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Social processing deficits in agenesis of the corpus callosum: narratives from the Thematic Apperception Test

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Abstract

Clinical observations suggest that individuals with agenesis of the corpus callosum (ACC) and normal IQ may have deficits in social intelligence. This study analyzed responses by normally intelligent individuals with ACC to pictures from the Thematic Apperception Test. A rating system was developed to assess three elements of story-generation: story logic, social understanding, and common content. Six individuals with ACC (five complete and one partial; IQs > 85) were compared to eight controls matched for sex, age, and IQ. Based on independent rankings of story protocols by two raters, the five individuals with complete ACC were found to be significantly impaired on all three criteria. The one individual with partial ACC performed better than the majority of controls in all three domains. Results demonstrated that individuals with complete ACC are impaired in understanding socially complex scenes and generating appropriate narratives. Absence of the anterior corpus callosum appears to be important for this deficit.

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1. Introduction

It is not unusual for individuals with agenesis of the corpus callosum (ACC) to have normal-range IQs despite the absence of a cortical pathway involving over 200 million axons.

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An important unresolved question regarding ACC is whether there are nevertheless more subtle cognitive deficits specifically attributable to callosal absence. There is a small literature of published studies that have described cognitive limitations in individuals with ACC. Parents of adolescents with ACC also report various forms of social disability in their child. [Brown and Paul \(2000\)](#) posited that absence of the corpus callosum prevents the right hemisphere from adequately communicating information regarding the correct emotional or social interpretation of information to the left hemisphere for verbal output. At the very least, callosal absence may limit successful integration of various forms of social information processing in the two hemispheres. Thus, we hypothesized that individuals with ACC will exhibit deficits in the ability to respond appropriately to complex social stimuli such as the pictures from the Thematic Apperception Test used in this study. For purposes of research into the contributions of the corpus callosum to higher cognitive and social processing, it is important to study ACC in individuals who have normal IQs since, in these individuals, callosal absence is likely to be the primary contributor to neuropsychological deficits.

Diminished interhemispheric transfer of information in ACC (e.g., [Brown, Jeeves, Dietrich, & Burnison, 1999](#); [Gott & Saul, 1978](#); [Jeeves, 1979](#)) appears to have an impact on particular aspects of intelligence and higher cognitive processing that is often not obvious in intellectual assessment. In her review of the neuropsychology of ACC, [Chiarello \(1980\)](#) commented that, “higher order functions (spatiomotor and perhaps in some cases linguistic performance) were found to be impaired even when the task did not explicitly require the interhemispheric exchange of information” (p. 152). [Sauerwein, Nolin, and Lassonde \(1994\)](#) have reported the most extensive neurocognitive evaluation of individuals with ACC and relatively normal intelligence. They concluded that ACC may be present in individuals who manifest no obvious cognitive symptoms, but suggested that more subtle deficits may be present.

Observations of individuals with ACC by parents and family members suggest a tendency to have difficulty with social communication and insight. According to their parents, children with ACC tend to offer “meaningless” or “out-of-place” comments in conversation ([Jeeves & Temple, 1987](#); [O’Brien, 1994](#)). 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 in verbalizing his feelings and exhibited marked weakness in the recognition and labeling of affect-laden speech and emotional prosody.

In an attempt to systematize similar reports that we were hearing from parents of older children and adolescents with ACC and normal-range IQs, we constructed a parent questionnaire involving 21 items eliciting Likert-scale (1–5) responses. Parents consistently reported a tendency of their child with ACC to talk in clichés, although not to talk excessively or to be lacking in normal expressive inflection. Parents also consistently indicated a tendency of their ACC children to miss the point of jokes and stories, to have poor social judgment, and to have difficulty in understanding facial expressions.

[Brown and Paul \(2000\)](#) provide descriptions of psychosocial processing deficits in two adults with ACC and normal-range IQs. These two individuals had a unique MMPI-2 profile (a large L–K difference) consistent with social and psychological naiveté. They also offered simplistic, nonemotional, and concrete interpretations of the Thematic Apperception Test (TAT) stimuli, and gave a significant number of unusual and uncommon responses to the Rorschach Inkblot

Test. Finally, they were impaired in interpretations of proverbs. Examining a larger group of adults with ACC, Paul, Van Lancker-Sidtis, Schieffer, Dietrich, and Brown (in press) report problems in interpretation of familiar idioms and identification of affective prosody, indicating a pattern of deficits in the paralinguistic and social aspects of language.

In order to assess social comprehension in normally intelligent individuals with ACC, this study utilized a common clinical psychology tool, the TAT (Murray, 1943). The TAT involves presentation of pictures suggesting complex social or psychological scenarios. For each picture, the client must tell a story that is recorded verbatim. Traditionally, TAT stories have been interpreted from a psychodynamic perspective with the goal of attaining insight into the psychological personality traits and developmental issues of the client. However, for the purposes of this study, a new rating method was developed to focus on basic narrative logic, common story content, and manifestation of social insight—domains that reflect the person's ability to recognize and interpret the implications of the social situations suggested by the pictures. It was hypothesized that this form of analysis of TAT protocols would reveal a disability in the interpretation of complex social stimuli among individuals with ACC.

2. Method

2.1. Participants

Participants included six males (ages 17–28), five with complete ACC and one with partial ACC. Evaluation of MRIs confirmed the presence of the anterior commissure in all six cases. These participants had Full Scale Intelligence Quotients (FSIQs) in the average range (mean FSIQ = 94.5, range = 87–105) and had completed an average of 11.7 years of education (range = 10–13 years). Subjects were recruited through referral from neurologists and from the directory of the ACC Network. For inclusion subjects had to be age 17 or over, have ACC confirmed by MRI, and exhibit a full scale IQ over 80. These cases include all adult subjects who met the aforementioned criteria, and for whom TAT results were available. However, they are part of a larger data set including children, and adolescents, and a few individuals with lower IQ. Identification numbers are given in relationship to the larger group.

2.1.1. Case A1

A1 is a right-handed, Caucasian male who was 18 years old at the time of testing. A1 was fortuitously diagnosed with ACC at age 8 when he participated in a study of regional brain metabolism (PET) in dyslexic boys. A subsequent MRI confirmed complete ACC and presence of the anterior commissure. The MRI also revealed enlarged lateral ventricles. Prior to the diagnosis of ACC, A1 was diagnosed with dyslexia, for which he received various types of special education. However, his current reading is normal, with a Reading score at the 23rd percentile on the Wide Range Achievement Test. Since the time of testing, A1 has graduated from high school and studied auto mechanics at a community college.

On the WISC-R, A1 had a FSIQ of 105 (VIQ = 97, PIQ = 114). His subscale scores were moderately scattered, with Comprehension, Arithmetic, and Digit Span falling 3–4 points below Vocabulary, Similarities, and Information. Within the performance domain, Coding was 3–4 points below Object Assembly and Block Design.

2.1.2. Case A2

A2 is a left-handed, Hispanic-American male who was 23 years old at the time of testing. In elementary school, he was diagnosed with Attention Deficit Disorder (ADD) and was treated with methylphenidate. At the age of 18, A2 received an MRI subsequent to a fainting spell, revealing complete ACC with presence of the anterior commissure. MRI also revealed mild heterotopic gray matter in both hemispheres. He graduated from high school, but had received some special education.

At age 16, A2 had a FSIQ of 87 on the WISC-R (VIQ = 80, PIQ = 96). His verbal subscale scores showed minimal scatter, as did the performance subscales with the exception of Picture Arrangement (4 points above the mean of PIQ subscales).

2.1.3. Case A3

A3 is a left-handed, Caucasian male who was 17 years old at the time of testing. At the age of 15, A3 received an MRI subsequent to a seizure (controlled with divalproex sodium at time of testing), revealing complete ACC with probable presence of the anterior commissure. The MRI also revealed dilated lateral ventricles and an interhemispheric cyst on the left. A3 repeated 6th grade and received various types of special education throughout his school years. He left school in the 11th grade and received a GED with home schooling.

At the age of 16, A3 was found to have a FSIQ of 97 (VIQ = 100, PIQ = 95) on the WISC-III. He showed minimal subtest scatter with the exception of relative elevation on Picture Completion (7 points above the mean of PIQ subscales).

2.1.4. Case A5

A5 is a right-handed, Caucasian male who was 27 years old at the time of testing. At the age of 11, A5 experienced right hand and arm tremors and eventually a generalized seizure. MRI findings indicated complete ACC, a mildly dilated third ventricle, and a 3–4 cm left parasagittal congenital interhemispheric cyst that slightly depressed the frontal horn of the left lateral ventricle. At the time of our assessment, he was medication free. A5 dropped out of high school in the 10th grade to be trained as a plumber. He did not receive any special education classes, but reported difficulty in math.

At the age 27, A5 was found to have a full scale IQ of 91 on the WAIS-R (VIQ = 87, PIQ = 99). His verbal subscale scores ranged from 6 on Arithmetic to 10 on Comprehension, and his performance scores ranged from 6 on Digit Symbol to 12 on Block Design and Object Assembly.

2.1.5. Case A21

A21 is a right-handed, Caucasian male who was 28 years old at the time of testing. At the age of 21, he was referred by a counselor to a neurologist. An MRI at that time revealed complete ACC. A21 graduated from high school after receiving various types of special education throughout his school years. From age 26–28, A21 was hospitalized three times for angry destructive behavior and concerns about suicide. He was diagnosed at age 26 with bipolar disorder, pervasive developmental disorder not otherwise specified, and attention deficit disorder. He was prescribed carbamazepine at that time, but ceased the medication upon his own initiative at age 28 and was unmedicated at the time of testing.

At age 28, A21 had a FSIQ of 94 (VIQ = 108, PIQ = 78) on the WAIS-R. His verbal subscale scores ranged from 10 to 14, with an outlying score of 7 on the Comprehension subtest. His performance scores ranged from 5 on Digit Symbol to 9 on Block Design.

2.1.6. Case P1

P1 is a left-handed, Caucasian male who was 25 years old at the time of testing. At the age of 19, he was diagnosed with obsessive–compulsive disorder (OCD). At the age of 20, he experienced a generalized seizure, apparently due to the OCD medication (which was subsequently changed to paroxetine and at the time of testing was sertraline). In response to the seizure, P1 received an MRI, revealing partial ACC with approximately 25% of the anterior corpus callosum present. A porencephalic cavity or cystic area was also present on the posterior medial aspect of the left frontal lobe. He graduated from high school, but received various types of special education throughout his school years.

At the age of 6 years and 10 months, P1 was found to have a FSIQ of 90 (VIQ = 74, PIQ = 111) on the WISC-R. At age 26, his IQ was retested using the Satz–Mogel version of the WAIS-R (Satz & Mogel, 1962), which revealed a FSIQ of 97 (VIQ = 81, PIQ = 126). At age 26, his verbal subscale scores ranged from 6 on Information and Vocabulary to 9 on Comprehension. His performance scores ranged from 8 on Picture Completion to 19 on Block Design.

2.1.7. Controls

Normal control participants 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 eight males, with a mean age of 20.63 years (range 18–36 years) and a mean education level of 12.63 (range 12–15 years). The mean FSIQ (as found on WAIS-R, Satz–Mogel version) was 96.63 with a range of 85–107 (mean VIQ = 94.63; mean PIQ = 97.5). All ACC subjects were native English speakers. Three control subjects had English as a second language, but in all the three cases they were attending U.S. schools at least by 7th grade and graduated from a U.S. High School.

Upon entrance into the study, all individuals with ACC 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's (1992) Ethical Principles and the National Institutes of Health Guidelines throughout the experiment.

2.2. Procedures

Six cards from the TAT (1, 2, 6BM, 8BM, 12M, & 13MF) were presented and the participants were asked to tell a story about the picture “with a beginning, middle and end and tell what the characters are thinking, feeling, and doing.” The TAT stories were recorded verbatim by the examiner, transcribed, and assigned random numeric codes (with acallosal individuals and controls interspersed to conceal group classification). Two independent raters, each with extensive TAT assessment experience, assessed the TAT protocols. The protocols for all six cards were read together, and each subject's responses were rank ordered according to the following categories: narrative logic, social insight, and inclusion of content commonly mentioned for the particular card.

3. Results

The control and ACC groups did not differ in FSIQ ($t = -.46$, n.s.), PIQ ($t = -.20$, n.s.), or VIQ ($t = -0.05$, n.s.). With respect to subtests most directly relevant to TAT story-telling, the groups did not differ on the Information subscale ($t = 1.64$, n.s.), but the control group had significantly lower Vocabulary subtest scores than subjects with complete ACC ($t = 3.83$, $P < .01$). The individual with partial ACC scored significantly lower than controls on VIQ ($z = -1.38$) and Information ($z = -1.42$), but showed no significant difference in FSIQ ($z = -.44$), PIQ ($z = .90$), or Vocabulary ($z = .21$).

Pearson correlations for inter-rater reliability were significant for each of the three categories of ranking (story logic: $r = .67$; $P < .01$; social insight: $r = .68$, $P < .01$; common content: $r = .72$, $P < .01$). In addition, a group-by-category-by-rater ANOVA of rankings indicated that rater was not a significant factor, nor did it interact with either of the other variables (rater: $F = 0.044$, d.f. = 1/11, n.s.; rater-by-category: $F = 0.035$, d.f. = 2/10, n.s.; rater-by-group: $F = 2.16$, d.f. = 1/11, $P = .17$; group-by-category-by-rater: $F = 0.71$, d.f. = 2/10, n.s.). Since there were no significant effects of rater, the rankings of both raters were averaged to produce a single score per category.

Prior to further analyses, the impact of English as a second language within the control group was assessed. The scores of the three English-second control subjects were compared to the five English-first controls, revealing no significant effects of either group ($F = 0.043$, d.f. = 1/6, n.s.) or group-by-category interaction ($F = 0.866$, d.f. = 2/12, n.s.). Therefore, the entire control group was included in subsequent analyses.

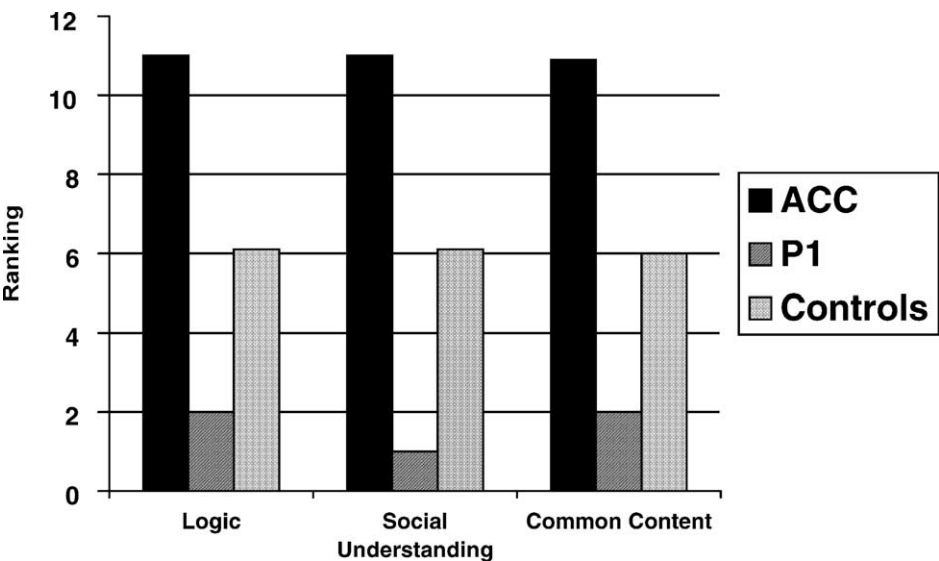


Fig. 1. Average rankings for individuals with ACC, controls, and subject P1 on the three domains of evaluation: story logic, evidence of complex social understanding, and inclusion of common content. For each category, a rank of “1” was given to the best story and “14” to the worst story. Final rankings for each individual consisted of the average ranking given by the two experienced raters.

Upon examination of the data, it was evident that there was little overlap in rankings between individuals with complete ACC and controls. Four participants with complete ACC were at the bottom of the rankings in all the three categories, while one overlapped with either one (story logic) or two (social insight and common content) controls. The individual with partial ACC (subject P1) performed better than the majority of controls. In fact, P1 had the highest average ranking for story logic and social insight, and next highest for common content. In Figure 1 can be seen mean ratings for each group for each of the three categories, with the results for subject P1 displayed separately.

A group (ACC vs. control)-by-category ANOVA was run eliminating case P1 and using the average rating for each subject on each category as the outcome measure. A significant group effect emerged ($F = 22.93$, d.f. = 1/11, $P < .001$), but neither the category effect ($F = 0.008$, d.f. = 2/10, n.s.) nor the group-by-category interaction ($F = 0.001$, d.f. = 2/10, n.s.) were significant. Post hoc comparisons of group differences in ranking were significant within every category (logic: $t = 3.27$, $P < .01$; social insight: $t = 3.32$, $P < .01$; common content: $t = 2.94$, $P < .02$).

4. Discussion

These data demonstrated that the TAT narratives of all five individuals with complete ACC ranked at or near the bottom in story logic, social insight, and appreciation of common story content, with little overlap between individuals with complete ACC and controls. In contrast, the one subject with partial ACC (25% of his anterior corpus callosum present) performed better than controls in all three TAT categories. This suggests that the corpus callosum (particularly the genu) is necessary for normal interpretation and narrative generation in response to TAT cards.

While the current results suggest that callosal absence results in failure of the ability to discern the social implications of TAT cards and to generate an appropriate story, these data do not provide information as to whether this deficit is unique to ACC. Other comparison groups that have not yet been tested may share this disorder. However, it is clinically important to describe deficits consistently associated with the normally intelligent individual with ACC, particularly when these persons are sometimes regarded as “asymptomatic” (Sauerwein et al., 1994).

Since all of the individuals with ACC also had some other neurological symptom or structural brain abnormality, one might question the validity of inferring that callosal agenesis was the common source of the deficits in responding to TAT cards. The case descriptions suggest a variety of symptoms such as seizures, psychopathology, attention deficit, and aggressive behavior, as well as structural brain abnormalities including cysts, enlarged ventricles, and gray matter heterotopia. However, the most likely source of a common behavioral deficit is a common brain abnormality, particularly when the brain abnormality is the absence of such a large structure as the corpus callosum. Presence of a variety of other behavioral diagnoses or brain abnormalities is more likely to add variance and obscure any common neuropsychological deficits than to result in a common deficit.

Another argument in favor of callosal absence being the source of the deficit is the absence of any deficit in the participant with partial ACC (P1). This individual had a history

of obsessive–compulsive symptoms, seizures, anti-seizure medications, and MRI evidence of a cystic area in the left frontal lobe. What is more, relative to the other individuals with ACC, participant P1 did not have a higher FSIQ or VIQ with which he might have compensated for his neurological abnormalities. Nevertheless, the TAT stories produced by P1 were at the top of the rankings in all the three categories. Thus, absence of the anterior corpus callosum seems to be an important contributor to poor TAT story-generation. Neither agenesis of the posterior corpus callosum, nor any of the other behavioral symptoms or structural brain abnormalities present in P1, appeared to have played an important role in the outcome. Finally, the absence of complex and socially rich TAT stories in individuals with complete ACC is consistent with previous findings of alexithymia in commissurotomy patients (Hoppe & Bogen, 1977), in neurologically intact patients with diminished interhemispheric transfer (Dewaraja & Sasaki, 1990; Zeitlin, Lane, O'Leary, & Schrift, 1989), and the case of ACC reported by Buchanan et al. (1980). Alexithymia is manifest in concrete thought, inability to find appropriate words to describe feelings, speech focused on repetitive details, poor fantasy life, lack of dreams, and lack of emotional expressiveness (Lesser, 1981; Sifneos, 1972, 1973). These symptoms would imply an inability to generate stories with appropriate social and emotional content to scenes presented in TAT cards. Hoppe and Bogen (1977) hypothesized that interhemispheric disconnection results in alexithymia by limiting the transfer of the affective experiences of the right hemisphere to the verbal control centers of the left hemisphere.

If the results presented herein are related to congenital absence of the corpus callosum rather than other neuropathology, what is the specific nature of the deficit in generating appropriate TAT stories? The following four hypotheses are suggested: (1) a problem with narrative language generation; (2) diminished emotional responsiveness; (3) reduced ability to communicate the elaborated semantic associations of the right hemisphere to the language centers of the left hemisphere; and (4) a failure of imagination due to reduction in the interconnectedness of the cortical networks necessary for more elaborative and creative thinking.

Deficits in expressive language ability in ACC can be ruled out on several accounts. First, controls for whom English was not their first language were able to perform at a similar level to English-first controls on all categories, indicating that these categories and the ranking procedure were not sensitive to primary language skill. Group comparison of verbal skills (VIQ) and fund of information (Information subtest) indicated no difference between the ACC and controls. However, the control group had significantly lower Vocabulary scores, indicating that the control group had a more limited range of words from which to choose in story-telling. Furthermore, the individual with partial ACC, who performed very well in TAT story-telling, had significantly lower VIQ and Vocabulary scores than the controls. Finally, neither clinical observations of the individuals with ACC nor reports from their relatives suggest an inability to tell a story if the information is already available in memory. By using a specific personal experience or familiar story, some individuals with ACC were able to generate coherent narratives. However, these narratives were usually poorly suited to the pictures, resulting in poor ratings on social insight and use of common content.

Another explanation for the current results might be lack of emotional responsiveness and consequent lack of empathetic emotional responses to enrich their story-generation. Again, this explanation would not be consistent with either laboratory observations of these individuals with ACC or parent descriptions. For example, anecdotal reports from one parent included

descriptions of situations in which he was both very angry (an argument with his father) and appropriately sad (the funeral of a grandparent).

Classic hemispheric laterality theory suggests that the right hemisphere plays an important role in processing socio-emotional information. The right hemisphere has been shown to be predominant for recognition of affect-laden speech and vocal prosody (e.g., Heilman, Scholes, & Watson, 1975; Starkstein, Federoff, Price, Leiguarda, & Robinson, 1994; Van Lancker, Kreiman, & Cummings, 1989; Van Lancker & Sidsis, 1992), recognition of faces and facial expressions (e.g., Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000; Asthana & Mandal, 2001; Mandal, Tandon, & Asthana, 1991; Marzi & Berlucchi, 1977; Newcombe, de Haan, Ross, & Young, 1989), expression of vocal prosody, gestures, and facial expressions (e.g., Tucker, 1981; Weintraub & Meulam, 1983), the broader semantic meanings of words (e.g., Burgess & Simpson, 1988; Chiarello, Burgess, Richards, & Pollock, 1990), and a sense of personal relevance (Van Lancker, 1991). Split-brain phenomenology would suggest that the cerebral commissures are important for transmitting this information to the speech generation areas of the left hemisphere (Sperry, Gazzaniga, & Bogen, 1969).

The results of progressive callosotomy on interhemispheric transfer of semantic information in the patient described by Sidsis, Volpe, Holtzman, Wilson, and Gazzaniga (1981) imply that the anterior corpus callosum can transfer semantically rich information, but cannot transfer specific visual, phonetic, or lexical information about words presented in the left visual field. Thus, there is reason to believe that complete ACC would result in some degree of isolation within the nondominant hemisphere of information about the broader semantic context of TAT pictures, and therefore, this information would not be available to the story-generating mechanisms of the left hemisphere. The results reported by Sidsis et al. (1981) would also suggest why presence of the genu in P1 would allow for stories with greater breadth of associative and semantic richness. This theory of reduced communication of the products of right hemisphere processing to left hemisphere language systems was the interpretation given by Hoppe and Bogen (1977) of alexithymia in split-brain patients.

Finally, the deficits described in this study may have been due to a reduced ability to imagine and think creatively. Bogen and Bogen (1988) hypothesized that the corpus callosum is necessary for creativity. It is clear that absence of the more than 200 million axons that would normally interconnect the cerebral hemispheres significantly reduces the richness of interconnectivity of cortical processing areas. This reduced interconnectivity would limit the complexity of cortical networks available to process the multivariate information necessary to image an appropriate past history and future outcome implied in TAT pictures. Deficits in imaginative perception of ambiguous stimuli were also evident in the impaired Rorschach performances of two cases of complete ACC described by Brown and Paul (2000).

The TAT was not used in this research according to its typical clinical application. In essence, we borrowed six TAT cards in order to provide standard, widely recognized, and socially complex stimuli for which the typical response of a normal individual would be well known by an experienced clinician. When protocols were evaluated according to the three content categories used in this study, the TAT was successful in eliciting important information about the ability of these subjects to comprehend social context and generate an appropriate narrative.

These data add significantly to the clinical neuropsychological description of individuals with ACC and normal-range IQs. Generation of an appropriate story based on the social and

interpersonal significance of pictures is not something that individuals with complete ACC can do in a normal fashion. Thus, testing of the neuropsychological status of an individual with ACC should not be limited to tests of old information and automatized mental processes, but should also include tests of the capacity for novel problem solving and imaginative language generation.

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