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Emotional arousal in agenesis of the corpus callosum

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Abstract

While the processing of verbal and psychophysiological indices of emotional arousal have been investigated extensively in relation to the left and right cerebral hemispheres, it remains poorly understood how both hemispheres normally function together to generate emotional responses to stimuli. Drawing on a unique sample of nine high-functioning subjects with complete agenesis of the corpus callosum (AgCC), we investigated this issue using standardized emotional visual stimuli. Compared to healthy controls, subjects with AgCC showed a larger variance in their cognitive ratings of valence and arousal, and an insensitivity to the emotion category of the stimuli, especially for negatively-valenced stimuli, and especially for their arousal. Despite their impaired cognitive ratings of arousal, some subjects with AgCC showed large skin-conductance responses, and in general skin-conductance responses discriminated emotion categories and correlated with stimulus arousal ratings. We suggest that largely intact right hemisphere mechanisms can support psychophysiological emotional responses, but that the lack of interhemispheric communication between the hemispheres, perhaps together with dysfunction of the anterior cingulate cortex, interferes with normal verbal ratings of arousal, a mechanism in line with some models of alexithymia.

Keywords: Agenesis of the corpus callosum; Emotional arousal; Emotional visual stimuli

1. Introduction

Patients with primary agenesis of the corpus callosum (AgCC) provide a unique opportunity to investigate the role of interhemispheric information transfer in social cognition. Primary AgCC is defined by complete absence of the corpus callosum, with minimal additional neuropathology and general cognitive functioning in the normal range (i.e., FSIQ>80). While such individuals can still utilize crosstalk via the anterior and subcortical commissures, these are small by comparison to the 200 million or so axons that typically comprise the human corpus callosum. It is intriguing that the principal domain of deficit for these patients is in the social sphere, deficits which are typically more evident to their significant others than to the patients themselves. A small but growing body of literature has examined difficulties in social processing in individuals with primary agenesis of the corpus callosum (Brown and Paul, 2000; Paul et al., 2004, 2003), but the mechanisms underlying these difficulties remain essentially unknown. Social processing requires the interaction of complex cognitive skills and emotional responsiveness. The literature to date regarding primary AgCC has hypothesized that the social deficits in this group are secondary to impairments in novel complex problem solving (Brown and Paul, 2000). While there is evidence of impaired problem solving in both non-emotional tasks (Brown and Paul, 2000; Garrels et al., 2001; Schieffer et al., 2000a,b; Symington et al., 2004a,b) and complex tasks involving emotional stimuli (Paul et al., 2004; Symington et al., 2004a,b), the nature of psychophysiological responsiveness in individuals with AgCC has not been investigated to date. The current study initiates an examination of both verbal recognition of emotional arousal and autonomic psychophysiological

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arousal in primary AgCC using standardized emotional images from the International Affective Picture Series (Lang et al., 1988).

1.1. Relationship between social and emotional processes

Neurological evidence has indicated that specific structures link emotional responses and cognition. Some examples of such findings are the correlated impairments in emotional response and complex social judgment following amygdala damage (Adolphs et al., 1998), and in emotional response and social decision-making following damage to the ventromedial prefrontal cortex (Bechara et al., 2000). Neuroimaging studies during the deliberation of risky decisions (e.g., in financial decision-making) found activation in the ventromedial and orbital frontal cortices (Critchley et al., 2000; O'Doherty et al., 2001). Likewise, Greene et al. (2001) found greater activation in frontal pole, posterior cingulate gyrus, and angular gyrus, when subjects were faced with moral dilemmas that recruited strong emotional responses. A substantial recent literature has identified a network of structures that mediate between our emotional responses to stimuli, and the cognition and behavior that ensues (Adolphs, 1999, 2003).

One issue of particular importance concerns the relative specializations of the left and right cerebral hemispheres in such processing. Differentially lateralized processing has been well documented for certain functions such as language, but the roles of each hemisphere in processing emotional and social information have been much more difficult to understand. However, Ross et al. (1994) have proposed a distinction between processing primary emotions by the right hemisphere, and socially related emotions by the left hemisphere. There are several other models of lateralized emotion processing that have been popular in the literature, which we briefly review next.

1.2. Lateralized processing of emotion

Historically, the right hemisphere has been thought to play a disproportionate role in emotional and social processing (Keenan et al., 1999, 2001). It has been argued that the right hemisphere may contain systems for social communication that are in many ways complementary to the left hemisphere' clear specialization for language (Blonder et al., 1993). Earlier studies showed that damage to the right hemisphere can impair discrimination, recognition, and naming of emotional faces or scenes (DeKosky et al., 1980), and suggested that the right hemisphere's role encompasses a variety of channels, including voice, face, and others (Borod, 1993).

Two main theories have been put forth to elaborate on the right hemisphere's role in emotion processing: that the right hemisphere participates in processing all emotions (the "right hemisphere hypothesis"), or that the right hemisphere is relatively specialized to process negative emotions, whereas the left hemisphere is relatively specialized to process positive emotions (the "valence hypothesis") (see Borod et al., 1998 and Canli, 1999 for reviews). To date, there has been some evidence pointing both to the right hemisphere hypothesis (e.g., Borod et al., 1998; Burt and Perrett, 1997), as well as data supporting the valence hypothesis (e.g., Canli, 1999; Lee et al., 2004; Reuter-Lorentz and Davidson, 1981), but the data are not compelling. Some modifications propose that the valence hypothesis may indeed hold for the experience and perhaps the expression of emotions, but that the perception of emotion is better described according to the right hemisphere hypothesis (Borod, 1992; Bryden, 1982; Canli, 1999). On the other hand, there is evidence that both the perception of emotion and aspects of the experience (awareness of the details of one's feelings) rely on the same right hemisphere mechanisms (Lane et al., 1995). There is also the related hypothesis that regions of lateral prefrontal cortex are specialized to process emotions/behaviors related to withdrawal (on the right) and approach (on the left) (Davidson, 1992; Davidson and Irwin, 1999).

A recent meta-analysis of 65 neuroimaging studies of emotion has led to revision of the above picture (Wager et al., 2003). The analysis found that, while there is indeed evidence for neural specialization for certain categories of emotion, dividing such specialization along the lines of "right hemisphere/left hemisphere" is too coarse a division. Rather, there appear to be differences in processing certain emotion categories (such as approach/withdrawal) related to specific neural structures (some of which indeed may show hemispheric asymmetry).

Overall, these revisions to older views of the roles of the cerebral hemispheres in emotion processing suggest that both left and right hemispheres interact importantly in emotion processing. However, there continues to be good evidence that the right hemisphere is more involved in processing of exteroceptive emotion cues, as well as in regulating psychophysiological emotional arousal (Morrow et al., 1981; Tranel and Damasio, 1994; Zoccolotti et al., 1982).

The above debates notwithstanding, it is clear that verbal labeling of emotions requires left hemisphere processing, given that language production is lateralized to the left hemisphere in the vast majority of people. One could thus envision the two hemispheres working in concert when tasks require verbal ratings of emotions, with the right hemisphere providing emotional expression and perception processing independently of language, and transfer of such processing to the left hemisphere being required in order to produce verbal descriptions and labels for the emotions.

An important finding that demonstrates the transfer of information between right and left hemispheres is an anomia for visually presented emotional facial expressions following focal damage in right posterior neocortex and white matter, despite intact facial recognition and emotional matching of the faces (Bowers and Heilman, 1984; Rapcsak et al., 1993, 1989). Given the selective emotional anomia found in these subjects, it appears unlikely that their impairment resulted from a general defect in recognizing the emotion, or a general defect in naming ability (although it should be noted that processing emotional speech content indeed appears to rely more on the right than the left hemisphere (Borod et al., 1992, 2000). Instead, it is plausible that these patients suffered from a disconnection between, on the one hand, information in right posterior cortices about the emotion shown in the face, and, on