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Communicative deficits in agenesis of the corpus callosum: Nonliteral language and affective prosody

Lynn K. Paul,[a] Diana Van Lancker-Sidtis,[b] Beatrix Schieffer,[a] Rosalind Dietrich,[c] and Warren S. Brown[a,d,*]

[a] The Travis Research Institute, Center for Biopsychosocial Research, Fuller Graduate School of Psychology, 180 N. Oakland Ave., Pasadena, CA 91101, USA
[b] Department of Speech-Language Pathology and Audiology, Steinhardt School of Education, New York University, USA
[c] Department of Radiology, School of Medicine, University of California, Irvine, USA
[d] Department of Psychiatry and Biobehavioral Sciences, and Brain Research Institute, University of California, Los Angeles, USA

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Abstract

While some individuals with agenesis of the corpus callosum can perform normally on standardized intelligence tests, clinical observations suggest that they nevertheless have deficits in the domains of fluid and social intelligence. Particularly important for social competence is adequate understanding and use of paralinguistic information. This study examined the impact of callosal absence on the processing of pragmatic and paralinguistic information. Young adult males with agenesis of the corpus callosum (ACC) were evaluated in the areas of nonliteral language comprehension, proverb recognition and interpretation, and perception of affective prosody. Ten ACC individuals with normal Wechsler IQ were compared to 14 sex, age, and IQ matched normal controls. The Formulaic and Novel Language Comprehension Test (FANL-C), Gorham Proverbs Test, and LA Prosody Test were administered. ACC subjects exhibited significant impairment on the nonliteral items of the FANL-C, but no significant difference from controls in comprehension of literal items. ACC subjects also exhibited significant deficits in both self-generated interpretation and recognition of proverb meaning, and in recognition of affective prosody. These results demonstrate that normally intelligent individuals with ACC are impaired in the understanding of nonliteral language and emotional-prosodic cues that are important in social communication. In all three tests, the performance of individuals with ACC was similar to patients with right hemisphere brain damage. Thus, persons with ACC appear to lack interhemispheric integration of critical aspects of language processed by the right hemisphere.

Keywords: Corpus callosum; Agenesis of the corpus callosum; Nonliteral language; Prosody; Proverbs; Idioms

1. Introduction

The investigation of patients with agenesis of the corpus callosum (ACC) has made an important contribution to understanding of the neuropsychology of the corpus callosum (Brown, Jeeves, Dietrich, & Burnison, 1999; Brown, Thrasher, & Paul, 2001; Jeeves & Milner, 1987; Jeeves & Temple, 1987; Sauerwein, Nolin, & Lassonde, 1994; Temple, Jeeves, & Vilarroya, 1990). The role of callosal function in language processing has been studied in ACC with respect to phonetic, syntactic, and semantic aspects of language (Dennis, 1981; Sanders, 1989; Temple, Jeeves, & Vilarroya, 1989; Temple et al., 1990). For example, Dennis (1981) found individuals with ACC to have specific deficits in syntactic comprehension, metalinguistic understanding, and confusion in dichotic listening due to temporal-acoustic overlap. However, Jeeves and Temple (1987) were not able to replicate the findings of Dennis (1981). Temple et al. (1990) found subtle dysfunction in phonological processing particularly evident in a diminished ability to formulate and recognize rhyme. Sanders (1989) also found deficient syntactic

* Corresponding author. Fax: 1-818-584-9630.
E-mail address: wsbrown@fuller.edu (W.S. Brown).

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comprehension in a 6-year-old child with ACC that was evident in an inability to "assign correct semantic roles to some sentence forms." (p. 59).

Despite the importance of nonliteral language and emotional-prosodic cues to social communication (referred to as paralinguistic or pragmatic functions), no research exists on the ability of persons with ACC to process these aspects of communication. However, anecdotal observations of parents and family members suggest a tendency of ACC individuals to have difficulty with the pragmatic and paralinguistic aspects of communication. According to their parents, children with ACC tend to offer 'meaningless" or "out-of-place" comments in conversation (Jeeves & Temple, 1987; O'Brien, 1994). Parents also report that their children with ACC interpret speech very literally, misinterpreting the meaning of nonliteral expressions such as idioms and proverbs. Consistent with these parent reports, Buchanan, Waterhouse, and West (1980) described emotional processing deficits in one adult with ACC and normal intelligence. Although this individual with ACC had normal verbal intelligence (VIQ = 98), he reported a history of difficulty verbalizing his feelings and exhibited marked weakness in the recognition and labeling of affect-laden speech and emotional prosody.

This paper examines the ability of individuals with complete ACC and normal IQ to process nonliteral linguistic forms—including idioms, speech formulas, and proverbs—and to accurately interpret affective prosodic speech.

1.1. Interhemispheric transfer in ACC

Most of the work done in the past half century on adults and children with ACC has investigated deficits in interhemispheric transfer and integration of information, i.e., whether ACC individuals show a "disconnection syndrome" similar to that seen in callosotomized or commissurotomized individuals (Sperry, 1974). Generally these studies have shown that individuals with ACC are capable of interhemispheric integration for simple visual and tactile information (e.g., Brown et al., 1999; Ettlinger, Blakemore, Milner, & Wilson, 1972; Gott & Saul, 1978; Jeeves, 1965; Sauerwein, Lassonde, Cardu, & Geoffroy, 1981; Saul & Sperry, 1968). For example, Chiarello (1980) found ACC patients to perform well on all tasks requiring transfer of visual or tactile information from one hemisphere to the other, with the exception of finger localization. Lassonde, Sauerwein, Chicoine, and Geoffroy (1991) found that on some tasks of intermanual transfer, ACC children out performed normal children. Brown et al. (2001) found entirely normal interhemispheric Stroop interference in a group of 10 individuals with ACC and normal IQ. In contrast to these reports of normal interhemispheric transfer in ACC, performance of adult callosotomy and commissurotomy patients is clearly deficient on tasks of interhemispheric sensory transfer. Taken together, these results indicate that presence of an anterior commissure, and/or ipsilateral sensorimotor pathways in individuals with ACC allow them to perform normally on simple transfer tasks despite callosal absence.

Clearer evidence of hemispheric disconnection in ACC has accumulated in studies of the transfer or integration of more complex information (e.g., Brown et al., 1999; Bryden & Zurif, 1970; Buchanan et al., 1980; Jeeves, 1979). For example, Brown et al. (1999) demonstrated normal ability of ACC subjects to make interhemispheric comparisons of single letters, but significant deficits in their ability to compare spatial patterns of five dots. A number of studies have demonstrated the presence of interhemispheric transfer of complex visual or tactile information in ACC, but with abnormally long response times and increased overall error rates (e.g., Lassonde, Lortie, Ptito, & Geoffroy, 1981). Again, studies in patients undergoing section of the corpus callosum support notions about partial transfer of information. In a study of transfer of lexical information following staged surgery of the corpus callosum, contextual and connotational meanings of words presented to the right hemisphere were available in the left hemisphere following section of the posterior one-third of the corpus callosum. For example, when the right hemisphere was presented with the written word "knight," the patient provided a spoken response (using the left hemisphere) "I have a picture in mind but can't say it... Two fighters in a ring... Ancient wearing uniforms and helmets... on horses trying to knock each other off...Knights?" (p. 345). Following complete section of the corpus callosum in this subject, semantic information presented to the right hemisphere, whether via pictures or written words, was no longer reported by left hemisphere speech mechanisms (Sidtis, Volpe, Holtzman, Wilson, & Gazzaniga, 1981). Limitation on the interhemispheric integration of complex information is presumably a manifestation of limitation in the amount of information that can be transferred via subcortical pathways or noncallosal commissures.

1.2. Hemispheric specialization in emotional processing

A unique role of the right (nondominant) hemisphere in processing emotions and emotional speech has been reported in the literature. Thus, patients with right hemisphere lesions were said to have significant deficits in the processing of affect-laden speech (Heilman, Scholes, & Watson, 1975) and in the expression of emotion through vocal prosody, gestures, and facial expression (Tucker, 1981; Weintraub & Meulam, 1983). Several studies have correlated right hemisphere damage with deficits in comprehension of emotional expression through vocal inflection (Bowers, Bauer, & Heilman, 1993; Starkstein, Federoff, Price, Leiguarda, & Robinson, 1994). A mirror-image result was reported in a case study that described a patient with global aphasia following left hemisphere stroke who was found to have intact comprehension of affective prosody and affective facial recognition (Barrett, Crucian, Raymer, & Heilman, 1999). In non-brain-damaged individuals, electroencephalogram (EEG) and positron emission tomography (PET) studies have found that right hemisphere regions are activated during recognition of emotional prosody (George et al., 1996; Pihan, Altennuller, & Ackermann, 1997). Spence, Shapiro, and Zaidel (1996) have suggested that the right hemisphere is superior in emotional processing due to greater control over autonomic nervous system responses to emotional stimuli.

Other investigators have reported affective-prosodic deficits in patients with either left or right-sided cortical and/or subcortical lesions, suggesting that both hemispheres play some role (Cancelliere & Kertesz, 1990; Schlanger, Schlanger, & Gerstman, 1976). Van Lancker and Sidtis (1992) studied errors in the processing of prosody by left hemisphere damaged (LHD) and right hemisphere damaged (RHD) patients and concluded that the differential performance of left and right hemisphere damage patients was due to hemispheric bias toward different acoustic features. In particular, they found that LHD patients appeared to base their decisions on fundamental frequency information, whereas the RHD appeared to rely primarily on durational cues in identifying emotional meaning. In contrast, Pell and Baum (1997a, 1997b) found that both RHD and LHD patients were as accurate as controls in ability to discriminate prosodic patterns for affective-prosodic and linguistic-prosodic stimuli, despite the fact that neither group was able to reliably comprehend linguistic-prosodic information (Pell & Baum, 1997a). Further analysis of comprehension errors (Pell & Baum, 1997b) did not reveal distinctions between RHD and LHD patients in the use of six acoustic features. It remains possible that other functions such as processing of the temporal and spectral parameters of speech may be lateralized (Robin, Tranel, & Damasio, 1990). Thus, the possibility remains that the left and right hemispheres play complementary roles in processing of the prosodic aspects of language (Pell & Baum, 1997b; Robin et al., 1990; Zatorre, Evans, Meyer, & Gjedde, 1992).

A role of interhemispheric pathways in the production and comprehension of affective prosody has been described (Cancelliere & Kertesz, 1990; Van Lancker & Breitenstein, 2000; Van Lancker, Pachana, Cummings, Sidtis, & Erickson, 1996). The findings of Ross, Thompson, and Yenkosky (1997) suggest that both the right hemisphere and the interhemispheric connection via the corpus callosum are critical in prosodic processing. Ross et al. examined the mechanisms underlying affective processing in both hemispheres by testing repetition and comprehension of affective prosody under progressively simplified linguistic conditions. They found that reducing the linguistic/verbal articulatory condition aided the performance of LHD patients, but not the RHD patients, a finding that supports right hemisphere lateralization of processing affective prosody. In addition, they found that "deep white matter lesions located below the supplementary motor area that disrupt interhemispheric connections coursing through the mid-rostral corpus callosum may contribute to affective-prosodic deficits..." (p. 28). This is consistent with findings of Klouda, Robin, Graff-Radford, and Cooper (1988) regarding deficits in affective prosody in a woman with an aneurysmal hemorrhage of the anterior corpus callosum. Thus, it is likely that interaction between the cerebral hemispheres is required for successful processing of emotional prosody (Ross et al., 1997; Van Lancker & Sidtis, 1992), allowing the enhanced ability of the RH in the experiencing and labeling of emotion to participate in larger, bi-hemispheric neural networks of information processing.

Work by Tompkins and colleagues suggests that the variability of findings regarding right hemisphere involvement in prosodic recognition may reflect the intervening variable of complexity. Tompkins (1991) utilized a priming paradigm with RHD, LHD, and healthy older adults to examine the impact of a priming story with emotional content on subsequent identification of vocal prosody in sentences of neutral content. The prime-target pairs were presented in two conditions designed to favor either automatic processing or more effortful processing. The results indicated that while RHD patients were more adversely affected by incongruent primes, they were able to revise initial predictions under less complex (more automatic) processing conditions. Tompkins concluded that the deficits in prosody recognition "arose when increased processing demands converged with decreased availability of mental resources." (p. 820). In another study, Tompkins and Flowers (1985) found that while RHD patients were impaired in distinguishing and labeling affective prosody on three levels of difficulty, LHD subjects performed similarly to normals on simple tasks but fell to the level of RHD patients on the most complex labeling task. They concluded that while the RH was dominant for reception and recognition of prosodic stimuli, increased cognitive demands required involvement of both hemispheres. This interpretation would explain why both RHD and callosal damage can result in prosodic deficits.

1.3. Nonliteral language and hemispheric interaction

Although the precise neural substrates responsible for nonliteral language are not clearly understood, there is considerable evidence that nonliteral phrases such as idioms are processed differently than novel, literal sentences (Horowitz & Manelis, 1973; Osgood & Housain, 1974). Normal listeners have been found to process nonliteral meanings more quickly than literal meanings when presented within idioms or ironic statements (e.g., Gibbs, 1980, 1986; Swinney & Cutler, 1979).

Nonliteral language deficits have been attributed to frontal lobe dysfunction (Benton, 1968; Cummings, 1985; Stuss & Benson, 1986) and to dysfunction of the right hemisphere (Benton, 1968; Brownell, Potter, Bihrle, & Gardner, 1986; Kempler, Van Lancker, Marchman, & Bates, 1999; Van Lancker & Kempler, 1987; Weylman, Brownell, Roman, & Gardner, 1989; Winner & Gardner, 1977). Several researchers have found that although RHD and LHD patients perform similarly on the WAIS vocabulary subtest, RHD patients are impaired in their ability to recognize the figurative meanings of proverbs (Hier & Kaplan, 1980; Myers & Linebaugh, 1981; Van Lancker & Kempler, 1987). Likewise, utilizing the Formulaic and Novel Language Comprehension test (FANL-C), Kempler and Van Lancker (1996) demonstrated that RHD patients were significantly more impaired on the nonliteral subtest than on novel, literal items (Van Lancker & Kempler, 1987). In studying commissurotomy patients, Zaidel (1978, 1982) found that the right hemisphere recognizes highly familiar linguistic stimuli that do not require computationally novel phonological and grammatical processing. Ability of the right hemisphere to process familiar linguistic stimuli would explain why some aphasic patients with severe language impairments subsequent to LHD can understand more of routine conversational interaction (that tend to rely on highly familiar phrases) than they can understand propositional language (Holland, 1980).

In work parallel to that conducted regarding prosodic processing, Tompkins and colleagues (Tompkins, Boada, & McGarry, 1992) examined the impact of complexity in the processing of nonliteral language forms in brain-damaged adults. They utilized a forced-choice reaction time word-monitoring task to assess implicit knowledge of familiar idiomatic expressions, compared to syntactically matched literal and control phrases containing the target word. On this simple reaction time task, the performance of both RHD and LHD patients was similar to controls. However, both brain-damaged groups performed more poorly than controls on an idiom definition task, a task that presumably involved multiple mental operations. Thus, although they showed impairment in an idiom-definition task, the brain-damaged adults could recognize these expressions within a normal range of performance in the simpler reaction time task. These results suggest that deficits in idiom-interpretation commonly reported in RHD patients are the result of impairment at some later stage of information processing (possibly requiring multiple brain areas), but not from the early stages of accessing and recognizing familiar idioms.

Tompkins (1990) also utilized a prime-target lexical decision-making task to examine the ability of RHD patients to utilize metaphoric and literal meanings of adjectives at two levels of attentional demand. Whereas the "automatic" task used a short inter-stimulus interval and instructions suggesting a large proportion of unrelated pairs, the "effortful" task established greater attentional demand by using a longer inter-stimulus interval and presenting instructions that suggested greater likelihood of related pairs. Although both RHD and LHD patients were slower than controls overall, both brain damaged groups retained sufficient knowledge of metaphoric meanings to demonstrate normal priming patterns on both the automatic and effortful processing tasks. The fact that there was not a significant performance difference between RHD and LHD groups suggests that both lexical and metaphoric semantic priming is bi-hemispheric. The final phase of this study examined the ability to overcome inaccurate external strategic task instructions. Here RHD patients had greater deficits than LHD patients. Thus, Tompkins concludes that while both hemispheres show intact lexical and metaphoric associative priming after CVA, when the task includes a significant secondary cognitive challenge such as generating one's own task strategy, individuals with RHD perform poorly more due to limited processing or attentional resources.

Van Lancker (1975, 1988, 1990) posits that language use can be described on a continuum from novel at one extreme to over-learned at the other. Whereas novel propositional language requires the use of grammatical and lexical rules for interpretation, over-learned, nonliteral stimuli have stereotyped forms and conventional meanings that need to be learned but not reprocessed every time they are encountered (Gibbs & Beitel, 1995). Context and familiarity are critical factors in eliciting the stereotyped form and conventional meaning necessary for idiomatic interpretation of a statement. For this reason, Van Lancker (1990) critiques proverb tests for attempting to include novel proverbs because proverbs and idioms are, by definition, nonliteral and, thus, their socially accepted meanings must be learned or "known." Working from a similar perspective, Nippold and Haq (1996) examined proverb comprehension in adolescents. Their results support the "familiarity" hypothesis that comprehension develops through meaningful exposure to currently utilized, rather than obscure, proverbs.

In addition to the necessity for a proverb to be known in order to be easily interpretable, the work of Nippold and Haq (1996) also supported the "metasemantic" hypothesis that emphasizes the importance of the degree of proverb abstractness. According to the "metasemantic" hypothesis, since proverb comprehension develops through analysis of words, concrete proverbs are more readily understood than abstract proverbs. Thus, both the familiarity of the proverb and the semantic complexity of the proverb may impact its interpretability. Furthermore, it appears that asking a subject to generate an interpretation of a proverb is a far more difficult and complex task than asking him/her to recognize an accurate interpretation. Whereas recognition of the standard meaning requires only an awareness of social convention, proverb interpretation requires (1) knowledge of the socially accepted meaning; (2) expressive communication skills; and (3) metalinguistic ability to provide a definition.

Since task demands influence the kind of results obtained, our study of nonliteral language processing in ACC uses three performance measures of nonliteral language competence. The Formulaic and Novel Language Comprehension Test (FANL-C; Kempler & Van Lancker, 1996) requires no verbal ability in the response, as it uses choice of appropriate line drawings as responses (see Fig. 1). The Gorham Test of Proverbs (Gorham, 1956a; Gorham, 1956b) has two subtests: one requiring verbal interpretation and the other providing multiple choice options.

In a previous paper (Brown & Paul, 2000), we reported that two ACC subjects performed poorly when

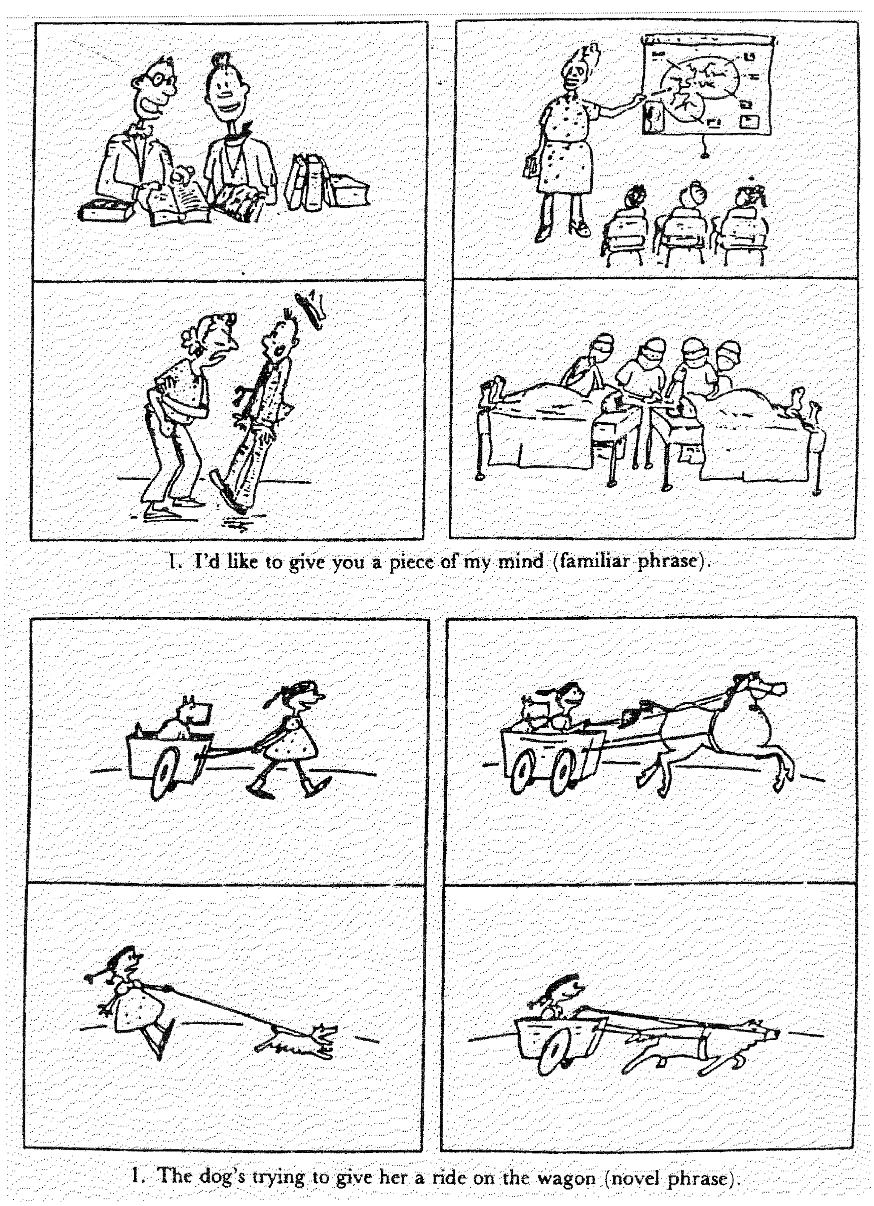

Fig. 1. Sample of two items from the FANL-C. Test participants are read aloud the sentence at the bottom of the each set of cartoons, and then are requested to point to the picture that best represents the meaning of the sentence. The upper item is a familiar, nonliteral idiom ("I'd like to give you a piece of my mind"). The bottom item is a matched novel sentence ("The dog's trying to give her a ride on the wagon").

asked to generate proverb definitions, but performed within normal limits on the written multiple choice version of the test. This suggests that although ACC subjects were able to perform relatively normally on a task that is impaired in RHD patients (proverb recognition), their performance was deficient in the context of the increased complexity of the proverb-generation task. Thus, it is possible that reduced interhemispheric communication in ACC limits access to the right hemisphere processing skills that are required for the more complicated tasks of generating an explanation of a proverb.

In summary, callosal absence in ACC reduces the quantity and/or efficiency of interhemispheric interactions such that complex material cannot be readily integrated. Absence of the corpus callosum may prevent the right hemisphere either from adequately communicating information regarding the correct emotional or nonliteral meaning of language to the left hemisphere for verbal output, or from successfully integrating information processed in the respective hemispheres. Therefore, we expected that individuals with ACC would exhibit poor performance on tests of affective prosody and nonliteral language. This expectation is consistent with reports from parents of language processing problems in individuals with ACC.

This study was designed to test the degree to which deficits in the comprehension of prosody and nonliteral language (proverbs and nonliteral idioms) are a consistent outcome of ACC even when IQ is normal.

2. Methods

2.1. Participants

A summary of the characteristics of the ACC individuals tested can be found in Table 1. Participants included 10 males ages 16–31 with complete ACC (mean age = 22.1). The participants had Full Scale Intelligence Quotients (FSIQs) in the average range (mean FSIQ = 93.0, range = 83 to 105) and mean education level was 12.2 (range 10–15). The participants did not reveal a consistent pattern of differences between Verbal IQ (VIQ) and Performance IQ (PIQ) (VIQ = 94.8; PIQ = 92.0). Three of the ACC subjects were left-handed. As can be seen in Table 1, five patients were taking psychoactive medications, four had other observable, relatively minor neurological abnormalities, and two had received neurobehavioral diagnoses.

Controls were recruited from community college psychology courses and from an employment agency. The control group was chosen to match the ACC group with respect to age, IQ, gender, and handedness. The control group consisted of 14 males, with a mean age of 22.9 years (range 15–28), a mean FSIQ of 93.4 (range 84–107; WAIS-R, Satz-Mogel version; mean VIQ = 92.9; mean PIQ = 95.1), and mean education level of 12.8 years (range 10–15). All ACC and control subjects were native English speakers.

Upon entrance into the study, all acallosal and control participants signed a form indicating consent to participate in this research (parents cosigned for the participants who were under age 18). All participants were treated according to the American Psychological Association Ethical Principles (American Psychological Association, 1992) and the National Institutes of Health Guidelines throughout the experiment.

2.2. Materials and procedures

Three measures were administered: LA Prosody Test, Formulaic and Novel Language Comprehension Test (FANL-C), and the Gorham Proverbs Test. The LA Prosody Test (Van Lancker, 1989) presents an audiotape of 16 simple semantically neutral sentences, each recorded by a professional female actress with one of four emotional-prosodic meanings (*happy, sad, angry, surprised*). Subjects respond by pointing to the matching

Table 1
Description of participants with agenesis of the corpus callosum

ID	Age	Sex	Hand	Ant. Comm.	WAIS/WISC FSIQ (VIQ/PIQ)	Other neuropathology or psychopathology	Medications
A18	16	M	R	Nv	84 (87/83)	None	Zoloft
A3	17	M	L	Yes	97 (100/95)	Interhemispheric cyst	Depakote
A20	18	M	L	Nv	103 (111/92)	None	None
A1	18	M	R	Yes	105 (97/114)	None	None
A2	19	M	L	Yes	87 (80/96)	Heterotopia of the left frontal grey matter; cortical dysplasia	Ritalin
A6	21	M	R	Yes	84 (85/86)	Dysgenesis of hemispheres bifrontally; interhemispheric cyst	None
A4	27	M	R	Yes	83 (79/90)	Dyslexia—expressive aphasia	Depakote Navane
A5	27	M	R	Yes	91 (87/99)	Left parasagittal interhemispheric cyst	Dilantin for seizure control
A21	28	M	A/R	Yes	94 (108/78)	Bipolar affective disorder	None
A7	31	M	R	Nv	102 (114/87)	None	None

Nv, not visible on MRI/CT.

emotion as shown by one out of the four line drawings of faces which display emotional expressions and are each labeled with the written word *surprised*, *happy*, *angry*, *or sad*. Response cards were randomly ordered for each stimulus presentation. The FANL-C (Kempler & Van Lancker, 1996) includes 20 literal and 20 nonliteral expressions, matched for length and grammatical structure, which are read to the participant. The participant must pick which one out of the four line drawings best fits the sentence (see Fig. 1 for sample). The 12-item free answer version and the 40-item best answer version of the Proverbs Test (Gorham, 1956a; Gorham, 1956b) were used to assess proverb interpretation and comprehension. In the free answer version participants were asked to write out the meaning of each proverb. In the best answer version, they were asked to choose one of our written responses to represent the best meaning of each proverb, with one out of the four choices being the correct abstract response and one being a concrete response. Items were scored according to Gorham's written criteria. The tests were administered individually as part of a larger neurocognitive and psychosocial test battery that occurred over four 2- to 3-h sessions. A variety of tests were administered during each session with breaks allowed as necessary to avoid fatigue.

3. Results

3.1. Prosody

On the prosody test, participants with ACC exhibited a mean score of 92.3% correct and controls had a mean of 97.8% (see Fig. 2A). Utilizing an independent samples *t* test, ACC participants were found to perform significantly worse than controls on this test of affective prosody ($t = -2.6$, $df = 21$, $p < .05$). While the degree of difference was not large, individuals with ACC showed consistent weakness in recognition of affective prosody.

3.2. Formulaic, nonliteral language

The mean score of participants with ACC was nearly equal to controls on the FANL-C literal items (ACC mean = 94.5%, control mean = 95.0%), but the ACC scores were worse on the FANL-C nonliteral items (ACC mean = 70.0%, control mean = 92.5%, see Fig. 2B). A repeated-measures ANOVA (group by measure) revealed a main effect of measure, indicating significantly better performance on the literal subtest than nonliteral subtest ($F = 18.86$, $df = 1$, $p < .001$). Controls did significantly better overall than the ACC group ($F = 7.4$, $df = 1$, $p < .05$). There was also a significant interaction effect between group and measure ($F = 12.52$, $df = 1$, $p < .002$). Post-hoc analyses indicate that the interaction effect is due to significantly poorer performance for the ACC group on the nonliteral items ($t = -2.78$, $df = 10.06$, $p < .05$), with no significant group difference on literal items. Thus, individuals with ACC had significant difficulty recognizing the meaning of nonliteral expressions, but were normal in their understanding of literal language.

3.3. Proverb interpretation

ACC subjects exhibited worse scores (i.e., chose fewer correct abstract meanings) than controls on both versions of the proverbs test (Multiple Choice: ACC mean = 50%, control mean = 63%; Free Response: ACC mean = 18%, control mean = 40%; see Fig. 2C). A repeated-measures ANOVA (group by test) revealed a significant main effect of group ($F = 662.189$, $df = 1$, $p < .001$), but no significant effect of test (multiple choice vs free response) or test-by-group interaction. In addition to making fewer correct (abstract) responses on the proverbs multiple choice, the ACC

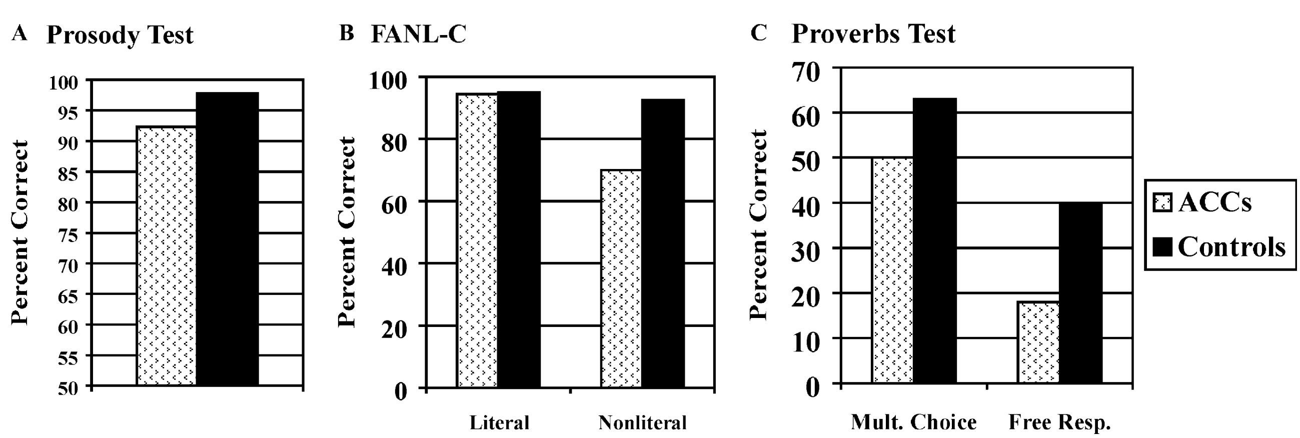

Fig. 2. Group mean results (percent correct) from individuals with ACC (lightly filled bars) and controls (dark bars) on measure of prosody (A), the literal and nonliteral items of the FANL-C (B), and the multiple choice and free response versions of the Gorham Proverb Test (C).

group also chose concrete answers significantly more often than controls ($t = 3.724$, $df = 23$, $p < .001$).

The verbal responses of the ACC subjects on the Free Response subtest of the Gorham Proverbs Test were examined more closely. Verbal interpretations for the 12 proverbs were available for 10 ACC and 12 normal-control subjects. First, a total word count was obtained for each group. ACC subjects gave briefer responses, reflecting relative impoverishment in their verbal production. The mean total number of words for interpreting the 12 proverbs in the Gorham Proverbs test for the ACC group was 59.5, with a range of from 35 to 62 words for the group per individual proverb, compared to 95.8 for the normal-control subjects, who ranged in total words per proverb from 86 to 139. A matched pairs t test comparing word-count responses for each of the target proverbs by the normal-control versus the ACC subjects was significant ($t = 13.2$, $df = 11$, $p < .0001$).

In addition, two measures independent of word count were utilized: an evaluation of the accuracy of "form" and of "content" in proverbs (Van Lancker & Rallon, in press). As discussed previously, proverbs can be described in terms of stereotyped form (identifiable in interpretation performance as number of structural propositions; propositions may appear as clauses or phrases) and conventional content (meaning). For example, "Where there's a will, there's a way" has two formal constituents, each of which can be examined for meaning (a subjective evaluation). The response from one ACC subject "When doing something" was scored 'incorrect' on form, because only one of the two constituents was present; and it was scored incorrect on meaning, because the conventional meaning is not adequately reflected in the response. In contrast, the response from a matched normal subject, "Anything is possible with effort and desire," received "correct" scores for both form, because two constituent propositions (*anything is possible* & *with effort and desire*) are present, and also with respect to meaning, because there is an approximate match with the conventional meaning. When individual responses from all subjects were evaluated for form and content, 67% of ACC responses contained proper form, compared to 85% of normal responses; this difference was significant ($t = -3.023$, $df = 22$, $p < 0.01$). For content, 49% of ACC responses contained appropriate meaning, compared to 69% of normal responses, also a statistically significant difference ($t = -2.467$, $df = 22$, $p < 0.05$).

The relatively lower scores on content (than on form) for both groups is probably due to the fact that some of the Gorham Proverbs are antiquated and, thus for certain proverbs, the meanings are obscure. This observation echoes the importance of familiarity, in the sense of usage currency, in subjects' performance in proverb interpretation. This issue obviously pertains more crucially to the semantic than the formal measures in this analysis. This qualitative analysis of the proverb interpretations suggests that the interpretations given by individuals with ACC are relatively verbally impoverished, and are less accurate with respect to the formal structure and semantic meaning of the proverbs than were those of the normal control group.

4. Discussion

This investigation of ACC includes the largest sample of individuals with IQ scores in the normal range studied thus far with respect to language. The results indicate that individuals with ACC and normal IQ have intact language processing for literal statements, but that they exhibit significant relative deficits in processing the nonliteral and emotional-prosodic meanings of language. These results are consistent with Buchanan et al.'s case study report of limited emotional processing in an individual with ACC, and with various anecdotal parent comments leading to the conclusion that children with ACC misconstrue the meta-meanings of conversation and, thus, tend to offer meaningless comments (Jeeves & Temple, 1987; O'Brien, 1994). With limited comprehension of the nonliteral information communicated in a conversation, individuals with ACC are likely to misunderstand and to be insensitive to the subtleties of social and emotional interactions.

Regarding comprehension of affective prosody, individuals with ACC exhibited lower performance than their peers with a normal corpus callosum. Previous literature found that similar prosodic deficits were associated with right hemisphere dysfunction and/or damage to subcortical white matter. Since none of our ACC subjects had right hemisphere damage (as per history, neuroimaging, and neuropsychological testing) and the only consistent neurological anomaly in the group was congenital absence of the corpus callosum, our findings support the hypothesis that affective processing involves callosally mediated integration of information from both hemispheres. The negative impact of callosal absence upon comprehension of affective prosody is consistent with the work of Van Lancker and Breitenstein (2000), Van Lancker et al. (1996), and Cancelliere and Kertesz (1990), all of whom described subcortical white matter connectivity as a critical mechanism in production and comprehension of affective prosody. Likewise, the reports described above of Ross et al. (1997) involving patients with RHD and LHD, and the case study of Klouda et al. (1988) reported relationships between presence of callosal lesions and affective-prosodic deficits which are similar to the prosodic deficits evident in our subjects with ACC. Thus, our results indicate that even with generally intact right hemisphere processing, interhemispheric communication via the corpus callosum is necessary for normal processing of prosodic cues.

The results reported herein demonstrate that significant deficits in both the recognition and free response forms of the Proverbs Test are also found in individuals with callosal agenesis. Further analysis of the proverbs free responses revealed that the answers of ACC subjects were evaluated as significantly below controls in both meaning and form. Problems in responding to the structure of the proverb is consistent with the syntactic deficits described in ACC by Dennis (1981) and Sanders (1989). Problems in comprehending proverb meaning may be related to the "meaningless" comments described by parents of ACC children (Jeeves & Temple, 1987; O'Brien, 1994) in that accurate comprehension of previous comments made by others is necessary for their own following comments to seem meaningfully related to the topic of conversation. We have observed a high frequency of slightly tangential remarks made by individuals with ACC in casual conversations.

The findings we report herein for proverb comprehension differed from our previous summary in our two-subject case study (Brown & Paul, 2000). In this case study, the two individuals with ACC showed normal-range proverb recognition, but impaired free responses. The current study included these two subjects (A1 and A2) and added eight more. Testing more subjects revealed significantly lowered performance for both recognition and free response.

As with proverb comprehension, where RHD has been associated with deficient performance (Hier & Kaplan, 1980; Myers & Linebaugh, 1981), the pattern of idiom comprehension deficits in ACC was similar to performance in RHD patients (Van Lancker & Kempler, 1987; Winner & Gardner, 1977). Similarly, individuals with ACC showed greater impairment on nonliteral items than on literal items on the FANL-C. Thus, both nonliteral language (idioms and proverbs) and prosodic processes require efficient interaction between the two hemispheres for successful processing (Van Lancker, 1990; Van Lancker & Breitenstein, 2000). Our findings are consistent with the results of Tompkins and colleagues (1990, 1991, 1992, 1985) who found that while the RH may be the primary processor of prosody and nonliteral language forms, deficits in these paralinguistic processing skills were evident in both RHD and LHD patients as task complexity increased requiring greater processing resources and bi-hemispheric involvement.

There are several possible explanations for the apparent requirement of bi-hemispheric integration for adequate processing of complex paralinguistic cues and nonliteral meanings. First, it is possible that since the left hemisphere is dominant in organizing appropriate verbal responses, callosal absence limits its access to the paralinguistic information processed by the right hemisphere. This perspective views the left hemisphere as a linguistic communication conduit. Thus, when the left hemisphere has only limited access to the information processing of the right hemisphere (as in ACC), the individual is unable to communicate regarding the information that is effectively trapped in the right hemisphere. This formulation, however, would not explain why acallosal subjects performed poorly even when responding by pointing to line drawings (as in the FANL-C).

Numerous studies suggest that contributions of multiple brain areas are required for successful processing of emotional prosody (Van Lancker & Breitenstein, 2000) and nonliteral meanings (Van Lancker, 1990). In the study by Benton (1968), impairment of either anterior frontal lobe affected performance on the Gorham Proverbs Test. Recent studies using Parkinson patients directly implicate subcortical structures in perception of emotional prosody; here, it is the temporal information in the stimuli that is most poorly perceived (see Breitenstein, Van Lancker, Daum, & Waters, 2001). Studies cited earlier in this paper have implicated both hemispheres in prosodic processing (e.g., Van Lancker & Sidtis, 1992; for review see Van Lancker & Breitenstein, 2000), with pitch processing associated more readily with right hemisphere function (Sidtis, 1980; Sidtis & Feldmann, 1990; Sidtis, 1984). According to Lalande, Braun, Charlebois, and Whitaker (1992), LHD and RHD patients show different types of impairments in processing prosody, dependent upon the type of semantic context available. RHD patients performed more poorly on a pure prosody task (emotional phrases hummed with vocal inflection but without words) than on a test requiring identification of emotional intention based solely on verbal context, and the LHD patients (nonsignificantly) showed the opposite trend. In this task design, as in some others mentioned, the differential findings in LHD and RHD processing suggest the possibility that each hemisphere makes a unique contribution to paralinguistic interpretation. Whereas recognition of the paralinguistic information (emotional/prosodic inflection based on fundamental frequency contour or nonliteral modes of meaning) may be preferentially processed in the right hemisphere, the ability to conduct comparative analysis and respond accurately in various task contexts appears to require bi-hemispheric integration.

It is well known that persons with ACC often have other clinical manifestations. As viewed in Table 1, certain other abnormalities of various kinds were indeed noted for about half of the subjects reported here. Thus, it could be argued that the differences between the ACC and control groups that we have reported are related to differences in other forms of structural brain abnormality (evidenced in the MRIs), or to other neuropathological conditions, or to neuroactive drugs, rather than being related to the absence of the corpus callosum. Several factors would suggest that this is not likely to be the case. First, the absence of the corpus callosum is a much larger and presumably more significant neuropathology than any of the others listed in Table 1. Second, it is clear from Table 1 that there is heterogeneity in the presence, type, and severity of other problems. This is more likely to create large within-group variance that would obscure the effect of a shared problem like ACC, rather than create a statistically significant group difference. Third, there were no group differences on the literal items of the FANL-C, suggesting that language-processing differences are not contributory. Similarly, using all but three of the same ACC subjects we recently reported entirely normal interhemispheric Stroop interference effects (Brown et al., 2001)—that is, in an experimental context (semantic interference) that would seem to be quite sensitive to a variety of other neuropathologies, no group differences were found.

In conclusion, it appears that individuals with ACC (and normal IQ) exhibit significant deficits in processing and accurately responding to nonliteral language forms and prosodic cues. Thus, individuals with ACC have a significant deficit in those areas of speech processing that are important for common social communication. Although a similar pattern of weaknesses has been demonstrated in individuals with RHD, our subjects did not have evidence of right hemisphere damage or structural abnormalities in their MRIs. Thus, our findings are consistent with the hypothesis that social/conversational deficits in ACC arise from the diminished interhemispheric integration of those aspects of language requiring significant involvement of the non-dominant hemisphere.

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