearson correlations were computed between DCT-Implied question accuracy and the coarse coding variables. After partialling out estimated working memory capacity, the association was small at both Short, $r(32) = .31$; $p > .05$, and Long test points, $r(32) = .13$; $p > .05$. Neither correlation approached the effect size criterion or statistical significance.

To explore further the possibility of a connection between activation of distant semantic features and DCT-Implied question accuracy, subsets of the RHD group were created based on DCT-Implied performance, and then compared on the coarse coding variables. High RHD comprehenders were designated with reference to the control group's mean performance on DCT-Implied questions. Specifically, high RHD comprehenders achieved a score of at least 17 out of the 20 possible. Three different cut-points were used to contrast high and low RHD comprehenders. Contrast 1 preserved the most participants with a conservative division between individuals who scored 15 or below on DCT-Implied questions ($n = 14$) with those who scored 17 or above ($n = 12$). Contrast 2 was the most liberal distinction and thus most likely to reveal a difference, but with the fewest participants. It compared subgroups who scored 14 and below ($n = 10$) vs 18 and above ($n = 9$). Contrast 3 reflects a middle-ground comparison, of individuals who scored 14 and below ($n = 10$) with those who achieved 17 and above ($n = 12$).

Descriptive data on the coarse coding variables for each RHD comprehension subgroup contrast are provided in Table 3. Because there were significant differences between all high vs low comprehending subgroups in estimated working memory capacity for language, subgroup performance on the DCT-I questions was compared using Analysis of Covariance.

After covarying for working memory capacity, none of the Short ISI subgroup comparisons was significant (all $F < 0.21$; $p > .05$). There was, however, a significant difference between the Contrast 3 subgroups in coarse coding at the Long ISI, $F(1, 19) = 5.43$; $p < .05$. The poorer comprehenders of DCT-I questions averaged nearly a full point lower in lexical decision accuracy to words that represent remote features of nouns, 1000 ms after those nouns were heard. The same comparison approached significance for subgroup Contrast 1, $F(1, 23) = 4.02$; $p = .057$.

Independent *t*-tests on the variables included in Table 1 indicated that this difference in coarse coding for Contrast 3 comprehension subgroups was not attributable to age, education, vocabulary recognition, syntactic comprehension, immediate or delayed story memory, visual perception, or visual-spatial skill (all $t < /1.93/$; $p > .05$). Beyond the already noted distinction in estimated working memory capacity for language, there was a significant subgroup difference in visual attentional capacity/neglect, $t(20) = -2.16$, $p < .05$. Lesion data for the high and low comprehension subgroups (see Appendix C) suggest that parietal damage may be linked with coarse coding impairment and relatively poor comprehension of implied material in discourse. Of the 10 poor comprehenders, 6 had a lesion involving the parietal lobe. However, the other poor comprehenders included one participant with damage purely anterior to the Rolandic fissure, and at least one individual with parietal involvement was grouped with the high comprehenders.

Coarse coding and High-level Inference comprehension in adults with RHD

For assessing the connection between RHD coarse coding and accuracy on the index of High-level Inference the analyses were similar to those above, except there was no need to use partial or covariance analyses. Pearson correlation coefficients were small and nonsignificant when High-level Inference comprehension was correlated with the coarse coding variables at either the Short, $r(32) = 0.17$; $p > .05$, or Long, $r(32) = 0.22$; $p > .05$, probe intervals.

Only 6 of the 33 participants with RHD performed above the control group mean on the High-level Inference variable, so comprehension subgroups were developed by including approximately the top and bottom quartile of the RHD group distribution into high and low comprehension subgroups, respectively. The high RHD comprehenders ($n = 8$) scored at least 11 on the High-level Inference questions (total possible = 18), while the low RHD comprehenders ($n = 7$) scored 7 or below. Descriptive data on the coarse coding variables for each subgroup are included in Table 3. Independent *t*-tests indicated no significant differences in coarse coding between high and low RHD comprehenders at either the Short, $t(13) = -0.23$; $p > .05$, or the Long test interval, $t(13) = -0.50$; $p > .05$.

DISCUSSION

This study was conducted to determine whether coarse coding facility would predict specific aspects of or types of narrative-level comprehension by adults with RHD. Coarse coding function was indexed by the accuracy of lexical decisions to peripheral semantic features of concrete nouns (e.g., “rotten” for apple), at both short and long intervals after participants heard the nouns. One discourse measure (DCT-I) came from a standardised test, and gauges comprehension of implied information. The second discourse measure was derived from experimental texts that were developed to assess “theory of mind”, although a more general high-level inference deficit could not be ruled out as a reason for poor performance by adults with RHD.

The group of adults with RHD in this study performed more poorly than the NBD control group on all four of these measures. There were no significant or meaningful associations between the coarse coding and discourse measures for the RHD group as a whole and no reliable differences in coarse coding between subgroups of good and poor RHD comprehenders on the High-level Inference task. There was also no significant distinction in coarse coding at the short ISI for RHD comprehension subgroups on the DCT-I measure. However, even after covarying for estimated working memory capacity for language, high and low RHD comprehenders per the DCT-I differed in coarse coding at the Long ISI. Poorer RHD comprehenders were less accurate than better RHD comprehenders at making lexical decisions to semantically distant features of concrete nouns 1000 ms after they originally heard those nouns, but not 175 ms after the nouns. Thus poor comprehension of implied information by adults with RHD was related to poor *maintenance* of activation for peripheral features of nouns. This result is consistent with a postulated link between some form of coarse-coding impairment and some aspects or types of discourse comprehension (e.g., Beeman, 1998; Beeman et al., 1994, 2000; Brownell, 2000). However, it is inconsistent with the thesis that an *early* impairment of activation for distant semantic information (Beeman, 1993) underpins RHD discourse inference and integration deficits.

Lesion data for the poorer comprehenders of DCT-I questions suggest possible parietal correlates of their impairments in comprehension and in maintenance of activation for peripheral semantic features, although this possibility remains to be assessed with larger samples and more precise localising information. Left inferior parietal cortex has been argued to act as a phonological store, supporting short-lived activation (Becker, MacAndrew, & Fiez, 1999; Jonides et al., 1998). A homologous right hemisphere region might serve a similar function for lexical properties normally activated and maintained in the right hemisphere. It is worth noting that the maintenance function in question appears to be independent of the concept of maintenance that is an integral part of the active working memory functions supported by dorsolateral prefrontal cortex. The comprehension subgroup difference in maintenance of activation for distantly related semantic features was significant even after estimated working memory for language was taken into account.

The overall result indicating a RHD group maintenance deficit for peripheral features of nouns may appear to contradict prior reports of a “suppression deficit” for this group, evidenced by abnormally prolonged maintenance for some secondary (Klepousniotou & Baum, 2005b) and contextually inappropriate meanings of words (Fassbinder & Tompkins, 2001; Tompkins et al., 2000). However, because the nouns in this study were embedded in neutral sentences, the suppression deficit account may not apply (see Tompkins et al., 2008 this issue). Suppression acts to dampen meanings or features that are superfluous to a given context (Gernsbacher, 1990), and all prior evidence for lexical-level suppression deficit in adults with RHD has come from studies with contexts that bias interpretation away from an alternate, unintended meaning (Fassbinder & Tompkins, 2001; Klepousniotou & Baum, 2005b; Tompkins et al., 2000). More generally, as emphasised by Tompkins et al. (2000), suppression function is an individual difference variable, and even when “suppression deficit” characterises a group with RHD, many individuals in that group will not have a suppression deficit. The nature of a particular sample of participants in any study can easily tip the average performance toward one characterisation or another, and it remains critically important in group studies to assess individual differences in demographic, clinical/neuropsychological, and lesion characteristics to try to understand the variation underlying a group mean.

There are several possible reasons why poor maintenance of activation for peripheral semantic features was not linked with poor RHD comprehension on the High-level Inference measure, as it was on the DCT-I questions. Among these are differences in structural and representational properties of the two types of texts themselves; in presentation of the two comprehension tasks; and in the nature of the target inferences in the two tasks.

First, the High-level stimulus texts include more characters than the DCT-I texts. These characters enter and leave the active narrative representation and each takes turns speaking. In addition, the first character who is introduced is not always the protagonist or focus of the story overall, so the listener must override standard narrative processing assumptions. Furthermore, the High-level Inference stories, but not the DCT-I texts, end in a statement that is literally false and that contradicts earlier text material. In all, these structural/representational features trigger quite a variety of competing activations and integration requirements. In terms of task presentation, each of the High-level Inference texts is periodically interrupted by comprehension questions. As such, the listener must transfer out of the mental work that is involved in building an integrated representation of the narrative, take a metalinguistic stance to search that representation and answer the question, and then shift back into discourse construction and integration processes. The High-level Inference task also queries inferences about characters’ knowledge and beliefs, and as such may tap a social dimension that has distinct cognitive underpinnings from those that support structural discourse representation and integration (e.g., Brownell & Martino, 1998). For narratives with this combination of characteristics and demands, it is likely that operations beyond the lexical level are centrally involved. It remains for other work to determine the interplay of lexical-level and discourse-level processes that support narrative comprehension.

In sum, activation of distantly or loosely related meanings and features of words has been proposed to underpin nonliteral language interpretation, discourse integration, some kinds of inference generation, and recovery when a reanalysis is required (e.g., Anaki et al., 1998; Beeman et al., 1994, 2000; Burgess & Chiarello, 1996; Richards & Chiarello, 1997; Titone, 1998). The results of this study provide evidence of a variant of this hypothesis of the relation between coarse coding and discourse processing. That is, adults with RHD who are particularly poor comprehenders of implied information in discourse are also poor at *sustaining* activation for peripheral semantic features of nouns, relative to good RHD comprehenders. More work is needed to assess the neuroanatomic correlates of this finding and more generally to establish the experimental conditions and participant characteristics that are reliably associated with lexical-level maintenance and suppression deficits after RHD. Further study also will help to ascertain the specific aspects of discourse processing that suffer when sustained peripheral feature activation is impaired in adults with RHD, whether being abnormally brief (maintenance deficit) or abnormally prolonged (suppression deficit).

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APPENDIX A

Sample stimulus from Discourse Comprehension Test (Brookshire & Nicholas, 1993)

Sample story

Neil Williams was short of money. The new term was about to begin and he didn’t have enough money to pay his tuition. So, one day, he walked to his parents’ home and borrowed their car. Then he drove to the bank to get a student loan. The loan officer at the bank was a tough old woman who always said she had never made a bad loan. She questioned Neil about his grades, about his sources of income, and about his plans for a job when he graduated. Things looked grim for Neil, especially when the woman asked for collateral because all Neil had to offer was his old wreck of a car. Finally the woman said to him that she wasn’t convinced that he really needed the money. Neil thought hard. He had to convince the woman that he really did need the money. “Well,” he said, “For lunch today I had a macaroni sandwich.” The woman looked at him with surprise. Then she took out a form and began writing. Finally she looked at Neil and said, with a smile, “You obviously need a loan—or someone to cook for you.”

Comprehension questions (and correct answers)

Was Neil a high school student? (No, Implied main idea)

Did Neil’s parents live nearby? (Yes, Implied detail)

Did Neil go to the bank to get a loan? (Yes, Stated main idea)

Did Neil need the money to start a new business? (No, Stated main idea)

Did Neil own a car? (Yes, Stated detail)

Did Neil go to the bank in the morning? (No, Implied detail)

Did Neil tell the woman that he had a cheese sandwich for lunch? (No, Stated detail)

Did Neil get the loan? (Yes, Implied main idea)

APPENDIX B

Sample stimulus from Winner et al. (1998)

Sample story: Jack and the Brownie

Betty baked some brownies for the church bake sale. She told her husband Jack not to eat a single one because he was on a strict diet. Then she went out to the store. While she was gone, her husband's friend came over. Jack was hungry and couldn't stick to his diet. When his friend left to go to the bathroom, Jack started eating the brownies.

Fact Question—Did Jack eat some brownies?

Meanwhile, Betty had forgotten something and came back home. Just as she was about to open the door, she saw Jack through the kitchen window, biting into a brownie.

First-Order Belief Question—Did Betty realise that Jack was eating a brownie?

Joke version—Betty walked into the kitchen. She looked angrily at Jack as he was chewing and held a half-eaten brownie in his hand. Betty walked out of the room. Jack's friend returned from the bathroom and asked Jack, “Hey, does Betty know that you are breaking your diet?”

Lie version—Jack did not see that Betty was watching him. As Jack was eating, his friend returned from the bathroom and asked him, “Hey, does Betty know that you are breaking your diet?”

Second-Order Belief Question—What do you think Jack told his friend? Yes or No?

Second-Order Follow-Up Question—Did Jack think that what he told his friend was really true?

Betty came back into the kitchen. She asked Jack, “Are you having a hard time sticking to your diet?” Jack replied, “I haven't eaten anything fattening all day.”

Second-Order Expectation Question—When Jack said that to Betty, did he think that Betty would believe him?

Interpretation Question—When Jack said, “I haven't eaten anything fattening all day,” was he: (a) lying to avoid getting caught, or (b) joking to cover up his embarrassment?

APPENDIX C

Lesion sites for participants with RHD in two comprehension subgroups on DCT-Implied questions

	MRI report of lesion site
Low Comprehenders	
	Watershed area between right MCA and PCA
	Right basal ganglia; right parietal-occipital region
	Right parietal
	Posterior limb of right internal capsule and centrum semiovale area of right parietal lobe
	Right basal ganglia; also right temporal lobe and right insular cortex; a small right temporo-parietal ischaemic infarct
	Right occipital-parietal
	Right frontal corona radiata extending into right putamen
	Right fronto-parietal
	Toward right vertex
	Right MCA distribution
High Comprehenders	
	Right basal ganglia, medial temporal lobe, insular region, and parietal-occipital region
	Right thalamus; involvement of temporal and occipital lobe
	Right posterior insular cortex
	Medial surface of right anterior lobe, and superior aspect and part of the posterior corpus callosum
	Posterior aspect of right putamen and body of right caudate nucleus
	Right MCA distribution
	Right basal ganglia
	Right basal ganglia involving the caudate nucleus, putamen and globus pallidus
	Right frontal lobe and right basal ganglia
	Right MCA distribution
	Right thalamus and internal capsule
	Right basal ganglia

DCT = Discourse Comprehension Test (Brookshire & Nicholas, 1993).

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TABLE 1

Demographic and clinical characteristics of two participant groups

Characteristics	***RHD (N = 32)***	***NBD (N = 38)***
Age (years)		
Mean (*SD*)	64.5 (11.8)	60.4 (9.6)
Range	42 N 85	45 N 84
Gender		
Male	16	19
Female	16	19
Education (years)		
Mean (*SD*)	14.2 (3.1)	13.9 (2.3)
Range	9 N 22	12 N 20
Lesion site (from CT/MRI report)		Not applicable
Right cortical anterior	3	
Right cortical posterior	10	
Right cortical anterior + posterior	5	
Right basal ganglia	8	
Right thalamus	1	
Right subcortical mixed	2	
Right MCA (unspecified)	3	
Lesion type (from CT/MRI report)		
Thromboembolic	17	Not applicable
Lacunar	2	
Haemorrhagic	13	
Months post-onset		
Mean (*SD*)	52.2 (50.9)	Not applicable
Range	4–167	
*PPVT-R[a]		
Mean (*SD*)	157.3 (11.3)	163.0 (11.2)
Range	132–173	115–174
*Cleft Object Sentence Comprehension[b]		
Mean (*SD*)	9.5 (.78)	9.8 (.44)
Range	7 N 10	8 N 10
*Auditory Working Memory for Language[c]		
Word recall errors		
Mean (*SD*)	13.2 (7.0)	5.0 (4.6)
Range	1–27	0–16
*Behavioural Inattention Test[d]		
Mean (*SD*)	137.0 (13.5)	144.0 (2.8)
Range	85–146	133–146
*Visual Form Discrimination[e]		
Mean (*SD*)	28.1 (3.5)	30.3 (2.2)

Characteristics	***RHD (*N *= 32)***	***NBD (*N *= 38)***
Range	20–32	24–32
*Judgement of Line Orientation[f]		
Mean (*SD*)	22.2 (5.2)	27.1 (4.2)
Range	9–30	16–33
ABCD[g] Story Retell		
*Immediate Retell		
Mean (*SD*)	13.2 (2.5)	14.4 (2.1)
Range	7–17	9–17
Delayed Retell		
Mean (*SD*)	12.7 (3.1)	13.6 (2.5)
Range	5–17	7–17

RHD = righthemisphere brain damage; NBD = non-brain damaged; anterior = anteriorto Rolandic fissure; posterior = posteriorto Rolandic fissure.

[a] PPVT-R = PeabodyPicture Vocabulary Test-Revised; Dunn and Dunn (1981; maximum = 175).

[b] Caplan (1987; maximum = 10; cleft object sentence subset).

[c] Tompkins et al. (1994; maximum errors = 42).

[d] Wilson, Cockburn, and Halligan (1987; maximum = 146; neglect cut-off = 129).

[e] Benton, Sivan, Hamsher, Varney and Spreen, (1983; age & gender corrected score; maximum = 35).

[f] Benton, Hamsher, Varney, and Spreen (1983; maximum = 32).

[g] ABCD = ArizonaBattery for Communication Disorders in Dementia; Bayles & Tomoeda, (1993; maximum = 17)

[*] significantdifference by independent *t*-test, $p < .05$

TABLE 2

Descriptive (*M*, *SD*) and statistical data on coarse coding and comprehension measures for two participant groups

	RHD (*N *= 32)	***NBD (*N *= 38)***
Coarse Coding measure (maximum = 16)		
Short ISI[a]	15.53 (0.72)	15.82 (0.39)
Long ISI[b]	15.31 (0.78)	15.76 (0.43)
DCT-Implied question accuracy (maximum = 20)[c]	16.00 (2.21)	17.10 (2.06)
High-level Inference accuracy (maximum = 18)[d]	9.47 (3.20)	12.34 (3.79)

RHD = right-hemisphere-damaged. NBD = non-brain-damaged. ISI = Interstimulusinterval condition. DCT = Discoursecomprehension test (Brookshire & Nicholas, 1993).

[a] $t(68) = -22.10$; $p < .05$

[b] $t(68) = -3.05$; $p < .05$

[c] $t(68) = -2.16$; $p < .05$

[d] $t(68) = -3.39$; $p < .05$

TABLE 3

Descriptive data (*M*, *SD*) on coarse coding variables for RHD comprehension subgroups

	Coarse coding (maximum = 16)	
	Short ISI	***Long ISI***
DCT-Implied question accuracy (maximum = 20)		
Contrast 1		
High comprehenders	15.83 (0.39)	15.75 (0.45)
Low comprehenders	15.36 (0.93)	15.00 (0.88)
Contrast 2		
High comprehenders	15.78 (0.44)	15.67 (0.50)
Low comprehenders	15.20 (1.03)	14.80 (0.79)
Contrast 3		
High comprehenders	15.83 (0.39)	15.75 (0.45)
Low comprehenders	15.20 (1.03)	14.80 (0.79)
High-level Inference accuracy (maximum = 18)		
High comprehenders	15.38 (0.74)	15.50 (0.53)
Low comprehenders	15.14 (1.07)	15.00 (1.00)

RHD = right-hemisphere-damaged. ISI = Interstimulusinterval condition. DCT = DiscourseComprehension Test (Brookshire & Nicholas, 1993). Contrast 1: High comprehender score ≥17; low ≤ 15. Contrast 2: High score ≥18; low ≤ 14. Contrast 3: High score ≥17; low ≤ 14. High-level Inference High score ≥11; low ≤ 7.