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**The interhemispheric transfer of emotional speech
in the intact brain**

by

Heather McNeely, B A

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of
the requirements for the degree of
Master of Arts

Department of Psychology

**Carleton University
Ottawa, Ontario
July 17, 1996**

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**"The interhemispheric transfer of emotional speech
in the intact brain"**

submitted by **Heather McNeely, B A.**

in partial fulfilment of the requirements for

the degree of **Master of Arts**

Bill Jones, Ph D., Chair
Department of Psychology

Shelley Parlow, Ph D
Thesis Supervisor

CARLETON UNIVERSITY

July 24, 1996

Abstract

This study was conducted to investigate the cerebral organization of emotional speech processing in the intact brain. Using a dichotic listening methodology, the interhemisphere interaction model of emotional speech was tested. This model proposes that if emotional prosody recognition and verbalization are differentially lateralized in the brain, enhanced interhemispheric exchange of information will occur when comparison of these two domains is relevant. Analyses were conducted to see if the processes involved in emotional prosody recognition and verbalization of emotional information are lateralized to the right and left hemispheres, respectively. A test involving the integration of these two lateralized domains was compared to another measure of efficiency of interhemispheric communication. Eighty-one Introductory Psychology students participated in this study. After eliminating outliers, 62 right handed participants remained, mean age 22.3 years (S.D. 3.78). There were 18 males, mean age 22.0 years (S.D. 2.13) and 44 females, mean age 22.4 years (S.D. 4.29). Dichotic listening results indicated that efficiency of interhemispheric communication was related to the ability to recognize and verbalize emotional speech in this sample. Sex differences related to hemispheric specialization and overall accuracy for emotional prosody recognition and verbalization were also found.

Interhemispheric Transfer of Emotional Speech

Acknowledgements

Two individuals made significant contributions to this project, and I would like to take this opportunity to extend my thanks. First, I would like to thank my supervisor, Dr. S. E. Parlow, for her most valuable help and guidance in the development of the theoretical and methodological design of this project. Her support was instrumental in making this research project a success. I would also like to thank Dr. J. Logan for providing both technical assistance and computer equipment for the production of the three dichotic listening tapes created for this study.

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(e.g., Bryden, Free, Gagne & Groff, 1991, McNeely, 1994). It is well established that the left hemisphere is primarily responsible for linguistic functions in most people (Leibman, 1991), but the distinct role that the left hemisphere plays in emotional speech has not been clearly investigated. Nor is it well understood how the two hemispheres work together to integrate the verbal and prosodic aspects of emotional speech. The present study was conducted to investigate the cerebral processes underlying the recognition of emotional prosody and its integration with the verbal aspects of emotional speech.

Four theoretical models of cerebral functioning in human emotional experience have been proposed in the literature. These models are based on the results of studies of emotion recognition communicated via many different modalities including facial expressions, film clips, memories, and prosody in both brain damaged and cerebrally intact participants. While three of these models discuss emotional functioning without regard to the modality of the stimuli, the interhemisphere interaction model applies particularly well to the understanding of emotional speech. This model was originally established to make sense of symptoms associated with a specific emotional disorder called alexithymia, which literally means "no words for mood" (Zeitlin, Lane, O'Leary & Schrift, 1989). Alexithymics are unable to recognize and verbalize emotions. Researchers in two labs (TenHouten, Hoppe, Bogan & Walter, 1986; Zeitlin, Lane, O'Leary & Schrift, 1989) have recently proposed that in the normal brain, emotion recognition centres in the right hemisphere must communicate with linguistic centres

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Emotional cognition plays a very important role in many aspects of human social communication (Collins & Kuczaj, 1991, Plutchik, 1988). According to Arndt and Janney (1991), "the ability to express and interpret feelings and attitudes is necessary for regulating personal affairs in all cultures" (p 521). These authors put into words what most people understand intuitively, that is, that the ability to produce, coordinate and understand emotional signals in speech is a "prerequisite for negotiating claims to power, respect, or equality, defining degrees of intimacy, showing affiliation or nonaffiliation, avoiding face threats, repairing interpersonal misunderstandings, and so forth" (Arndt & Janney, 1991, p 521-522). Although emotional communication plays some role in all aspects of our lives, the cerebral processes involved in the production, coordination, and comprehension of emotional speech are not well understood.

Humans communicate emotions through both linguistic and non-linguistic elements. Specifically, words convey their literal meaning, but information as to the true intentions of the speaker is often conveyed through non-verbal modes such as facial expressions, gestures, and the use of affective tone. According to Dawes and Kramer (1966), "affective tone is a pervasive dimension of interpersonal behaviour" (p 574). Emotional prosody is a term used to describe affective tone created by the modulation of the human voice in communicating emotion. Researchers have shown that the right hemisphere is dominant for the recognition of emotional prosody in both brain damaged (e.g., Heilman & Bowers, 1990) and in cerebrally intact individuals

(e.g., Bryden, Free, Gagne & Groff, 1991, McNeely, 1994). It is well established that the left hemisphere is primarily responsible for linguistic functions in most people (Leibman, 1991), but the distinct role that the left hemisphere plays in emotional speech has not been clearly investigated. Nor is it well understood how the two hemispheres work together to integrate the verbal and prosodic aspects of emotional speech. The present study was conducted to investigate the cerebral processes underlying the recognition of emotional prosody and its integration with the verbal aspects of emotional speech.

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in the left hemisphere in order to process emotional speech. They argue that this process is disrupted in alexithymia. In the present study, the interhemisphere interaction model of emotional speech was tested with a normal population.

Before elaborating on the interhemisphere interaction model and how it was tested in the present study, some background issues regarding the investigation of the neuropsychology of emotion are addressed. General issues in the neuropsychological investigation of emotion are presented first. These general issues include: (1) cerebral organization, (2) theories of emotion, and (3) theories of callosal connectivity. Theoretical issues specific to understanding the features of emotional speech are also addressed, followed by methodological issues of relevance to the present study.

General Issues in the Neuropsychological Investigation of Emotional Speech

Cerebral Organization

Hemispheric Specialization of Function

It is well established that the two hemispheres are differentially specialized for various functions. Over the past several decades, research with brain damaged, commissurotomed, and cerebrally intact individuals has revealed much regarding the specialization of function in the left and right cerebral hemispheres. In general, the left hemisphere has been found to be specialized for processing verbal (Bulman-Flemming & Bryden, 1995), analytic, and sequential material (Bradshaw & Nettleton,

1981) while the right hemisphere has been found to be specialized for processing nonverbal, visual-spatial, and holistic material (Critchley, 1991; Heller, 1990).

Left hemisphere linguistic functions.

Benson (1993) recently wrote: "In no other animal species and no other human function is hemispheric specialization as dramatic or nearly complete as is the unilateral concentration of language capability in the left hemisphere of the right handed adult human" (p.18). Indeed, virtually all right handed, and most non-right handed, individuals have language skills located in the left hemisphere.

This fact first came to light in the late 1800's, when French surgeon Paul Broca examined post-mortem the brains of several patients who had suffered language impairment of sudden origin. He found that in 95% of the cases, there was a common lesion in a small area of the left frontal lobe. Later research confirmed that damage to this area is associated with the inability to produce normal speech, and this part of the brain became known as Broca's area. Subsequently, it was shown that damage restricted to Broca's area resulted in only a temporary speech loss, while damage involving Broca's area and the surrounding area of the left frontal lobe results in a more severe, long-lasting loss of expressive speech. Similar damage to the right frontal lobe does not result in loss of speech. The role that left frontal regions play in language production has been further substantiated with the use of computerized brain scanning equipment. Such modern technology allows one to see the increase in cerebral blood flow, signifying cerebral activity, to these areas of the left frontal lobe

of the intact brain during speech production (summarized from a review by Kalat, 1988)

While people with damage to Broca's area can comprehend language better than they can produce it, those who suffer damage to another area of the left hemisphere show the opposite pattern. After damage to a particular area of the left temporal lobe, patients produce fluent, nonsensical speech. They do not understand spoken or written language, their own or that of others (Benson, 1993). In 1874, Carl Wernicke observed a language comprehension deficit, in the absence of expressive speech disorder, in patients who had damage to a particular area of the left temporal lobe, now called Wernicke's area (Kalat, 1988).

In summary, it is now widely accepted that Broca's area in the left frontal lobe is responsible for the production of speech in the normal brain, while Wernicke's area in the left temporal lobe is involved in the comprehension of language. However, depending on the nature and location of brain damage within the left hemisphere, several sub-types of language disorder, called aphasia, may be observed. Therefore, it is important to note that left hemisphere linguistic processing is not isolated to these two distinct regions. The interested reader should see Benson (1993) for a review of aphasia.

Right hemisphere emotional prosody recognition.

It is well established that in normal humans, the right hemisphere plays a dominant role in the recognition of many types of emotional stimuli (Borod, 1993;

Bryden & Ley, 1983), including emotional prosody (Bowers, Bauer & Heilman, 1993; Emmorey, 1987). The earliest observations indicating hemispheric specialization for emotional prosody were made by Hughlings Jackson in the late 1800's. He concluded that emotional speech was preserved in aphasic patients with left hemisphere lesions, as they could say "yes" or "no" in tones expressive of different feelings (see Borod, 1993; Morais & Ladavas, 1987; Shapiro & Danly, 1985; Shields, 1991).

Recent studies have confirmed that emotional prosody recognition is predominantly a function of the right hemisphere (for a review see Heilman & Bowers, 1990). For example, Heilman, Bowers, Speedie and Coslett (1984) presented right hemisphere damaged (RHD) patients, left hemisphere damaged (LHD) patients, and normal controls with sentences filtered so that speech content was unintelligible. The participants were asked to identify the emotional tone of the stimuli (happy, sad, or angry) either verbally or by pointing to a line drawing of a facial expression of the emotion. The RHD group performed significantly worse than the LHD group and the normal controls, indicating that the right hemisphere is dominantly involved in the recognition of emotional prosody. Similar results have also been reported by Tompkins and Flowers (1985) and Tompkins (1991).

Convergent evidence for the role of the right hemisphere in processing emotional prosody also comes from dichotic listening studies with cerebrally intact participants. Several studies have revealed a significant left ear advantage for recognizing emotional prosody in normal subjects (e.g., Bryden et al., 1991; Hatta &

Aytetani, 1985; Herrero & Hillix, 1990; Shipley-Brown, Dingwall, Berlin, Yeni-Komshian & Gordon-Salant, 1988), with more emotional tones being correctly identified from the left ear than from the right ear. Taken together, the results of studies with brain damaged and with intact subjects provide quite strong evidence that the right hemisphere is dominant for the recognition of emotional prosody

Crossed Organization

As discussed above, the cerebral cortex is divided into two halves, or hemispheres, one on the left and one on the right. Each hemisphere receives most of its sensory information from the contralateral (opposite) side of the body and controls most body movement on the contralateral side as well (Kalat, 1988). In fact, the hemispheres have only limited motor control and sensory input from the ipsilateral (the same) side of the body (Kalat, 1988). Thus, one can generally assume that the left side of the brain controls and receives input from the right side of the body and the right side of the brain controls and receives input from the left side of the body

Since the present study focusses on the auditory modality, the remainder of the discussion of the functional organization of the brain focusses on the organization of the auditory system. In terms of the auditory system, the principle of crossed organization outlined above means that the sensory information presented to the right ear is sent primarily to the left auditory cortex, while sound presented to the left ear is sent primarily to the right auditory cortex (Bryden, 1988). Although some auditory information is transmitted to the ipsilateral auditory cortex, this stimulation is much

weaker than the contralateral stimulation. Recent evidence indicates that when there is dichotic presentation of auditory stimuli, ascending contralateral auditory pathways are "stronger, more numerous, and more rapidly conducting than ipsilateral ones" (Bryden, 1988, p. 10; see also Bryden & Bulman-Flemming, 1994). Due to this crossed arrangement, right ear input is better received at the left auditory cortex and vice versa (see Appendix A).

Interhemispheric Transfer of Information

Sensory and motor information is transmitted to the contralateral side of the brain or body via bundles of axons, called the commissural fibres (Bogen, 1993; Leibman, 1991). The largest of the commissural fibre tracts is the corpus callosum (Bogen, 1993; Leibman, 1991), which runs longitudinally between the two cerebral hemispheres. The cell bodies of these fibres lie in both cerebral hemispheres. The corpus callosum can be sub-divided into four sections, proceeding from the front of the brain to the back: rostrum, genu, body, and splenium (see Appendix B). Medical cases in which callosal fibres have been surgically separated as a treatment for epilepsy (an operation called commissurotomy) or injured in some way, have provided evidence that the corpus callosum performs a variety of important roles, including the transfer of information between the two hemispheres (see Bogen, 1993 for a review). Studies in which only part of the corpus callosum has been damaged suggest that there may be channels within the callosum differentiated by the types of information carried within them (Banich, 1995).

Of particular relevance to the present study is the interhemispheric transfer of auditory information, particularly verbal and emotional information. During the course of a commissurotomy in which the sections of the corpus callosum were cut in stages, Sidtis, Holtzman, Wilson and Gazzangia (1981) observed that cutting the anterior 3 to 4 cm of the corpus callosum is sufficient to produce auditory disconnection for verbal information (described in Sidtis, 1988). Left ear performance on dichotic consonant-vowel syllables fell from 67% before surgery to 23% after surgery while right ear performance increased from 77% to 100%. The low left ear score occurred because verbal information presented to the right auditory cortex could not be transmitted across the corpus callosum to the left hemisphere language centres. This finding indicates that under normal circumstances, verbal auditory information is transmitted through the fibres located in the anterior 3 to 4 cm of the corpus callosum. There is also some evidence based on partial commissurotomy data that verbal motor information responsible for the production of speech crosses at the genu, while other linguistic information crosses at the splenium (Roeltgen, 1993).

According to one school of thought, channel specialization within the corpus callosum results from the organization of the brain in general. Anterior portions of the callosum connect anterior sections of the brain and more posterior sections connect posterior portions of the two hemispheres (Banich, 1995). Neuroanatomical studies with monkeys have confirmed the presence of discrete fibre channels within the corpus callosum that do not overlap with other areas. However, in humans, this segregation

appears to be less precise than previously believed. For instance, while it was assumed that fibres carrying somatosensory information were located anterior to those carrying auditory information, it appears that these two types of fibres may be intermixed (Banich, 1995).

A note of caution is in order when interpreting information about modality specific callosal channels. The information regarding channels is based on inferences drawn from behavioural disturbances after callosal damage or section in a small number of individuals. Extraneous factors associated with brain injury may influence post-traumatic behaviour such that clear cause and effect relationships about callosal organization cannot be reliably stated (Heilman & Valenstein, 1993). In summary, while evidence clearly indicates that information crosses between the two brain hemispheres via the callosal fibres (see Bogen, 1993; Sidtis, 1988), evidence regarding specialized information transfer at particular portions, or channels, of the corpus callosum should only be used as a guide for further research. Nevertheless, the implication is that the callosum should not be thought of as a unitary information transfer system, but as a collection of fibres capable of acting independently (Banich, 1995).

Theories of Emotion

As discussed above, a consensus as to the general organization of the human brain has been reached. However, the specific neurophysiological systems involved in

various types of emotional processing are less well understood. Several general theories regarding the cerebral organization of emotion have been proposed, and the three most common are discussed below. Because the present study investigated a specific aspect of emotional functioning, emotional speech recognition and verbalization, the interhemisphere interaction theory of emotional speech is considered in most detail below.

Hierarchical Theory of Emotion

Hierarchical theories of emotion have been proposed by researchers including Leventhal (1979, 1984) and Buck (1989). According to Buck (1989), there is a biologically based hierarchy of primary motivational-emotional systems, called primes. At a basic level, primary emotions preserve homeostasis and adaptation. For example, in response to physical pain, a fearful response promotes the "fight or flight" survival instinct. The autonomic nervous system prepares the organism for action by heightening essential functions such as heart rate and muscle tonus, while decreasing non-essential ones such as digestion (Reeve, 1992). This basic "lower level", or sub-cortical, system fuses various sources of information, including stimuli from the environment, into a crude but quick representation of the emotional situation. The resulting motor, autonomic and subjective reactions fuse together in an "undifferentiated experiential matrix" (Tucker & Frederick, 1989, p 38). Thus, at a very basic level, primary emotions such as fearful interact with bodily systems to promote a quick, instinctive, survival reaction.

In contrast, the "higher level" cortical emotional memory system forms a more reflective analogue of emotional experience. Primes interact with learning and cognition so that at higher levels the behavioural manifestations of emotions are very complex. This is the processing route that is most likely involved when complex emotional information such as behaviour of others must be evaluated (Gainotti, Caltagirone & Zoccolotti, 1993). For example, in social situations, one does not necessarily respond instinctively to emotional primes. Instead, humans learn through experience to reflect on their feelings and consider the consequences of various reactions. As such, a primary emotional response, such as fighting, may be modified by cognition. "If I hit him everyone will think I'm an jerk and he's liable to press charges". The basic sub-cortical emotional response is thus modified by higher learned cognitive processes.

Multi-Component Theory of Emotional Functioning

Hierarchical theory describes human emotional functioning in terms of interactions between functions operating at different levels of cognition. Other theorists emphasize the concept that emotional functioning is made up of distinct components. According to Gainotti et al. (1993), in the context of a complex social environment, emotions must be conceptualized as an "organized multi-component system". These components include the perception of emotion, the comprehension or understanding of emotion, and the production of emotional

expressions Bored (1993) also supports the notion of a multi-component system of emotional functions involving these three major elements

Hierarchical and multi-component theories are easily reconciled The perceptual component of emotional experience is likely a "lower level", or sub-cortical, process Sensory information regarding the emotional stimulus is registered by the appropriate sensory system, (for example, visual information is received by cells in the retina). This information becomes part of the "undifferentiated experiential matrix" of the sub-cortical emotional memory system This basic sensory information is then shared with higher, cortical, levels of processing, at which point the sensory information may be reflected upon and interpreted in comparison to memory for previous emotional events. In this sense, the comprehension of emotion requires cortical processing. With regards to the third component of emotional functioning, a response to emotional information may be mediated by either sub-cortical or cortical systems. In response to primary emotional information, response behaviour is an instinctive "knee-jerk" reaction - something one does "without thinking", so to speak For example, you may scream when startled. However, this instinctive reaction may be inhibited by higher level cognitive processes, and a "planned" response may be substituted. For example, when you consider the intentions of the person who startled you, and the social situation, you may respond by saying, "Oh, you caught me off guard!" The latter would reflect higher cortical processing.

In summary, one may conceptualize emotional functioning in terms of a multi-component hierarchical system. The three components of emotional functioning described above involve differing levels of sub-cortical and cortical processing, as well as interaction between hierarchical levels. The present study focuses on the recognition and interpretation of emotional speech stimuli, therefore, both sub-cortical and cortical processing levels of processing are likely involved. However, neither hierarchical or multi-component theories refer to the cerebral organization of the specific processes involved in integrating the verbal and prosodic aspects of emotional speech. In contrast, the interhemisphere interaction theory does refer to the specific processes involved in emotional speech. However, before discussing the interhemisphere interaction theory, it is necessary to gain an understanding of hemispheric specialization theories of emotion.

Hemispheric Specialization Theories of Emotion

Currently, there is a debate in the literature regarding hemispheric specialization for emotion. Evidence supporting the 'right hemisphere hypothesis' indicates that the right hemisphere is dominant for emotion regardless of valence (e.g., Bored et al., 1988, Bryden & Ley, 1983; Christman & Hackworth, 1993, Heilman et al., 1984, Herrero & Hillix, 1990), while the 'valence hypothesis' is based on the argument that the left hemisphere is involved in positively valenced emotions while the right is involved in negatively valenced emotions (e.g., Dimond & Farrington, 1977).

The valence hypothesis

After damage to the right hemisphere, patients are more likely to exhibit an inappropriately cheerful or indifferent mood, while those afflicted with left hemisphere damage are more likely to be depressed (Bryden, 1982). Emotional changes have also been noted during selective sedation of each hemisphere after lateralized sodium amytal injection (the Wada test). This procedure is used primarily to determine the locus of speech in patients who are about to undergo brain surgery for epilepsy or tumour removal, therefore it is important to keep in mind that these patients do not have normal cerebral organization. However, when the right hemisphere is anesthetized, most patients exhibit a euphoric reaction, but when the left hemisphere is inactivated most patients become depressed (Collet & Duclaux, 1987, Gainotti et al., 1993). These emotional reactions are interpreted as reflecting the non-anesthetized hemisphere's characteristic emotional style, and have been cited as evidence for a left hemisphere involvement in positive emotions and a right hemisphere involvement in negative emotions (Bear, 1983, Tucker & Frederick, 1989).

These findings have been corroborated by the results of research with cerebrally intact individuals. Electroencephalogram (EEG) studies have revealed greater relative right frontal activation to be associated with negative emotional behaviours (distress, gaze aversion) in normal infants, while greater relative left frontal activation is associated with positive, approach behaviours (positive vocalizations, expressions of joy, reaching out with hands) (Fox, 1991). Furthermore, in adults,

positive mood has been associated with greater relative left frontal EEG activation, and negative mood (disgust) with significantly greater relative right frontal EEG activation (Davidson, Ekman, Saron, Senulis & Freisen, 1990).

As such, the results of studies of emotional experience, or mood, in brain damaged, cerebrally anesthetized, and cerebrally intact subjects indicate that there is a relationship between valence and lateralization of emotional function. These results have been interpreted as support for role of the right hemisphere in processing negative emotion, and the left hemisphere in processing positive emotion.

The right hemisphere hypothesis.

The ability to evaluate emotional information in all modalities appears to preferentially involve the right hemisphere regardless of the valence of the stimuli. This ability is disrupted by damage to the right temporo-parietal regions, but not by damage to the equivalent areas of the left hemisphere (Heller, 1990). For example, in tasks that require the identification of emotional prosody in semantically neutral sentences, patients with right hemisphere damage typically perform more poorly than those with damage to the left hemisphere (Heilman & Bowers, 1990). Similarly, the recognition of emotional facial expressions (positive and negative) is more disrupted in patients with right hemisphere damage compared to those with similar damage to the left hemisphere, and to normal controls (Kulikov & Sidorova, 1985). Since recognition of emotion is more impaired after right hemisphere damage than after left, this has been cited as evidence supporting the dominance of the right hemisphere in

the recognition of emotion regardless of valence. Similar results have been reported by Bowers et al. (1993).

The results of brain damage studies have been corroborated by research with a cerebrally intact population. Various studies with non-brain damaged participants have revealed a right hemisphere superiority for the recognition of emotional prosody (Bryden et al, 1991; Bryden & MacRea, 1988; McNeely, 1994), as well as for facial expressions of emotion (Bored & Koff, 1990; Bryden & Ley, 1983; Hirschman & Safer, 1982).

Interpretation and Integration of the Hemispheric Specialization Theories

This review of the literature suggests that the valence hypothesis predicts mood, but not the recognition of emotional stimuli. If there is cerebral asymmetry for processing positive versus negative emotions as proposed by the valence hypothesis, one would expect right and left hemisphere damaged patients to exhibit particular emotion recognition deficits. In effect, one would expect right hemisphere damaged patients to be impaired at recognizing negative but not positive emotions, and the reverse for left hemisphere damaged patients. However, Bowers, Bauer and Heilman (1993) report that they have "never found evidence for hemisphere-specific valance asymmetries across any of [their] affect-perception studies with focal lesion patients" (p.439). The absence of a valence effect has also been noted in a literature review by Bored (1993).

The discrepancy between the valence hypothesis and the right hemisphere hypothesis may be resolved if one realizes that "there is no compelling reason to assume, as is commonly done, that because a hemisphere is associated with a particular mood state, that hemisphere is specialized to process information corresponding to that emotion" (Heller, 1990; p. 169). In light of the multi-component model of emotional functioning, one may interpret the discrepant "emotion" results in the following manner. The neuropsychological system specialized for emotional perception and evaluation regardless of valence may be located within the right hemisphere. Distinct from this right hemisphere system, a separate neuropsychological system for mood incorporates relative levels of activity of both the right and left hemispheres. As such, when a task involves the subjective experience of emotions or feelings, a neuropsychological system involving both left and right hemisphere activity is involved.

This interpretation has been supported in reviews of the literature in this area (Bowers et al., 1993; Heller, 1990; Pereverzeva, 1980; Ross, 1984), as well as by recent evidence from Bowers et al. (1993). Bowers et al. report that right hemisphere damaged patients are impaired at "reading" facial and prosodic affective cues regardless of valence. However, when the same patients are asked to recall personal emotional experiences, some evidence for a valence effect emerged. Left hemisphere damaged patients were more likely to recall negatively toned memories than the right hemisphere damaged patients who did not differ from normal controls. These results

highlight the neuropsychological distinction between the perception and the experience of emotion and support the theory that separate neuropsychological systems subserve these different components of emotional functioning.

The present study concerns the *recognition* of emotional prosody, and not the *experience* of emotion or mood. Therefore, the emotional prosody recognition centre(s) referred to in the remainder of this paper are assumed to be lateralized to the right hemisphere. A discussion of the cerebral processes involved in the experience of emotion will not be undertaken here (the interested reader should see Heller, 1990).

The Interhemisphere Interaction Theory of Emotional Speech

The three theories described above are based on the results of emotion communicated via many different modalities, all of which may have different neuropsychological substrates in the normal brain. The interhemisphere interaction model was developed to explain the particular neuropsychological processes involved in emotional speech. This model is based on the assumption that "if processing of linguistic content and emotional intonation depend on cognitive systems differentially lateralized in the brain, enhanced interhemispheric exchanges of information are likely to occur when comparison of the two dimensions is especially relevant" (Morais & Ladavas, 1987, p.90).

The interhemisphere interaction model has been best articulated by TenHouten, Hoppe, Bogen and Walter (1986) in order to explain the symptoms associated with alexithymia. Alexithymia is a multidimensional personality construct defined by the

following four characteristics: (1) difficulty identifying and describing feelings, (2) difficulty distinguishing between feelings and bodily sensations of emotional arousal, (3) restricted imagination, and (4) concrete and reality-based cognitive style (Taylor, Bagby, Ryan & Parker, 1990). It has been proposed that "alexithymia has as a contributing neurophysiological basis a relative lack of communication between the left and right cerebral hemispheres" (TenHouten et al., 1986, p. 312). This theory hinges on the assumption that the ability to recognize emotions is lateralized to the right hemisphere while the ability to verbally label these emotions is lateralized to the left hemisphere. A deficit or disconnection affecting communication between these two parts of the brain results in inability to verbally articulate emotions, characteristic of alexithymia (Zeitlin et al., 1989).

The interhemispheric interaction model evolved from earlier work by Hoppe and Bogen (1977), who studied the emotional expression of epileptic patients before and after commissurotomy. After the surgical separation of the two hemispheres, some of their patients exhibited a paucity of emotional speech similar to that of alexithymic individuals. This observation led Hoppe (1977) to suggest that a "functional commissurotomy" or inhibition of callosal activity may be the underlying cause of alexithymia.

Hoppe's functional commissurotomy hypothesis has been supported by research involving both commissurotomized and cerebrally intact individuals. TenHouten, Hoppe, Bogen and Walter (1986) studied the spoken and written responses to a film

depicting death and loss produced by eight commissurotomed patients and their matched controls. The commissurotomy patients were much more like alexithymics than were the controls. For example, the patients used significantly fewer affect-laden words; they tended not to fantasize, imagine, or interpret emotional symbols; and they tended to describe circumstances surrounding events rather than their feelings about the events, all of which are characteristics of alexithymia. An exception was one control subject who was highly alexithymic. The fact that one presumably cerebrally intact control subject was deficient in the ability to recognize and verbalize emotions depicted in the film is important because it indicates that a complete commissurotomy may be a sufficient, but not a necessary, condition for alexithymic symptoms (TenHouten et al., 1986). Rather, a "functional commissurotomy" or lack of communication between the two sides of the brain may be sufficient to cause a deficit in the recognition and verbalization of emotions.

Further research by Zeitlin et al. (1989) with cerebrally intact individuals produced evidence to support the hypothesis that a functional commissurotomy may be related to alexithymic symptoms. Zeitlin et al. assessed interhemispheric transfer of tactile information in two groups, alexithymic Post Traumatic Stress Disorder patients, and normal controls. If the functional commissurotomy hypothesis is correct, alexithymic individuals should have a lower level of interhemispheric transfer compared to normal controls. This is exactly what these researchers found, as outlined below.

A tactile finger localization task was used as a behavioural measure of interhemispheric transfer. The task involves isolating sensory input to the fingertips. The examiner touches the fingertips of blindfolded participants. In the uncrossed condition, the participant is asked to indicate the fingertip that was touched by pointing to it with the thumb of the same hand. As activity is isolated to one hand, processing is thought to involve only the hemisphere contralateral to the hand being touched. In contrast, the crossed condition involves interhemispheric communication, as this time the participant indicates which fingertip was touched by pointing to it with the opposite hand. For example, if the right index fingertip was touched, the participant is required to point to it with the left index finger, and the sensory information from the hemisphere contralateral to the right index finger (i.e., the left) must be communicated to the motor processes of the hemisphere controlling the left index finger (i.e., the right). Using this measure, Zeitlin et al. (1989) found a strong association between alexithymia as measured by the Toronto Alexithymia Scale (TAS), and lack of interhemispheric communication. The authors interpreted these results as supporting the hypothesis that interhemispheric communication is required for the recognition and verbalization of emotional information.

Theories of Callosal Connectivity

The corpus callosum plays a large role in the interhemisphere interaction model of emotional speech, as this pathway is believed to be the primary structure involved

in linking the two cortical structures concerned. However, despite a recent increase in the amount of research pertaining to the commissural fibres, researchers such as Clarke and Zaidel (1994) admit that the functions of the corpus callosum in higher cognitive processing are not well understood. Clarke and Zaidel (1994) describe two models which have emerged in the literature to provide a theoretical basis for making predictions as to the possible relationships between degree of callosal connectivity and behavioural laterality effects. The excitatory and inhibitory models of callosal connectivity are discussed below.

The Excitatory Model

The excitatory model assumes that the corpus callosum's major role is to share information between the two cerebral hemispheres. In this model, as callosal connectivity increases, the amount of information that is transmitted, or shared, between the hemispheres also increases. Therefore, someone with high callosal connectivity should be relatively proficient at performing tasks which require the integration of information between two different sides of the brain, such as the recognition and verbalization of emotional speech.

The Inhibitory Model

The other theoretical model of callosal connectivity described by Clarke and Zaidel (1994) proposes that the primary role of the corpus callosum is to inhibit transfer of information between the two cerebral hemispheres. In effect, the callosal fibres form a "shield" between the lateralized activities of the two sides of the brain

In this case, higher callosal connectivity would result in better shielding of information, highlighting the differences between the two hemispheres. In terms of the interhemisphere interaction model of emotional speech, given an inhibitory role, higher callosal connectivity would decrease the transfer of information between right hemisphere emotional prosody centres and left hemisphere verbal centres, resulting in decreased ability to recognize emotional speech. The implications these two models of callosal connectivity have for hypotheses about the recognition and verbalization of emotion in the present study will be discussed subsequently.

Specific Theoretical Considerations in the Investigation of Emotional Speech

Features of Emotional Speech

As mentioned above, emotional speech is composed of both verbal and emotional elements. The verbal aspects of emotional speech are also referred to as the segmental features of language, while the emotional aspects of speech are included in the suprasegmental features of language.

Segmental Features of Language

Language involves a pairing of sounds with meaning. In English, sounds such as "b" and "e" have meaning only in conjunction with other sounds, for example in the word "be". These sounds are referred to as segments, which are combined to create meaningful words. Some words may have meaning in isolation, such as "thanks" or "hello". However, words are also combined to form phrases which convey meaning

beyond that of a single word. For example, the words, "I am leaving home now", form a relationship which conveys a meaning beyond that of any individual word. This type of meaning is referred to as propositional.

Language is used by speakers to perform speech acts. While words may be used to convey their linguistic meaning (i.e. the meaning of the words and combinations of words), the true intentions of the speaker are often communicated by the way in which the words are uttered. For example, the words "you look terrific" may be used as a compliment or as an insult depending on the speaker's intentions. To perform this, and other, speech acts, speakers use not only the segmental level but also what is referred to as the suprasegmental level of language (summarized from personal communication with Ann Stuart Laubstein, July 18, 1996).

Suprasegmental Features of Language

Meaning of a sentence is often altered by the way in which it is spoken. Literally meaning "above the segment", suprasegmental features of language serve to enhance the propositional aspects of speech. One way meaning may be modified is by conveying emotional information (Ross, 1993). The suprasegmental features which are employed to modify speech include: pitch, loudness, timbre, tempo, stress, accent, pauses, intonation and melody, all of which may be subsumed under the term prosody (Ross, 1993).

Prosody refers to the melodic line of speech (Cancelliere & Kertesz, 1990), which is produced by the suprasegmental features listed above. Prosody may be

divided into four components: intrinsic, intellectual, inarticulate and emotional (described in Ross, 1993). Intrinsic prosody serves specific linguistic functions in speech, such as syntactical disambiguation. For instance, raising intonation at the end of a sentence indicates that a question is being asked. Intellectual prosody is used to convey the speaker's attitude, for example, by stressing certain words in a sentence one may convey sarcasm. Inarticulate prosody involves the use of paralinguistic elements such as grunts and sighs. Finally, emotional prosody refers to the use of melodic signals to communicate affective information such as happiness, anger, sorrow, etc. (Bored, 1993; Emmorey, 1987; Ross, 1993; Shapiro & Danly, 1985; Shipley-Brown et al., 1988). For example, with the addition of emotional prosody indicating anger (such as rapid, high volume pronunciation) the phrase "I am leaving home now" conveys more information about the true intentions of the speaker above and beyond the information communicated via the propositional aspects of language alone.

In summary, emotional speech is made up of two major elements: the segmental features, or verbal element, and the suprasegmental features, or emotional prosodic element. As described above, the recognition of these two features of emotional speech occur within opposite hemispheres of the normal human brain. Processing associated with the verbal element is lateralized to the left hemisphere while processing associated with emotional prosody is lateralized to the right hemisphere. According to the interhemisphere interaction theory, emotional speech

results when these two aspects of speech information are combined through information transfer across the corpus callosum

Methodological Considerations

Dichotic Listening

This study, like most other investigations of the cerebral organization of emotional speech in the intact brain, involves the use of dichotic listening tests. Dichotic listening is a non-invasive method of assessing cerebral lateralization of function, and it has been used to investigate the lateralization of several types of auditory stimuli including environmental sounds (Krashen, 1973, Piazza, 1980), music (Gates & Bradshaw, 1977; McNeely, 1994), words (Wexler & Hawles, 1983), and emotional prosody (Bryden et al , 1991; McNeely, 1994; Shipley-Brown et al , 1988).

During a traditional dichotic listening task, different auditory stimuli are presented simultaneously to each ear, and participants are asked to describe what they hear. An indirect index of hemispheric specialization for the information presented is calculated based on the difference in the number of correct responses given from the right ear (left hemisphere) versus the left ear (right hemisphere). In general, a right ear advantage (REA) is found on verbal tasks, while a left ear advantage (LEA) is found for non-verbal material (Bryden & Bulman-Flemming, 1994, Hugdahl, 1995)

Dichotic listening may also be used to assess interhemispheric communication. For example, in order for verbal stimuli to be recognized after presentation to the left

ear, stimuli must be transmitted via the corpus callosum to left hemisphere language centres. Thus, a higher left ear score on a verbal dichotic listening task may be interpreted as reflecting higher, or more efficient, interhemispheric communication (Clarke & Zaidel, 1994).

In the present study, both traditional and alternative interpretations of dichotic listening are used. Two of the tests, the Emotional Prosody Recognition (EPR) task (McNeely, 1996) and the Verbal Emotional Contexts (VEC) task (McNeely, 1996), are used in the traditional sense to assess hemispheric specialization of function. Interhemispheric communication of verbal information is assessed using the Fused Dichotic Words Test (FDWT, Wexler & Hawles, 1983). The details of these particular tasks are discussed subsequently.

Subject strategies in dichotic listening

Differences in the strategy participants use to complete dichotic listening tasks are sometimes problematic for interpretation of observed ear advantages. In many dichotic listening tasks, subjects are presented with competing auditory stimuli at each ear and are asked to report all they can, thus leaving the strategy for accomplishing the task up to the individual. If a participant attempts to compensate for the distraction of competing stimuli by attending selectively to the right ear, for example, the right ear score will be artificially inflated.

However, there are ways to minimize the potential for selective attention in dichotic listening. In the Fused Dichotic Words Test stimulus qualities have been

improved to decrease selective attention. In this dichotic listening task, subjects hear simultaneous presentation of two words that differ in first letter only, for example goat in the right ear and coat in the left. The two words fuse together to form the perception of one word. Since the subject experiences hearing only one word in both ears, subject strategies are decreased as they are unlikely to try to selectively attend to one ear or the other. Nevertheless, the item that is heard more often is the one presented to the right ear. This fused dichotic test yields a very consistent and robust right ear advantage in normal right handed subjects (Bryden, 1988, Wexler & Hawles, 1983).

Another dichotic listening task used in the present study, the Dichotic Emotion Recognition Task (DERT, McNeely, 1996), is designed with the intent of minimizing the potential for selective attention. In this task, similar nonsense phrases are presented to both ears simultaneously. In one ear the phrase is spoken with an emotional tone, in the other with a neutral tone, varying randomly between the ears. The purpose is to name to the emotional tone. Participants are instructed to attend to both ears, and must do so to adequately perform the task since they cannot predict which ear will be presented with the emotional tone. Therefore, it is unlikely that a participant would actively try to attend to one ear or the other. The potential for selective attention in the DERT is further reduced by the nature of the sound qualities. The same female voice is heard in both ears, played at the same volume, with onset and offset times synchronized to the tenth of a second. The similarity of the sounds in

both ears diminishes the potential for selective attention as it is very difficult to differentiate between the ears.

Sex Differences

Although there is some evidence of sex-related differences in lateralization of function, and also in the efficiency of interhemispheric communication, these findings are not consistent in the literature. For example, while Piazza (1980) found a greater right ear advantage for verbal stimuli for males as opposed to females, Hiscock and Hiscock (1988) found the opposite. In terms of the lateralization of emotion recognition, at least one study of facial expression of emotion indicated that females were more strongly right hemisphere lateralized for emotion recognition than males (Ladavas, Umiltà & Ricci-Bitti, 1980). However, some dichotic listening studies have found evidence that males are more likely to exhibit a left ear advantage for emotional prosody (Bryden et al., 1991; McNeely, 1994), while Herrero and Hillix (1990) found no effect of sex for the recognition of emotional prosody. However, as these studies varied in many ways including differences in modality of stimuli, it is not possible to determine a clear consensus regarding sex differences in the lateralization of linguistic and emotional processing.

Inconsistent results have also been found when sex differences in efficiency of interhemispheric communication have been examined. In terms of the anatomy of the corpus callosum, several studies investigating sex differences in callosal length and area have found no significant differences between males and females (see Witelson &

Kigar, 1984 for a review). However, more recent information suggests that the minimum body width of the corpus callosum may be larger in females than in males (Clarke & Zaidel, 1994). Although it is not clear how, callosal size could theoretically influence interhemispheric communication. Given the excitatory model, a larger fibre tract would presumably facilitate and enhance sharing of information between the two sides of the brain. This would predict greater interhemispheric transfer of information in females. Alternatively, in terms of the inhibitory model, a larger fibre tract could enhance the inhibition of interhemispheric communication, which would mean poorer interhemispheric communication in females. Since evidence for sex differences in callosal size are inconclusive, and the effects of larger callosal size on interhemispheric transmission are unknown, both males and females were included in order to explore for any sex-related differences in lateralization of function and interhemispheric communication.

Handedness

There is fairly consistent evidence indicating that left handers are less likely to have "typical" cerebral organization. For example, left handers are less likely to have left hemisphere language representation (Bryden et al., 1991) in that they are less likely to show the typical right ear preference on verbal dichotic listening tasks (Bradshaw, 1989; Bryden et al., 1991; McNeely, 1994). This suggests that left handers are more likely than right handers to have right hemisphere or bi-lateral language representation.

There is also some evidence of callosal differences in left handers. Some anatomical evidence indicates that the posterior portion of the corpus callosum may be thicker in left handers (Hellige, 1993). This area of the corpus callosum is believed to connect the parietal and temporal lobes, which are involved in language, learned motor sequences, and visuo-spatial functions (Hellige, 1993). If true, in terms of the excitatory model of callosal connectivity one would expect enhanced performance by left handers on tasks that require integration of information between the right and left parietal and temporal lobes. Or, in terms of the inhibitory model, left handers would perform more poorly on tasks that require integration of information between right and left parietal and temporal lobes. In contrast, Clarke and Zaidel (1994) found no handedness differences in callosal measures, and interpreted this finding as consistent with the majority of studies that have examined this issue.

The present study is designed to require interhemispheric communication between prosodic and linguistic centres. As such, the results could be biased if individuals with atypical language lateralization or differences in interhemispheric communication are included. Since it is well established that left handers are more likely to have atypical language lateralization than right handers, and in view of evidence that they may also have anatomical callosal differences, only right handers are included in the present study.

Carry-over Effects

Carry-over effects occur when the effects of one experimental condition are still present when the participant begins the next task. Thus changes induced by the first task could affect performance on the second task (Cozby, 1989). In the present study, the changes caused by the experimental tasks have to do with priming one hemisphere or the other, depending on the nature of the stimuli presented. When a verbal dichotic listening task is presented first, the left hemisphere, which is specialized for verbal processing, becomes more activated than the right. The left hemisphere is thus primed to receive verbal stimuli. If another verbal task is administered following the first one, left hemisphere performance would be enhanced because that hemisphere had already been primed.

In the present study, the order of test administration is counterbalanced so as to decrease the possibility of lateralized hemispheric priming effects being carried-over from one task to the next. The order of the dichotic listening tasks is set up so that the content switches between a right hemisphere dominant task and a left hemisphere dominant task.

Order Effects

Another potential problem associated with a within subjects design such as that used in the present study, is the effect of task order, when the order of presenting the tests affects the dependent variable(s) (Cozby, 1989). In effect, being given a particular test second rather than third could differentially influence performance

possibly due to practice effects. As described in detail in the section on design of the present study, two different task orders are used to attempt to exert some control over order effects in the present study

Valence of Affective Stimuli

The dichotic listening tasks in the present study involve emotional stimuli of four different valences: happy, sad, angry and fearful. In effect, there are three "negative" emotions but only one "positive". The supporters of the "valence hypothesis", discussed above, would argue that the greater number of negative emotions would bias responses in favour of the right hemisphere. This theory proposes that the right hemisphere is dominant for processing negative emotional stimuli, while the left plays a dominant role in processing positive emotional stimuli. If this were the case, a higher number of negative emotional stimuli would bias responses to an emotion recognition task in favour of the right hemisphere.

However, comprehensive reviews of the literature, also discussed above, indicate that hemispheric differences related to valence apply only to the *experience* of emotion, and not to the recognition of emotion. Evidence supports the dominant role of the right hemisphere in the *recognition* of emotion regardless of valence (e.g., Bored et al., 1988; Bryden & Ley, 1983; Christman & Hackworth, 1993; Heilman et al., 1984; Herrero & Hillix, 1990). Since the present study involves the recognition of

emotional tone, the inclusion of three negative versus one positive emotional valence is not expected to bias responses.

The use of the emotions happy, sad, angry and fearful is consistent with the emotion recognition literature. The majority of studies using dichotic listening to assess emotional prosody recognition have used these four emotional tones (e.g., Bryden et al., 1991). Although a few studies have included surprise as a positive emotion (e.g., Lalande, Braun, Charlebois & Whitaker, 1992), it is not used in the present study as it was anticipated that surprise would be difficult to convey with emotional prosody. As well, the use of surprise would be less consistent with the majority of previous studies.

Design of the Present Study

The interhemisphere interaction model was developed to explain specific cognitive/emotional deficits associated with alexithymia. However, evidence regarding the association of a "functional" commissurotomy with alexithymia indicates that this model may provide a reasonable theoretical basis for the investigation of the neuropsychology of emotional speech in the intact brain. In the present study, the applicability of this model for understanding the cerebral organization of emotional speech in the intact brain is tested using a within subjects design.

A significant limitation to the Zeitlin et al. (1989) test of the interhemisphere interaction model of emotional speech, is the way in which interhemispheric

communication was assessed. The authors point out that the "finger localization task is not the most appropriate way to assess the deficit in interhemispheric communication associated with alexithymia" (p. 1438). The crossed condition finger localization deficits exhibited by the alexithymics suggest the possibility of a generalized interhemispheric transfer deficit. However, when theorizing about the cerebral processes involved in emotional speech, an interhemispheric communication task involving emotional stimuli is a more appropriate measure.

Ideally, this interhemispheric communication test would involve the integration of emotional prosody and verbal information. Bulman-Flemming and Bryden (1995) used a dichotic listening task in which the words bower, tower, power and dower are spoken in happy, sad, angry and neutral emotional tones, and the subject is instructed to listen for a two component target, such as tower spoken in an angry tone. Although this test does involve the integration of verbal and prosodic information, it does not reflect the complex phrases that make up "real-life" emotional speech. Therefore, the Dichotic Emotion Recognition Test (DERT, McNeely, 1996), described below, was created to establish an experimental situation that would reflect the cerebral processing required in "real-life" emotional speech.

Assessing the Recognition and Verbalization of Emotional Speech

To interpret information in emotional speech, one must recognize the emotional prosody being conveyed and then verbally articulate this information. The DERT was designed to involve both of these aspects of processing. In this task, nonsense phrases

such as "dan hite ruffa gorp", spoken in varying intensities of the emotional tones happy, sad, angry and fearful, are paired dichotically with similar nonsense phrases spoken in a neutral tone of voice. The emotional and neural phrases vary randomly between the ears, and subjects are asked to say the name of the emotional tone that they hear. In effect, subjects are required to recognize the emotional prosody (right hemisphere processing) and then verbalize it (left hemisphere processing). As such, the processing demands of this task require interhemispheric communication.

The total score on the DERT is used as a measure of participants' ability to integrate emotional prosody and verbal information from the two hemispheres. If the interhemisphere interaction theory of emotional speech is supported, those with efficient interhemispheric communication should have a high DERT score, while those with less efficient interhemispheric communication should have a low DERT score.

The DERT is administered twice during the testing session. Since the DERT is the test of most theoretical interest in this study, to avoid potential carry-over effects from other tasks it is included early in the testing session. The results of the first administration of the DERT (DERT1) reflect the participant's ability to recognize and verbalize emotions before any potential priming may have occurred due to their experience with the other dichotic listening tests. Thus, total score on DERT1 could be interpreted as reflecting participants' "true" ability to recognize and verbalize emotional speech information. However, it is also possible that at the beginning of the testing session participants might be experiencing some nervousness about being in an

experiment, which could affect performance. Also, since dichotic listening tends to be a novel and, at first, a somewhat confusing task for most people, it is possible that performance on DERT1 may be further confounded by participants being unprepared for the task. Thus, although DERT1 total score reflects "true" ability to recognize and verbalize emotional speech, it could also reflect, at least somewhat, the effects of subject nervousness and inexperience with a task.

The second administration of the DERT (DERT2) takes place after the participant completes all of the dichotic listening tasks except for the Fused Dichotic Words Test. At this point, participants are more relaxed and familiar with the experimental situation and with the dichotic listening methodology. Given this, DERT2 total score may be considered a more accurate reflection of participants' ability to recognize and verbalize emotional speech, unhindered by the effects of nervousness or unfamiliarity with a task. However, DERT2 performance is certainly influenced by a practice effect from DERT1, as well as from experience with the other dichotic listening tests. Nevertheless, carry-over effects are not likely to directly influence DERT2 scores, as participants spend the 15 minutes directly preceding the second administration filling out questionnaires.

Total scores from both administrations of the DERT are included in separate analyses to examine the effects that order of test administration has on the ability to recognize and verbalize emotional speech information.

Assessing Alexithymia

The present study is concerned with one of the characteristics of alexithymia, the recognition and verbalization of emotion, and the DERT has been designed to specifically assess this characteristic. However, the Toronto Alexithymia Scale (TAS, Bagby, Taylor, Parker & Loisele, 1990) is included as an established measure of the alexithymia construct. Including the TAS also allows for a more direct comparison of the present study with the Zeitlin et al. (1989) study, which compared TAS scores to interhemispheric communication of tactile information.

Assessing Efficiency of Interhemispheric Communication

To see if the ability to recognize and verbalize emotional speech information on the DERT is related to efficiency of interhemispheric communication, another measure of interhemispheric communication is needed. To maintain a consistent methodology between the tests used in the present study, another dichotic listening test is used to assess efficiency of interhemispheric communication.

A non-standard interpretation of the Fused Dichotic Words Test (FDWT, Wexler & Hawles, 1983) is used in the present study to assess interhemispheric communication of verbal stimuli. During this task, participants hear the simultaneous presentation of two words that differ in first letter only, such as goat in the right ear and coat in the left. The two words fuse together so that the participant perceives only one word. A response is made by circling the word they heard on a list of four

similar words. Typically, more words are chosen after presentation to the right ear (Bryden, 1988; Wexler & Hawles, 1983).

In the traditional use of this test, a laterality index is calculated to determine language lateralization. The original formula developed by Wexler and Hawles (1983) for use with the FDWT is: $\text{right ear score} - \text{left ear score} / \text{right ear score} + \text{left ear score}$. The denominator is included to control for overall accuracy of responses. Use of this formula has been shown to give a robust right ear advantage (Bryden & Bulman-Flemming, 1994), which has been interpreted as supporting left hemisphere lateralization for verbal stimuli. This interpretation has been corroborated by work by Zattore (1989), who found a very robust right ear advantage on this test which was closely related to language lateralization as determined by the Wada test.

An alternate method of interpreting the results of the FDWT involves calculating a measure of efficiency of interhemispheric communication. The rationale behind this method stems from the theory that words chosen after left ear presentation reflect interhemispheric communication while words chosen after right ear presentation do not reflect interhemispheric communication (Clarke & Zaidel, 1994). In the present study, a measure of efficiency of interhemispheric communication is calculated with the following formula: $\text{total correct left ear responses} - \text{total correct right ear responses}$. This method of calculating a difference score was also used by Brizzolara, Ferretti, Brovedani, Casalini and Sbrana (1994) to calculate interhemispheric transfer time (IHTT), in a testing paradigm in which subjects respond to a lateralized visual

stimulus with either the ipsilateral (uncrossed, no interhemispheric communication) or contralateral (crossed, interhemispheric communication required) hand Brizzolara et al. subtracted uncrossed hand/hemifield reaction time from crossed hand/hemifield reaction time.

A difference score is calculated as a measure of interhemispheric communication rather than looking at left ear scores alone. This controls for overall accuracy differences. For example, if someone has poor hearing and has a relatively low number of correct responses from both ears, their left ear score alone would be low compared to the rest of the sample group. The denominator of the original Wexler and Hawles (1983) equation was dropped from the alternative formula used in the present study. Accuracy was not judged to be a potential problem in the present study as participants performed at 96.5% accuracy on the FDWT. Furthermore, the use of the formula left ear score - right ear score (without the denominator) is consistent with that used by Brizzolara et al. (1994).

Control of Potential Lateralized Deficits

In any study in which interhemispheric communication between two different regions of the brain is assessed, it is necessary to ensure that unilateral processing in each lateralized region is intact (Banich, 1995). Otherwise, deficits restricted to one hemisphere or the other could be misinterpreted as deficits in interhemispheric communication. Zeitlin et al. (1989) recognized this necessity. However, the way in which they attempted to meet this control was not optimal.

Zeitlin et al (1989) recognized that, due to the role of the right hemisphere in the recognition of emotion, and the role of the left in verbal functions, a deficit in either of these lateralized functions could contribute to alexithymic symptoms. To ensure that lateralized functioning of the right and left hemispheres were intact in their participants, Zeitlin et al. (1989) compared left hand and right hand performance on the uncrossed condition of the finger localization task. As discussed above, the uncrossed condition of this task does not involve interhemispheric transfer of information. Since alexithymics' left and right hand performance in the uncrossed condition was normal, the authors concluded that "the deficit in alexithymic individuals is not due to a dysfunction in the right or left hemisphere but, rather, is specific to interhemispheric transfer" (Zeitlin et al., 1989, p. 1437).

However, establishing that the sensori-motor functions of the left and right hemispheres were normal was not an adequate control for the possibility of selective deficits to either left hemisphere language or right hemisphere emotional prosody centres. To control for these particular possible deficits, tasks specifically designed to unilaterally assess left hemisphere linguistic functions and right hemisphere emotional prosody functions should have been employed. The present study includes such control tasks to establish that the separate verbal and prosodic functions of the two hemispheres are intact.

Right Hemisphere Emotional Prosody Recognition

To verify that participants have adequate emotional prosody recognition, a purely nonverbal emotional prosody recognition control task is needed. This requirement would be fulfilled by an emotional prosody recognition task involving a non-verbal response. To be consistent with the right hemisphere processing taking place during the DERT, another dichotic listening task was created specifically for this study.

The Emotional Prosody Recognition Task (EPR, McNeely, 1996) involves the dichotic presentation of the same nonsense phrases as used in the DERT. In the EPR task, the nonsense phrases are paired with meaningless jumbles of linguistic sounds called cocktail party noise. Participants are asked to attend to both ears, and ignoring the content of the phrases (nonsense), indicate the emotional tone used by the speaker by pointing to a choice of four pictures of a female face showing happy, sad, angry and fearful expressions (Ekman & Freisen, 1975). Participants use a pencil held in the left hand to point to the appropriate facial expression. Since this task is intended to assess unilateral right hemisphere processing of emotional prosody, the left hand response is employed for two reasons: (1) it does not require left hemisphere verbal processing which could confound right hemisphere emotional processing, and (2) left hand pointing reflects right hemisphere motor activity which could enhance right hemisphere functioning (see Ely, Graves & Potter, 1989 for similar use of left hand

motor response). Therefore, this task is expected to reflect unilateral right hemisphere recognition of emotional prosody.

Left Hemisphere Verbal Processing

To ensure that unilateral left hemisphere emotional speech functions is adequate, a purely verbal dichotic listening task involving recognizing and labelling emotions is needed. Although several dichotic listening tasks with verbal stimuli are available, including the FDWT, none of these tasks deal specifically with verbal material particular to emotional speech. Therefore, a third dichotic listening test was created specifically for this study.

The Verbal Emotional Contexts Task (VEC, McNeely, 1996) involves the dichotic presentation emotionally meaningful sentences paired with cocktail party noise. For example, the sentence "You must leave someone you hold dear" is spoken in a neutral, "matter of fact" voice, paired with cocktail party noise. Participants are asked to attend equally to both ears and to verbally identify the emotion implied in the context of the sentence, in this example, sadness. Since the stimuli in this task are segmentally related meaningful words, and the response is spoken word, this task is considered to involve unilateral verbal processing. Therefore, a right ear advantage is expected. This would support the role of the left hemisphere in recognizing and verbally labelling linguistic emotional information.

The stimulus sentences used in this task were originally used by Braun, Baribeau, Ethier, Daigneault and Proulx (1989), and a French version was used by

Lalande et al. (1992) in studies with brain damaged participants. In these studies the sentences were presented monaurally. The task was modified for the present study by pairing the sentences with cocktail party noise for dichotic presentation, thus increasing the difficulty of the task. This is necessary because a young normal sample is expected to have more efficient cognitive functioning than an older clinical sample. Since the sentences were designed by Braun et al. (1989) for use with an older clinical population, they were piloted with a university student population before being recorded in dichotic format.

A pilot sample of 22 university students (12 females and 10 males), with a mean age of 25.8 years (S.D. = 4.6) , was given a list of the 23 emotionally connotative sentences on paper (Appendix D), and asked to indicate the emotion implied in each sentence by circling one of the four choices: happy, sad, angry or fearful. Overall, there was an 86% concordance between the pilot sample responses and the emotions intended to be implied in the sentences. This concordance rate compares well to the 85% concordance rate observed by the normal controls in the Lalande et al. (1992) study. It was concluded that these phrases could be reliably used with a university student population.

In summary, using the EPR and VEC tasks as control conditions, it is anticipated that any lateralized deficits in the recognition of emotional prosody or verbalization of emotional information could be identified. Screening for adequate performance on these two tasks increases the probability that deficits in performance

on the DERT would not be due to unilateral deficits in either the right or left hemispheres, but to inefficient communication between these two intact regions of the brain. Therefore, the use of modality specific control tasks strengthens evidence in support of the interhemisphere interaction hypothesis.

Mood and the Recognition and Verbalization of Emotional Speech

It has been proposed that differences in mood may affect the ability to recognize emotion. In particular, some research indicates that being in a negative mood affects social-emotional judgements (see Clarke & Williamson, 1989, for a review). If this is true, differences in mood could present a problem in the present study. To control for possible affects that differences in mood could have on the present study, the Beck Depression Inventory was used to measure participants' moods.

The present study is intended to find support for the interhemisphere interaction model of emotional speech by indicating that the ability to recognize and verbalize emotional prosody is positively related to efficiency of interhemispheric communication. The present study is designed to improve upon the Zeitlin et al. (1989) study in two ways: (1) more appropriate control measures are used to assess the adequacy of left hemisphere linguistic and right hemisphere emotional functions, and (2) emotional and verbal stimuli, as opposed to tactile stimuli, are used to assess interhemispheric communication in relation to emotional speech.

Hypotheses

Main Hypotheses

Based on the preceding review of the literature, with specific reference to the interhemisphere interaction model and the suggestions generated from the research by Zeitlin et al. (1989), four main hypotheses are tested in the present study. **Hypothesis 1:** there would be a significantly greater left ear versus right ear score on the Emotional Prosody Recognition task, indicating right hemisphere lateralization for the nonverbal task of recognizing emotional prosody. **Hypothesis 2:** there would be a significantly greater right ear versus left ear score on the Verbal Emotional Contexts task, indicating left hemisphere lateralization for the linguistic processes involved in emotional speech.

Hypothesis 3 states that there will be a relationship between the ability to recognize and verbalize emotional speech on the DERT, and efficiency of interhemispheric communication on the FDWT. Given the excitatory and inhibitory models of callosal connectivity discussed previously, two different outcomes are predicted for Hypothesis 3. In terms of the excitatory model of callosal connectivity, **Hypothesis 3a** predicts that higher scores on the DERT will be related to higher efficiency of interhemispheric communication. In other words, greater sharing of information between the two hemispheres will result in increased ability to recognize and verbalize emotion, as well as more words correctly recognized after presentation to the left ear on the FDWT. See Figure 1 for a graph of this hypothetical relationship

Figure 1: Excitatory model: anticipated relationship between degree of callosal connectivity and the ability to recognize and verbalize emotional speech.

In terms of the inhibitory model of callosal connectivity, Hypothesis 3b predicts that as callosal connectivity increases, scores on the DERT and left ear scores on the FDWT will both decrease. Given increased shielding of information transfer between the two hemispheres, the ability to integrate emotional prosody recognition and verbalization of emotional speech will be hampered. Greater shielding of interhemispheric exchange of information is also hypothesized to result in greater laterality effects. As such, one would expect greater right ear (left hemisphere) advantage on the FDWT as callosal connectivity increases. See Figure 2 for a graph of the hypothetical relationship between DERT total score and efficiency of interhemispheric communication on the FDWT in terms of the inhibitory model of callosal connectivity.

Figure 2: Inhibitory model: anticipated relationship between degree of callosal connectivity and the ability to recognize and verbalize emotional speech.

Hypotheses 3a and 3b make opposite predictions regarding the relationship between efficiency of interhemispheric communication and the ability to recognize and verbalize emotional speech. See Table 1 for a hypothetical comparison of the excitatory and inhibitory models with regard to performance on the tasks used to test Hypothesis 3 in the present study.

Table 1

A comparison of excitatory and inhibitory models for subjects with high callosal connectivity

Excitatory Model	Inhibitory Model
high DERT total score	low DERT total score
decreased laterality effect on FDWT	enhanced laterality effect on FDWT
higher left ear score on FDWT	lower left ear score on FDWT

To replicate the analysis performed by Zeitlin et al. (1989) as closely as possible, Hypothesis 4 predicts a significant positive relationship between TAS score and efficiency of interhemispheric communication on the FDWT. Linear Regression analyses were planned to test Hypotheses 3 and 4

Supplemental Hypotheses

Several other exploratory analyses are planned based on the literature regarding the influence of sex differences on lateralization of function and interhemispheric communication. Based on the findings of previous research by McNeely (1994) with the predecessor of the DERT, the VERT-M, it is expected that: (1) males will be more strongly right hemisphere lateralized on the DERT; but that (2) females will have a higher overall score on the DERT. Comparisons of means for males and females were planned for all four dichotic listening tasks, as well as for the Toronto Alexithymia Scale in order to clarify the nature of the difference, if any, between the sexes for these tasks.

Finally, to test the hypothesis that mood state may have influenced performance on the DERT, a regression analysis was planned to explore the relationship between Beck Depression Inventory Score and DERT total score.

Method

Participants

Eighty-one Carleton University students volunteered to participate in this study for course credit. After eliminating univariate and multivariate outliers, a total of 62 cases remained for statistical analyses. This sample of 62 students had a mean age of 22.3 (S.D. = 3.7). There were 18 males with a mean age of 22.0 years (S.D. = 2.1) and 44 females, mean age 22.4 years (S.D. = 4.2). The Edinburgh Handedness

Inventory (Oldfield, 1971; Appendix C) was used to ensure that only right handed participants were included. A handedness index was calculated based on the following formula: $(\text{total right hand choices} - \text{total left hand choices} / \text{total right hand choices} + \text{total left hand choices})$. The present sample had a mean handedness index of .80 (S.D. = .16), on a scale where +1.00 indicates complete right handedness and -1.00 indicates complete left handedness.

Apparatus

Stereo cassette deck.

All of the dichotic listening tapes used in this study were presented to participants using the AKAI Stereo Cassette Deck, Model HX - 1C, with Dolby Noise Reduction B Type and tape selector at CrO₂, with balance set at the middle.

Stereo headphones.

Participants listened to the tapes through BASS Power Sound Stereo Headphones, Model Number HP - 800V. Impedance = 8 ohms, Samarium Cobalt Magnet, Frequency Response = 16 - 22 kHz.

Procedure

Testing took place on a one-to-one basis in sessions lasting approximately 90 minutes per participant. All testing was conducted by the same female examiner, in a quiet room of the university that was free from distraction. Before beginning, all participants were informed of their rights as volunteers including the right to

discontinue at any time. All participants completed the tests in a single session each. Participants were questioned with regards to personal history of hearing deficits of any kind.

The order of test administration was counterbalanced to decrease the possibility of lateralized hemispheric priming effects being carried over from one task to the next. The order of the dichotic listening tasks was set up so that the content switched between a right hemisphere dominant task and a left hemisphere dominant task. Two different orders were used, and task order alternated between participants.

Task order 1.

- Informed consent
- Edinburgh Handedness Inventory
- Dichotic Emotion Recognition Test (DERT) Trial 1
- Verbal Emotion Recognition Test (VEC)
- Emotional Prosody Recognition Test (EPR)
- Toronto Alexithymia Scale
- Emotional Contexts Questionnaire
- Dichotic Emotion Recognition Test (DERT) Trial 2
- Fused Dichotic Words Test (FDWT)
- Beck Depression Inventory
- Debriefing

Task order 2.

- **Informed Consent**
- **Edinburgh Handedness Inventory**
- **Dichotic Emotion Recognition Test (DERT) Trial 1**
- **Emotional Prosody Recognition Test (EPR)**
- **Verbal Emotional Contexts Test (VEC)**
- **Toronto Alexithymia Scale**
- **Emotional Contexts Questionnaire**
- **Dichotic Emotion Recognition Test (DERT) Trial 2**
- **Fused Dichotic Words Test (FDWT)**
- **Beck Depression Inventory**
- **Debriefing**

Materials

Emotional Prosody Recognition (EPR) Task

Through stereo headphones, participants heard a total of 96 nonsense phrases (see Appendix D) such as "dan hite ruffa gorp" spoken by a female voice in variations of four emotional tones: happy, sad, angry and fearful. Before preparing the phrases in dichotic format, four independent raters listened to the phrases monaurally to verify that the phrases did convey the intended emotional tones, achieving an average accuracy rate of 86%. The nonsense phrases were paired dichotically with cocktail

party noise, randomized between the ears. Each ear was presented with an equivalent number of each emotional tone: 50% of trials the stimulus phrase is heard at the right ear and 50% at the left ear. Participants were instructed to attend to both ears, and ignoring the content of the phrases (nonsense), indicate the emotional tone used by the speaker. Participant responded by pointing to a choice of four pictures of a female face showing facial expressions of the emotions happy, sad, angry and fearful (Ekman & Freisen, 1975). Participants used a pencil held in the left hand to point to the facial expression. Half way through the test, participants were asked to reverse the headphones. This task took approximately 10 minutes to complete.

The number of emotional stimuli correctly identified for each ear was calculated. Since this test is hypothesized to involve right hemisphere processing, the mean number of correct left ear responses was expected to be greater than mean number of correct right ear responses. Although all participants completed the entire test battery, data was screened prior to analysis to ensure that only data from those with intact right hemisphere emotional prosody recognition were included.

Verbal Emotional Contexts (VEC) Task

Using stereo headphones, participants listened to four sets of the same 23 emotionally meaningful sentences paired dichotically with cocktail party noise. The sentences were all spoken with neutral prosody by the same female voice. Two independent raters listened to the phrases monaurally, and verified that the sentences are all spoken with neutral prosody by the same female voice. Participants were

instructed to attend to both ears and verbally state the emotion implied in the context of the sentence, in the above example, sadness. To familiarize them with the response categories, participants viewed a cue card for the first 10 sentences with the words happy, sad, angry and fearful printed in black ink. The stimulus sentences were presented randomly to each ear: 50% were presented to the right ear and 50% to the left. Half way through the task the subject was asked to reverse the headphones. This test took 12 minutes to complete.

Scores for each ear were calculated based on the number of emotions correctly identified. A response was deemed correct if it matched the response provided by the subject to the same sentences in a questionnaire format (see Appendix E). Since the stimuli are segmentally related meaningful words, and the response is a spoken word, this task was considered to involve verbal processing. Therefore, it was expected that more sentences would be correctly identified after right ear presentation. This would support the role of the left hemisphere in recognizing and verbally labelling linguistic emotional information.

Again, although all participants completed the entire test battery, data were screened prior to analysis to ensure that only data from those subjects who had normal left hemisphere recognition and verbalization of emotional words were included in further analyses.

Dichotic Emotion Recognition Task (DERT).

Through stereo headphones, participants listened to the same 96 nonsense phrases (see Appendix D) spoken by the same female voice in varying intensities of the emotional tones happy, sad, angry and fearful, as used in the EPR task. However, in the DERT, the emotionally toned phrases are paired simultaneously with similar nonsense phrases spoken with neutral prosody by the same female voice. The stimulus phrases are randomized between the two ears, for a total of 50% at the right ear and 50% at the left. An equivalent number of each of the four emotional tones is presented to each ear. Participants were instructed to attend to both ears and to verbally indicate the name of the emotional tone they heard. To familiarize them with the categories, for the first 10 pairs of phrases, participants viewed a cue card containing both pictures of the four female facial expressions used in the emotional prosody task, as well as printed labels of the four target emotions happy, sad, angry and fearful. The use of both pictorial and printed linguistic cues is intended to distribute potential priming effects between the two hemispheres, so that neither the right hemisphere emotion recognition centres nor the left hemisphere linguistic centres benefit from the cue card more than the other. This task took 10 minutes to complete.

This task was scored based on the total number of emotional tones correctly labelled. Scores could range from 0, indicating no emotional tones correctly verbalized, to 96, indicating all emotional tones correctly verbalized. To test the main

hypothesis, DERT total score was used as a continuous variable in linear regression analysis. In other analyses, mean left ear score was compared to mean right ear score to see if an ear advantage was present for this task

Fused Dichotic Words Test (FDWT)

Through stereo headphones, participants listened to the FDWT (Wexler & Hawles, 1983, Appendix F). This task involves the simultaneous presentation of two words that differ in first letter only, such as goat in the right ear and coat in the left. The two words fuse together so that the perception is of hearing only one word. Participants responded by circling the word they heard on a list of four similar words. On two occasions during the task, participants were asked to reverse the headphones. This task took approximately 10 minutes to complete.

In scoring this task, a right ear score was obtained by summing the total number of words chosen from the list that were presented to the right ear. Similarly, a left ear score was calculated. A measure of interhemispheric communication of verbal stimuli was calculated for each participant by subtracting the right ear score from the left ear score. This difference score was used to test the main hypothesis as a continuous variable in linear regression analysis.

Beck Depression Inventory.

The Beck Depression Inventory (BDI; Beck et al., 1979, Appendix G) is a well established 21 item inventory designed to measure intensity of clinical

depression. Participants are asked to select statements which best describe how they have been feeling over the past week including the day of testing. For example, "(0) I do not feel sad, (1) I feel sad, (2) I am sad all the time and I can't snap out of it, (3) I am so sad or unhappy that I can't stand it". Scores may range from 0 to 63. The original cut off scores provided by Beck et al. (1988) were used in the present study: none or minimal depression = 0 to 9; mild to moderate depression = 10 to 18; moderate to severe depression = 19 to 29; and severe depression = 30 to 63. The BDI was self administered and took approximately 10 minutes to complete. The BDI was used in the present study to assess participants' mood in order to explore the possibility that depressed mood may have some influence on the ability to recognize and verbalize emotions.

Toronto Alexithymia Scale.

The Toronto Alexithymia Scale (TAS; Bagby et al., 1990; Appendix H), is a 26 item self report measure of the alexithymia construct, which has demonstrated acceptable internal consistency and test-retest reliability in normal adult and clinical samples (Bagby et al., 1990; Taylor et al., 1990). To complete the TAS, participants were asked to state how much they agreed or disagreed with a variety of statements, using a likert scale varying from 1 (strongly disagree) to 5 (strongly agree). For example, "When I cry I always know why". This questionnaire was self-administered and took approximately 10 minutes to complete. The TAS was used to measure the extent to which participants' displayed alexithymic symptoms. TAS scores were used

as a continuous variable in comparison to efficiency of interhemispheric communication of verbal information on the FDWT.

Emotional Contexts Questionnaire.

This questionnaire (see Appendix D) contained the 23 phrases used in the Verbal Emotional Contexts dichotic listening task. Participants were asked to read the sentences describing various contexts or situations in which a particular emotion is likely to be evoked, and select the emotion that best fits the context of the sentence from the choices: happy, sad, angry, or fearful. This questionnaire took approximately 5 minutes to complete and was used to score the accuracy of each participants responses provided in the dichotic listening version (VEC) of this same set of phrases.

Creating the Three New Dichotic Listening Tasks

Recording original stimuli.

All verbal and prosodic stimuli were recorded on a single channel by the same female speaker using an AKG D320B microphone and an AKAI Stereo Cassette Deck, Model HX-1C. Dolby Noise Reduction was set at Type B, the tape selector was set at CrO₂, and the recording level was set at 7.0 on a 10 point scale. Stimuli were recorded on TDK SA60, IEC II/Type II high position cassette tapes.

Digitizing stimuli and generating dichotic listening tapes.

Stimuli were transferred to a sound file in the computer software package SoundEdit16 on a MacIntosh Performa 5200 CD computer using a Luxman Stereo

Cassette Deck, K-321, HX PRO, with the Dolby Noise Reduction setting at Type B. SoundEdit16 computer software was used to edit and pair stimuli for dichotic presentation. All voice stimuli were put through the "smooth" effect, which simulates a low pass filter smoothing out the highest frequencies and imperfections in sound quality.

Two channels were established in SoundEdit16, one for the left ear and one for the right. For the EPR and VEC tasks, cocktail party noise was imported from a SoundEdit16 CD, and amplified by 200% three times to be equivalent in amplitude to the voice stimuli. Dichotic pairs were created with voice phrase in one channel and cocktail party noise in the other, randomly switching back and forth between one ear channel and the other. For example, pair (1) voice in right ear/noise in left; pair (2) voice in left ear/noise in right, etc. For the DERT, dichotic pairs were composed of nonsense phrases spoken with emotional prosody and nonsense phrases spoken with neutral prosody.

Through SoundEdit16, onset and offset times for voice/noise and voice/voice pairs were synchronized to the tenth of a second. All inter-stimulus intervals were set at 4 seconds of silence. The two channels were mixed in SoundEdit16 to produce stereo output, and were recorded using the Luxman Stereo Cassette Deck onto TDK SA60 IEC II/ Type II High Position cassette tapes. The cassette deck settings for recording the final dichotic tapes were as follows: record balance = middle, record level = 8.0, Dolby Noise Reduction Type B.

Results

Preliminary Analyses

Prior to analysis, the data were examined using the Descriptives and Regression procedures of SPSS to check for univariate and multivariate outliers. Outliers are cases with such extreme values on one or a combination of variables that they unduly influence the results, particularly in regression analysis where the presence of an outlier may alter the slope of the regression line (Tabachnick & Fidell, 1989). Therefore, it was important to eliminate outliers before analyzing the data.

After one trial, ten univariate outliers were identified. Six cases (cases 3, 4, 29, 36, 43 and 81) were univariate outliers due to extreme z scores on Edinburgh Handedness Index, indicating extreme left handedness. Cases 12 and 59 were univariate outliers due to extreme z scores on the Verbal Emotional Contexts task, these two cases performed much more poorly than the rest of the sample on this task. Case 74 was a univariate outlier due to a high z score for Age (he was 61 years old), and case 67 was a univariate outlier due to a high z score for Hearing Loss (she had only 25% hearing in one ear). All of these univariate outliers were eliminated. Cases 21 and 22 were eliminated as technical difficulties occurred during testing. For these two cases the stereo headphones had been switched to the mono setting, rendering dichotic listening results invalid. After eliminating these twelve cases, the analysis was repeated. No additional univariate outliers were identified.

Using the criterion Mahalanobis distance with $p < .001$, two cases were identified as multivariate outliers. Cases 16 and 70 were eliminated due to extremely high scores on Mahalanobis distance. After eliminating these cases, no additional multivariate outliers were identified.

Data Screening

Data were also screened to ensure the control conditions regarding intact right hemisphere emotional prosody recognition and left hemisphere verbal processing were met. Standardized scores for the Emotional Prosody Recognition Task and the Verbal Emotional Contexts Task were examined. Any z score outside ± 3.00 indicates abnormally low or high performance on that measure (Tabachnick & Fidell, 1989). On the EPR task, all z scores were within ± 3.00 for both the right ear and the left ear on this task. This indicates that all subjects performed within an average range of each other. No individual obtained a z score less than -3.00 which would have indicated deficient right hemisphere emotional prosody recognition.

However, on the VEC task, two cases were identified which had z scores below -3.00 indicating performance worse than average on this left hemisphere processing task. Cases 12 and 59 were eliminated to control for the possibility that deficient left hemisphere processing might have confounded their performance on the DERT.

After eliminating these two cases for poor performance on the VEC task, no further cases were identified as being significantly different from the rest of the sample

for either of the two control tasks. Therefore, the remainder of the analyses were conducted with the expectation that any deficit in performance on the DERT could be attributed to differences in interhemispheric communication and not to deficits in either right hemisphere or left hemisphere processing alone.

Main Analyses

One-tailed paired t -test analyses were performed using the SPSS for Windows PC program to test Hypotheses 1 and 2. Hypothesis 1 was that there would be a higher mean left ear score than mean right ear score on the Emotional Prosody Recognition task. There was no significant difference between the mean left ear score (38.79, S.D. = 6.45) and the mean right ear score (38.36, S.D. = 6.69), $t(61) = 1.14$. Because a mean total score of 77.145 out of 96 (S.D. = 12.787) was obtained, ceiling effects did not likely contribute to the lack of significant difference between the two ears.

Hypothesis 2 was that there would be a larger right ear than left ear score on the Verbal Emotional Contexts task. Although the relationship was in the expected direction, the mean number of right ear responses (42.24, S.D. = 4.24) was not significantly larger than the mean number of left ear responses (41.85, S.D. = 4.36), $t(61) = -1.61$. A mean total score of 84.1 correct responses out of 92 (S.D. = 8.43) was observed for the sample as a whole, indicating that ceiling effects might have played a role in the ear differences on this task.

A linear regression analysis was performed using SPSS to test Hypothesis 3, that there would be a significant linear relationship between DERT total score as the dependent variable, and "interhemispheric communication" (as measured by the FDWT difference score), as the predictor. The FDWT difference score accounted for 12.7% of the variance in DERT total score for trial 1, which was significant at $F(1,60) = 8.73, p = .0045$. When administered a second time, 13.9% of the variance in DERT total score was explained by the FDWT difference score, $F(1,60) = 9.69, p = .0028$.

The nature of the relationship between performance on the DERT and efficiency of interhemispheric communication was not consistent with either of the predictions based on the two models of callosal connectivity. Given an individual with high callosal connectivity, Hypothesis (3a) predicted high DERT scores to be associated with high left ear scores relative to right ear score on the FDWT, while Hypothesis (3b) predicted low DERT scores to be associated with low left ear relative to right ear scores on the DERT. However, a significant negative linear relationship was found between DERT total score and FDWT difference score. In effect, high DERT scores were associated with low relative left ear versus right ear scores on the FDWT (see Figures 3 and 4).

Hypothesis 4, that TAS scores would be related to efficiency of interhemispheric communication (as measured by FDWT difference score) was tested using another SPSS Regression. This time, TAS score was the dependent variable and FDWT difference score was the predictor. The difference between left ear and right

ear scores on the FDWT did not account for a significant proportion of the variance in TAS score, $F(1,60) = 42$. This indicates that in the present sample, differences in alexithymic symptomatology was not related to differences in efficiency of interhemispheric communication. However, only 7 participants (11% of the sample) were classified as alexithymic, based on a TAS score greater than or equal to 74 (Taylor et al., 1990).

Figure 3: Relationship between interhemispheric communication (FDWT) & ability to recognize and verbalize emotion (DERT), for the entire sample on DERT 1

Figure 4. Relationship between interhemispheric communication (FDWT) & ability to recognize and verbalize emotional speech (DERT), for entire sample on DERT 2.

Supplemental Analyses

One-tailed paired t-tests and one-way Analysis of Variance (ANOVA) analyses were performed for additional analyses described below

Sex differences.

It was predicted that there would be a right hemisphere advantage on the DERT for the sample as a whole, and that males would be more strongly right hemisphere lateralized than females on this task. Despite the absence of a left ear advantage for the sample as a whole, a significant right hemisphere advantage was observed for males only, on the second (but not first) trial of the DERT. The mean number of left ear responses ($M = 34.7$, $S.D. = 7.7$) was significantly greater than the mean number of right ear responses ($M = 32.6$, $S.D. = 7.0$), $t(17) = 2.56$, $p = .01$. For females, the mean number of left ear responses ($M = 37.7$, $S.D. = 6.2$) did not differ significantly from the mean number of right ear responses ($M = 37.0$, $S.D. = 6.4$).

Also as predicted, when left ear and right ear scores were added together, females obtained a significantly higher mean total score ($M = 74.9$, $S.D. = 11.9$) on the second administration of this task than did males ($M = 67.3$, $S.D. = 14.3$), $F(1,60) = 4.60$, $p = .036$.

On the Emotional Prosody Recognition task, when examining males and females as separate groups, a significant right hemisphere advantage was observed for females. For females only, there was a significantly larger mean left ear score ($M =$

39.8, S.D. = 6.1) than right ear score ($M = 38.9$, S.D. = 6.6), $t(43) = 1.84$, $p = .036$.

Although females did have a higher mean total score on this task ($M = 78.7$, S.D. = 12.4) it was not significantly better than males' mean total score ($M = 73.4$, S.D. = 13.3), $F(1,60) = 2.23$.

On the Verbal Emotional Contexts task, there was no significant sex difference in terms of lateralization of verbal function. The laterality quotient for females ($M = .004$, S.D. = .02) was not significantly different from that for males ($M = .007$, S.D. = .03), $F(1,60) = .187$. However, females obtained a significantly higher VEC mean total score ($M = 85.6$, S.D. = 6.2) than males ($M = 80.3$, S.D. = 11.7), $t(1,60) = 5.43$, $p = .02$.

On the Fused Dichotic Words Test, males ($M = .112$, S.D. = .153) and females ($M = .096$, S.D. = .132) did not differ in terms of laterality quotient, $F(1,60) = .165$.

No sex difference was noted on mean Toronto Alexithymia Scale score either, males ($M = 64.4$, S.D. = 11.9) versus females ($M = 61.2$, S.D. = 10.4), $F(1,60) = 1.17$. Males and females did not differ in terms of BDI score. The mean score for males ($M = 9.2$, S.D. = 5.2) was not significantly different from the mean for females ($M = 11.6$, S.D. = 8.3), $F(1,60) = 1.21$.

Mood state and recognition of emotion.

The Beck Depression Inventory was included to control for the possibility that depressed mood, might influence the ability to recognize emotion. The mean BDI score for the entire sample was 10.9 (S.D. = 7.6) with a range of 0, indicating no

evidence of depression, to 34, indicating severely depressed mood. A Linear Regression analysis was performed to see how much of the variance in DERT total score could be predicted from the BDI scores. The result of this analysis was not significant. BDI score accounted for only 0.9% of the variance in DERT total score for the sample as a whole, $F(1,60) = .46$, and 1.5% of variance in DERT trial 2 total score, $F(1,60) = .92$.

Pearson Product Moment Correlations were performed to compare all dependent variables with each other. There was a significant correlation between BDI score and only one other variable in the present study. BDI score and TAS score were positively correlated, $r = +.297$, $p = .019$.

Task order effects.

Comparisons of means through SPSS one-way ANOVA was conducted to compare the scores of participants in the two orders of test administration, order 1 $n = 32$, and order 2 $n = 30$. There were no significant differences between the two groups on any of the experimental variables. Therefore, they were judged to represent the same overall population of university students.

However, the two order groups did differ in terms of the relationship between FDWT difference score and DERT total score. Two linear regression analyses were conducted for each order group separately, with DERT administration 1 (DERT1) total score and DERT administration 2 (DERT2) total score as the two dependent variables, and FDWT left ear - right ear difference score as the predictor in both sets of analyses.

For the order 1 sub-group, FDWT difference score did not predict a significant amount of the variance in DERT total score for either DERT1, $F(1,30) = 1.83$, $p = .186$ (Figure 5) or DERT2, $F(1,30) = .565$, $p = .458$ (Figure 6). In contrast, the negative linear relationship between DERT total score and FDWT difference score was highly significant for order sub-group 2. In DERT1, FDWT difference score accounted for 21.4% of the variance in DERT total score $F(1,28) = 7.63$, $p = .010$ (Figure 7). In DERT2, FDWT difference score explained 34.8% of the variance in DERT total score, $F(1,28) = 14.94$, $p = .0006$ (Figure 8). This suggests that order effects might have differentially influenced the correlation between efficiency of interhemispheric communication and total score on the DERT.

Figure 5 Relationship between of interhemispheric communication (FDWT) & ability to recognize and verbalize emotional speech (DERT), for task order group 1 on DERT 1.

Figure 6: Relationship between interhemispheric communication (FDWT) & ability to recognize and verbalize emotional speech (DERT), for task order group 1 on DERT 2.

Figure 7 Relationship between interhemispheric communication (FDWT) & ability to recognize and verbalize emotional speech (DERT), for task order group 2 on DERT 1.

Figure 8: Relationship between interhemispheric communication (FDWT) & ability to recognize and verbalize emotion (DERT), for task order group 2 on DERT 2.

Hypothesis 3 was tested again for the sample as a whole, this time statistically controlling for order. Multiple regression analysis was conducted two times with DERT total score for administrations 1 and 2 as the two dependent variables, with task order and FDWT difference score as the two predictors. For administration 1 of the DERT, order and FDWT difference score together accounted for 13.75% of the variance in DERT total score, $F(2,59) = 4.70$, $p = .013$. Controlling for order, FDWT difference score accounted for 12.7% of the variance in DERT total score, $F(1,59) = 8.58$, $p < .01$. Similarly, for administration 2 of the DERT, together order and FDWT difference score accounted for 13.9 % of the variance in DERT total score, $F(2,59) = 4.77$, $p = .012$. Statistically controlling for order, FDWT difference score still accounted for 13.9% of the variance in DERT total score, $F(1,59) = 9.537$, $p < .01$.

Discussion

The cerebral organization of emotional speech in the intact brain was investigated in the present study. The interhemisphere interaction model states that interhemispheric communication between right hemisphere emotional prosody recognition centres and left hemisphere verbal centres must occur in order to have normal emotional speech. Research with commissurotomy patients (Hoppe & Bogen, 1977, TenHouten et al., 1986) and alexithymics (Zeitlin et al., 1989) has found support for the role of the corpus callosum in integrating these two aspects of emotional speech. In the present study, this model was tested with a normal population.

Overall, the results of this exploratory investigation are encouraging. Two of the planned hypotheses (supplemental hypotheses 1 and 2) are supported by the data, and two are partially supported (hypotheses 1 and 3). The intriguing exception to this pattern is the relationship observed between the ability to recognize emotional prosody and verbally label it (DERT total score) and efficiency of interhemispheric communication for verbal information (FDWT difference score). Although this linear relationship is statistically significant, the form does not correspond to what would be anticipated based on either the excitatory or inhibitory models of callosal connectivity alone.

Control Conditions

A number of important "control" conditions were included in the design of this study. First, tests of the ability to recognize emotional prosody and to verbalize emotional information (the EPR and VEC tasks respectively), were intended to assess unilateral right and left hemisphere processing. All subjects in the final sample had adequate performance on these tests. Thus, any differences in the test requiring the interhemispheric integration of these two lateralized processes (the DERT) are not attributable to deficient performance by either the left or the right hemispheres alone. As such, this is considered to be an improvement upon the Zeitlin et al. (1989) study, which used the Tactile Finger Localization Task to ensure that unilateral processing of the right and left hemispheres were intact.

The Beck Depression Inventory was included in the present study to control for the possibility that mood state might differentially influence the ability to recognize and verbalize emotional speech on the DERT. Despite a sufficient range of scores on the BDI, differences in mood do not explain a significant proportion of the variance in DERT total score. This indicates that, in the present study, being in a depressed mood does not differentially influence the ability to recognize and verbalize emotion on the DERT.

The absence of a relationship between BDI score, or mood state, on DERT performance is consistent with previous studies which failed to find a relationship between mood and social judgements (e.g., Forgas & Moylan, 1988). The lack of a relationship between mood and cognitive judgements about emotional prosody in another person's voice can be explained in the context of the multi-component system of emotional processing in the human brain. As discussed in more detail previously, it has been hypothesized that a sub-cortical neuropsychological system(s) is responsible for the experience of emotion, or mood. This system is thought to be distinct from the more cortical neuropsychological system(s) involved in making judgements about complex social-emotional stimuli, such as the process of recognition and verbalization of emotional information involved in the DERT. The finding that BDI score is not consistently related to differences in DERT total score in the present sample, supports the notion that the emotional state one is in does not affect one's ability to perform the cognitive operations necessary to make judgements regarding the emotional prosody

involved in social communication. In effect, these results support the hypothesis held by several researchers in the field (Bowers et al., 1993, Heller, 1990, Pereverzeva, 1980; Ross, 1984) that distinct components of emotional functioning, in particular mood and recognition, are capable of operating independently.

Although BDI scores are not correlated with the ability to recognize and verbalize emotion, they are positively correlated with alexithymia in the present sample. The more depressed participants are also the most alexithymic. This correlation is in keeping with the literature, as TAS score has previously been found to be positively correlated with BDI score (Taylor et al., 1990).

While differences in the unilateral right and left hemisphere processing, as well as mood differences, were controlled in the present study, two methodological constraints were uncontrolled in the present study. Uncontrolled differences in cultural background and first language could have influenced results in the present study.

As is normal in the Canadian student population, the present sample included students from many different cultural backgrounds. It is possible that the interpretation of emotional prosody may vary in different cultures so that a given emotional tone may be recognized as fearful by someone from an Anglo-Saxon cultural background, for example, but as anger by someone from an Oriental cultural background. Also, a female speaker conveyed the emotional prosody on both tasks, and there may be cultural differences regarding beliefs about whether or not it is appropriate for females to express emotions such as anger. Thus, depending on

cultural differences, some participants may have had limited "real life" experience with some of the emotional stimuli, which may have differentially influenced their ability to perform the experimental tasks. This possibility could be examined in future research

Students who spoke a English as a second language were also included in the present study. First language was not controlled for as all students wishing to attend Carleton University, whose native tongue is not English, must demonstrate proficiency in English by obtaining a TOEFL score of at least 550. As such, for those participating in the study, understanding of English should have been comparable to the rest of the sample group. However, it is possible that performing dichotic listening tests in one's second language is more difficult than daily use of the language. The effects of language differences would be most noticeable in the form of inconsistent responses on the VEC task, if the participant was not familiar with the meaning of the words used in the phrases. Future research could control for the effects of language differences, by holding first language constant, or by studying differences between subjects based on language.

Lateralization of Emotional Prosody Recognition

The expected left ear advantage was not observed on the Emotional Prosody Recognition Task in the present sample. However, the obtained results do not disconfirm the results of other dichotic listening studies which have revealed a

significant left ear advantage for emotional prosody (e.g. Bryden et al., 1991; Herrero & Hillix, 1990; McNeely, 1994).

The absence of an ear advantage is probably not due to ceiling effects, as participants achieved an average accuracy rate of approximately 80%. However, a gender effect may have affected the results. Hypothesis 1 is partially supported, as females showed a significant left ear advantage on the EPR task, while males did not. The nature of this sex difference in relation to other sex differences observed in the results of this study is discussed in more detail below.

Lateralization of Verbal Emotional Processing

Again, the expected right ear advantage on the Verbal Emotional Contexts Task was not observed. However, ear differences, although small, were in the expected direction. Performance on this test may have been near ceiling levels, as participants obtained an average accuracy rate of approximately 91%. As such, ceiling effects may have masked an underlying left hemisphere dominance for verbal emotional information.

The results of the VEC task cannot readily be compared with other dichotic listening tasks, as no other studies have used similar dichotic listening tasks to assess lateralization of the verbal aspects of emotional speech in normal participants. However, the observed trend towards a left hemisphere dominance on this task is in keeping with the results of brain damage studies. For example, when the VEC phrases were presented monaurally to left and right hemisphere damaged patients by Lalonde

et al (1992), the left hemisphere damaged patients were more impaired at identifying the verbally implied emotion than were the right hemisphere damaged patients.

Similar results were also found by Tompkins (1991). The trend towards better performance by the right ear (left hemisphere) on the VEC task in the present study supports the hypothesis that in non-brain damaged individuals the left hemisphere is dominant for processing the verbal aspects of emotional speech.

In future research, the VEC task could be improved by increasing the difficulty in two ways. (1) using shorter inter-stimulus intervals, and/or (2) using distracter stimuli made up of neutral tone/neutral content phrases, as opposed to cocktail party noise. Adults tend to be able to ignore background noise, such as cocktail party noise, and selectively attend to one voice when listening to meaningful speech. This is probably what occurred during the performance of the VEC task, increasing the likelihood of recognizing the content of phrases regardless of which ear they were presented to.

It would also be beneficial in future research to test the EPR and VEC tasks with a larger sample. Although power analysis indicated that a sample size of 62 was large enough to obtain an 80% chance of observing a medium sized effect (Keppel, Saufley & Tokunaga, 1992), replication with a larger sample would increase the probability of observing a significant ear advantage on both of these control tasks.

Integrating Emotional Prosody and Verbal Information

At the outset of this investigation, it was anticipated that the ability to recognize emotional prosody and then verbally label it would require sharing of information between the two cerebral hemispheres. This hypothesis corresponds well to the interhemisphere interaction model of emotional speech, and is based on evidence that emotional prosody recognition is lateralized to the right hemisphere while verbal processing is lateralized to the left hemisphere in most right handed adults. Given this differential lateralization, communication between the two hemispheres would be required whenever a comparison of the two domains is relevant, as it is in the DERT.

Based on the excitatory model of callosal connectivity which states that as degree of callosal connectivity increases interhemispheric exchange of information increases, a positive linear relationship was predicted between total score on the DERT and a measure of efficiency of interhemispheric communication (FDWT difference score). As discussed previously, it was anticipated that those with high callosal connectivity would have a higher level of interhemispheric exchange in information (indicated by higher relative left than right ear scores on the FDWT) and would be better at integrating the right hemisphere emotional prosody recognition with left hemisphere verbalization (indicated by higher total scores on the DERT)

However, the obtained results indicated that those with the highest level of interhemispheric communication (higher relative left than right ear scores on the

FDWT) had the lowest total scores on the DERT. In effect, in terms of the excitatory model, it would appear that higher connectivity and increased interhemispheric exchange of information is related (at least in this sample) to decreased ability to integrate the differentially lateralized sources of information required on the DERT. In contrast, it appears that those with the least amount of information exchanged between the hemispheres performed best on the DERT (see Figure 4). Logically, this relationship does not make sense, since information from opposite sides of the brain must be shared in order to perform the DERT.

Thus, the excitatory model does not fully explain the relationship observed between the ability to recognize and verbalize emotional information, and observed level of interhemispheric communication. Another hypothesis was also generated regarding this relationship in terms of the inhibitory model of callosal connectivity. Under this model, it was anticipated that individuals with high callosal connectivity would have increased inhibition, or shielding, of information between the two sides of the brain. As discussed previously, high connectivity would be associated with decreased level of interhemispheric communication (lower relative left than right ear scores on the FDWT) and decreased ability to recognize and verbalize emotional speech (lower total scores on the DERT). However, the present results indicate that those with lowest interhemispheric communication are the best at recognizing and verbalizing emotional speech on the DERT. In terms of the inhibitory model of callosal connectivity alone, again, the obtained results do not make sense.

The relationship observed between the ability to integrate right hemisphere emotional prosody recognition with left hemisphere verbalization and level of interhemispheric communication cannot be fully explained in terms of either the excitatory or inhibitory models of callosal connectivity alone. However, there is no reason to assume that these two models of callosal connectivity are mutually exclusive.

According to Clarke and Zaidel (1994), the corpus callosum may contain excitatory and inhibitory "control codes", and the relative participation of each is determined largely by the functions required to perform a particular task. Given a task that requires the comparison of information between areas differentially lateralized in the brain, high callosal connectivity may function to enhance sharing of information. This could be the case for the type of processing involved in the DERT, where right hemisphere emotional prosody recognition must be combined with left hemisphere verbalization. In contrast, when the task involves only one stimulus domain and performance requires the lateralized functioning of only one hemisphere, high callosal connectivity may function to inhibit information transfer from the non-dominant hemisphere. For example, on the FDWT all stimuli are verbal, therefore performance would be best if the hemisphere specialized for verbal information dominated while the hemisphere non-dominant for verbalization was inhibited. This would result in higher laterality effects, or lower interhemispheric communication. In effect, rather than viewing the corpus callosum as "excitatory" or "inhibitory", the corpus callosum may fulfil both functions depending on the nature of the task at hand. Therefore,

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higher callosal connectivity would be associated with an increased ability to adapt callosal functioning to suit the task demands

Viewing the corpus callosum as an adaptive structure that functions in either excitatory or inhibitory roles depending on the nature of the task at hand, the results of the present study may be neatly interpreted. If performance on the DERT requires communication between the two hemispheres, in order to obtain a high score on this task the corpus callosum must allow for interhemispheric sharing of information. Thus, the excitatory model may be used to explain performance on the DERT. Those participants with high callosal connectivity are most accurate at recognizing and verbalizing emotional speech due to efficient interhemispheric exchange of information. The FDWT, on the other hand, does not require interhemispheric exchange of information. In contrast, performance is maximal on this task when the specialized role of the left hemisphere for verbal processing is high-lighted. As such, in the context of the FDWT, high callosal connectivity results in enhanced shielding of information transfer between the two hemispheres. Thus, those with high callosal connectivity have lower relative left than right ear scores on the FDWT. In this context, the more efficient brain would be highly lateralized (with low interhemispheric communication) for a language task, but would have high sharing between the hemispheres for processing emotional speech information.

The study of the role of the corpus callosum in higher cognitive processes is a new area of inquiry. The excitatory and inhibitory models of callosal connectivity

transmitted to the dominant hemisphere for recognition leading to high accuracy by both ears

Social factors could also account for the difference between males and females on the VEC task. As a group, males tended to respond more variably on this task, as indicated by a larger standard deviation. Inconsistent responses could be related to social pressures to be "tough", leading males to give socially expected responses on one presentation while true ideas may have "slipped out" on other presentations. For example, on 3 out of 4 dichotic presentations of the sentence "you meet an old friend that you like very much", one male participant responded that he would feel no emotion in that situation. However, on paper he indicated that he would feel happy in that situation. Perhaps young males were hesitant to reveal their true ideas about emotions to the female examiner recording their verbal responses to the dichotic listening task, but were willing to be honest in the more anonymous paper version. Response discrepancies such as this resulted in the overall lower mean score for males. The extent to which such discrepancies are due to the influence of social pressures, or to unknown cerebral differences is speculative.

This area of emotion recognition research is relatively new. One may speculate that a physiological predisposition in the form of a larger corpus callosum uniquely causes females to be better at recognizing the prosodic and verbal aspects of emotional speech. Alternatively, social influences could uniquely account for these same sex differences, as females tend to be socialized to attend to emotional information more

seven alexithymics correspond to the pattern observed for the sample as a whole. These three alexithymic participants appeared to have relatively high sharing of information between right hemisphere emotional prosody recognition and left hemisphere verbalization centres, as indicated by high DERT scores, but appeared to have low interhemispheric communication of the FDWT. Thus, given the interpretation offered above for the changing role of the corpus callosum depending on task demands, these three alexithymic participants appear to have efficient cerebral functioning.

Of particular interest, are two of the alexithymic individuals who performed one standard deviation or more below the group mean on the DERT. These individuals also appeared to have relatively low interhemispheric communication as indicated by lower left ear than right ear scores on the FDWT. Their performance on these two measures suggests an association between low interhemispheric communication and decreased ability to integrate right hemisphere emotional prosody recognition and left hemisphere verbalization, at least in some alexithymic individuals. This provides partial corroboration for the results of the Zeitlin et al (1989) finding that alexithymics had a relatively low amount of information sharing between the two hemispheres. The similarity between this second trend and the Zeitlin et al (1989) results, indicates that future research with a larger sample of alexithymic participants may provide corroborating evidence for the interhemispheric interaction model of emotional speech.

The fact that there appear to be two sub-groups within the alexithymic subjects in this sample is also noteworthy. Alexithymia is a multi-dimensional personality construct, with a difficulty identifying and describing feelings being only one aspect of the disorder. Other features of alexithymia are difficulty distinguishing between feelings and bodily sensations, restricted imagination, and concrete cognitive style. The two trends observed within the alexithymic group could have been due to differences in the nature of the alexithymic symptoms. In effect, participants within the two sub-groups were all classified as alexithymic, but for different reasons. The most notable difference is that the alexithymics in the first sub-group did not have difficulty recognizing and verbalizing emotion, while those in the second sub-group did experience difficulty in this regard.

The presence of these two sub-groups within the alexithymics in the present sample conforms to the observation of at least three different factors within the Toronto Alexithymia Scale (Bagby, Taylor & Parker, 1994). Bagby et al. (1994) compared scores on TAS items to self-reports on the NEO Personality Inventory (Costa & McCrea, 1985). The NEO is a measure of 5 basic personality dimensions: neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness. Factor 1 of the TAS correlated most significantly with the neuroticism scale of the NEO, as characterized by high correlations with depression, anxiety, neuroticism, vulnerability, negative emotions and high self-consciousness. Factor 2 of the TAS contained positive correlations with the neuroticism scale and negative correlations

with both the extraversion scale and the openness scale. Factor 2 of the TAS was associated with low openness to feelings, low assertiveness and high self-consciousness, depression, negative emotions and low openness, and high vulnerability. Finally, Factor 3 of the TAS was negatively related to the NEO openness scale, indicating low openness to experience. Factor 3 correlated most significantly with low openness to feelings and experience, low openness to aesthetics, low openness to ideas and low openness to fantasy (Bagby et al., 1994).

Given the existence of these three factors within the TAS, combined with the two different trends observed in the present study, one may hypothesize that only a sub-group of alexithymic individuals have difficulty recognizing and verbalizing emotions. Unfortunately, the sample of alexithymic participants in the present study was too small to look at the individual TAS factors to see if one factor is associated with the ability to recognize and verbalize emotional information. This could be a topic for future research, however.

Influence of Task Order

The participants in the two task orders did not differ with regards to any of the experimental variables, considered uniquely. However, the two order groups did differ in terms of the correlation between the ability to recognize and verbalize emotional speech (DERT total score) and efficiency of interhemispheric communication (FDWT difference score). The nature of the relationship was the same for both task order groups, with higher DERT total scores

being associated with lower FDWT left-right difference scores, however, the linear relationship was significant only for order group two. This difference between the two task order groups could be interpreted in two ways: (1) in terms of the hemispheric activation hypothesis, or (2) as random chance.

One way of interpreting the differential effects of task order on the relationship between the ability to recognize and verbalize emotional speech and interhemispheric communication in the present study, stems from an alternative interpretation of Kinsbourne's (1974) activation hypothesis. In Kinsbourne's theory, activation of the left hemisphere by, for example, a verbal task, results in the maintenance of left hemisphere dominance (i.e., inhibition of the right hemisphere) over time. During this time, tasks which require left hemisphere specialized processing are enhanced, while the performance of tasks which require right hemisphere specialization is compromised. In the current study, it would appear that early activation of the right hemisphere in task order 2 may have differentially influenced performance on the FDWT. In contrast to Kinsbourne's theory, initial activation of the right hemisphere as in task order group 2 may have had a lasting effect on cognitive function, while initial activation of the left hemisphere as in task order 1 appears not to have lasting effects on cognition. Future research could address the activation hypothesis by increasing the sample sizes for the two task order groups.

It is possible that early activation of the right hemisphere for task order group 2 differentially affected performance on the FDWT, leading to a difference in the

magnitude of the correlation between DERT total score and interhemispheric communication. However, for the following four reasons, it is probable that this difference was due to chance factors. (1) statistically controlling for task order, the linear relationship between DERT total score and interhemispheric communication was virtually unchanged, (2) the direction of the correlation was the same form for both order groups, (3) both order groups performed 30 minutes of identical left hemisphere mediated (questionnaires) and interhemisphere mediated (DERT2) tasks which likely nullified any initial activation differences between the two order groups, and (4) the sample sizes of the two order groups were quite small. Further research with larger sample sizes for the two task orders will confirm whether the observed difference is due to chance or to the effects of hemispheric activation.

Sex Differences

Two specific sex differences were anticipated based on research with the predecessor of the DERT, the VERT-M (McNeely, 1994). It was anticipated that males would be more strongly right hemisphere dominant on the DERT, while for females, lateralization would be attenuated and coupled with higher overall accuracy on the DERT. As discussed below, these two predictions were supported by the results of the current study. It is important to keep in mind that fewer males than females were included in the present study, which weakens the interpretation of observed sex differences. Replications in future research involving larger and equal

samples of males and females would strengthen the evidence for sex differences in cerebral function

Sex differences in the lateralization of emotional prosody recognition

In the present study, difference in the lateralization of emotional prosody recognition may have been related to sex. When examining the DERT in terms of lateralization of processing, it was found that on the second trial (but not the first) of this task males were significantly right hemisphere dominant while females were not. This finding is consistent with that observed by McNeely (1994) with the VERT-M, and supports one of the supplemental hypotheses proposed at the outset of this study. However, on the other emotional prosody recognition task, the EPR, females, but not males, showed a significant left ear advantage.

Males were right hemisphere dominant on the DERT, while females were right hemisphere dominant on the EPR. One may attribute this sex difference in emotional prosody recognition to the major differences between the two dichotic listening tasks. The emotional stimulus phrases used in these two tasks are identical, but the tasks differ in two ways. 1) the mode of response and 2) the type of distracter stimuli.

In terms of mode of response, participants respond to the EPR by pointing to a facial expression of the target emotion with their left hand, while on the DERT participants respond verbally by saying the name of the emotional tone. It might be that females are right hemisphere dominant for emotional prosody recognition when the response is mediated by the right hemisphere as seen on the EPR task. In contrast,

males are right hemisphere dominant for emotional prosody recognition when the response is mediated by the left hemisphere as on the DERT in the present study and the VERT-M in the 1994 study

The type of distracter stimuli also differed between the two tasks. On the EPR, the nonsense emotional phrases are paired with cocktail party noise, while on the DERT the distracter phrases are nonsense phrases similar to the stimuli but spoken in a neutral tone. If females are highly distracted by the cocktail party noise on the EPR task, responses would be most accurate when the emotional stimulus is presented to the ear dominant for emotional prosody recognition. This is what was observed, as females have a significant left ear advantage on the EPR task. An interesting note regarding this speculation is that one female participant indicated that she found the cocktail party noise much more distracting than the neutral nonsense phrases. If females in this sample are less distracted by the neutral nonsense phrases on the DERT, they may have been better able to "tune out" the distracter and therefore would have had similar levels of accuracy between the two ears resulting in no left ear advantage, as observed.

In turn, if males are highly distracted by the neutral nonsense phrases, they would have been more accurate on the DERT when the stimuli was presented to the dominant ear. This pattern is observed as indicated by the significant left ear advantage for males on the DERT. Furthermore, if males are not distracted by the

cocktail party noise, the ear advantage would not be as apparent, as indicated by a lack of a significant left ear effect for males on the EPR task.

Thus, these results indicate that the performance of males and females on tasks of emotional prosody recognition could be influenced by mode of response and/or nature of distracting stimulus. These hypotheses should be verified through future research, as they may reveal that the discrepancies in the literature regarding the presence and nature of sex differences could be related to methodological differences between the tests used.

Sex differences and overall accuracy

In general, females in this sample were more accurate than males. As anticipated based on the McNeely (1994) results, females had higher scores on the DERT (trial 2). Females were also significantly more accurate than males, regardless of ear, on the VEC task. This pattern of higher accuracy was also observed on the EPR task. Similar results were found by Hirschman and Safer (1982) who observed that females were generally more accurate at recognizing and naming emotional facial expressions.

Sex related differences in accuracy could be accounted for by two possible mechanisms. (1) some evidence indicates that females have a larger minimum width of the corpus callosum than males (Clarke & Zaidel, 1994), which could mean that females have more efficient interhemispheric communication than males. (2) socialization processes may encourage females to be attentive to the emotional

expressions of others. Also, it is possible that both mechanisms interact to produce a socially re-enforced physiological predisposition for females to be better at recognizing emotional information in human communication.

As discussed earlier, there is some anatomical evidence which indicates that females may have a larger corpus callosum than males. In particular, recent measurements made by Clarke and Zaidel (1994) with magnetic resonance imaging in normal males and females revealed significantly larger minimum callosal body widths (the isthmus) in females. In the absence of MR images in the present study, sex differences in callosal size could not be ascertained. However, one may assume that the student volunteers in this study are representative of the same overall population from which Clarke and Zaidel (1994) obtained their student volunteers. Therefore, one may also assume that the females in the present study are likely to have a larger minimum body width of the corpus callosum than the males. If a larger corpus callosum, and/or a larger minimum body width is associated with more efficient interhemispheric communication (better sharing), then the higher mean total score of the female group on the DERT supports the hypothesis that communication between the two sides of the brain is required for recognition and verbalization of emotion. In effect, physiological callosal differences could account for the higher accuracy of the females as opposed to the males on the emotional prosody recognition dichotic listening tasks.

However, the more accurate performance by females could also be accounted for by differences in socialization. Girls tend to be encouraged to be attentive to the emotional expressions of others, whereas boys are more often encouraged to be logical and unconcerned with emotion. In effect, sensitivity to the emotions of others is a socially-encouraged "female" characteristic, which could account for better performance by females on the two emotion recognition tasks employed.

Females were also significantly better than males at consistently recognizing the emotions implied in the Verbal Emotional Contexts task. Accuracy was established by comparing results of the VEC dichotic listening task to each participant's own responses to the same emotional contexts presented in a questionnaire format. A difference between the responses given to the VEC dichotic listening task and those provided on paper, results in a lower total score. Inconsistent responses could occur for either, or a combination, of the same two reasons discussed above in the context of the emotional prosody recognition tasks. (1) physiological reasons due to callosal size differences, (2) social pressures for females to attend to emotions; or these two mechanisms could interact to produce the observed differences in performance between the females and males.

Physiological differences in the size of the corpus callosum could have affected performance on the VEC dichotic listening task. More efficient interhemispheric communication would result in a higher over-all score on any of the four dichotic listening tasks, as stimuli presented to the non-dominant hemisphere could be rapidly

transmitted to the dominant hemisphere for recognition leading to high accuracy by both ears

Social factors could also account for the difference between males and females on the VEC task. As a group, males tended to respond more variably on this task, as indicated by a larger standard deviation. Inconsistent responses could be related to social pressures to be "tough", leading males to give socially expected responses on one presentation while true ideas may have "slipped out" on other presentations. For example, on 3 out of 4 dichotic presentations of the sentence "you meet an old friend that you like very much", one male participant responded that he would feel no emotion in that situation. However, on paper he indicated that he would feel happy in that situation. Perhaps young males were hesitant to reveal their true ideas about emotions to the female examiner recording their verbal responses to the dichotic listening task, but were willing to be honest in the more anonymous paper version. Response discrepancies such as this resulted in the overall lower mean score for males. The extent to which such discrepancies are due to the influence of social pressures, or to unknown cerebral differences is speculative.

This area of emotion recognition research is relatively new. One may speculate that a physiological predisposition in the form of a larger corpus callosum uniquely causes females to be better at recognizing the prosodic and verbal aspects of emotional speech. Alternatively, social influences could uniquely account for these same sex differences, as females tend to be socialized to attend to emotional information more

than males. Speculating further, perhaps this socialized emotion recognition training results in an increase in callosal size in females. Or, perhaps a pre-existing larger callosum leads females to encourage their daughters to take advantage of their natural predisposition. Regardless of which came first, it is likely that callosal size differences and socialization forces interact to result in a female tendency to be better at recognizing emotional speech than males. This issue should be examined in future research with larger, and equal, sample sizes of males and females.

Conclusion

The investigation of the neuropsychology of emotional speech and the role of the corpus callosum in the integration of right hemisphere emotional prosody recognition and left hemisphere verbalization is an emerging area of inquiry. The literature to date is strong on theoretical but weak on empirical studies. Thus, a conclusive picture as to the cerebral organization of emotional functions remains elusive. The results of the present study suggest that there is a relationship between callosal function and the nature of the task processing demands.

Rather than viewing the role of the corpus callosum as exclusively excitatory or inhibitory, the results of the present study are compatible with the view proposed by Clarke and Zaidel (1994) that callosal fibres may provide both excitatory and inhibitory functions depending on the nature of the task. When task demands require interhemispheric exchange of information, as in recognizing emotional prosody then

verbalizing this information, high callosal connectivity facilitates this exchange and improves performance. In other situations in which the lateralized functioning of one hemisphere over the other is required for optimal task performance, high callosal connectivity results in an increased ability to inhibit information transfer from the non-dominant hemisphere, as observed here on the Fused Dichotic Words Test. Thus, the degree of callosal connectivity may be related to cognitive efficiency, with the function of the callosal fibres changing to meet the changing demands of the environment.

This "cognitive efficiency" model of callosal function is compatible with the interhemisphere interaction model of emotional speech. Individuals who appear to have high callosal connectivity are most proficient at integrating right hemisphere emotional prosody with left hemisphere verbalizations, while those who appear to have low callosal connectivity are least proficient at recognizing and verbalizing emotions. Future research in which anatomical measures of callosal connectivity are directly compared with performance on the DERT and the FDDWT would be of great benefit in corroborating the hypotheses generated from the current exploratory study.

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Appendix A

Crossed Organization of the Auditory System

From Bryden, 1988

Appendix B

The Anatomy of the Corpus Callosum

From: Leibman, 1991.

Appendix C

The Edinburgh Handedness Inventory

Please indicate your preference in the use of hands in the following activities by putting a "+" in the appropriate column. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, put "++". If in any case you are really indifferent, put "-" in both columns.

Some of the activities require both hands. In these cases, the part of the task, or object, for which hand preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.

LEFT

RIGHT

1. Writing		
2. Drawing		
3. Throwing		
4. Scissors		
5. Toothbrush		
6. Knife (without fork)		
7. Spoon		
8. Broom (upper hand)		
9. Striking a match (match)		
10. Opening a box (lid)		

i) Which foot do you prefer to kick with?		
ii) Which eye do you use when using only one?		

L.Q.		DECILE	
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Appendix D

Dichotic Emotion Recognition Test Stimuli

- anti laurel tromple cert
- bevey haxel orentonish
- dan hite bruthel gorp
- dan hite ruffa gorp
- with ralf leck long
- es key grass weed
- over bassa fervy masso
- omni fren mistam
- wis rell laquellum
- look clut ma foot
- lert sash guash gleeb
- hash king rash weed
- essay key de ras weed

Appendix E

Emotional Contexts Questionnaire

Listed below are several sentences describing various contexts, or situations in which a particular emotion is likely to be evoked. Please choose the emotion which best fits the context by circling H for happiness, S for sadness, A for anger, or F for fearful.

<u>Context</u>	<u>Emotion</u>			
1) You are walking on a very high and narrow rock ledge.	H	S	A	F
2) You meet an old friend that you like very much.	H	S	A	F
3) Going to funerals.	H	S	A	F
4) A server with poor manners spills red wine on your expensive new pants.	H	S	A	F
5) No one remembers that it's your birthday.	H	S	A	F
6) You discover that someone has been stealing large sums of money from you over a long period of time.	H	S	A	F
7) After you see a dramatic and poignant film you feel you have a heavy heart.	H	S	A	F
8) Your employer offers you two weeks free vacation to anywhere at all.	H	S	A	F
9) You learn that your home has been robbed.	H	S	A	F
10) You must leave someone you hold dear.	H	S	A	F
11) An angry bear appears in front of you in the middle of the forest.	H	S	A	F
12) Your boyfriend or girlfriend tells you he or she loves you truly and takes you in his or her arms.	H	S	A	F

13)	The airplane you are aboard for Europe suddenly does a nose-dive.	H	S	A	F
14)	You lose control of your car on an icy road.	H	S	A	F
15)	You win a prize wanted by many people.	H	S	A	F
16)	Your doctor tells you that you have AIDS.	H	S	A	F
17)	Someone cancels an appointment at the last minute for the third time
in a row.	H	S	A	F
18)	You find yourself face to face with a truck coming at full speed in a
narrow street.	H	S	A	F
19)	You open a beautiful, big, birthday present.	H	S	A	F
20)	You feel misunderstood during a heated conversation.	H	S	A	F
21)	Your fiance leaves you for the rest of your life.	H	S	A	F
22)	You are splashed by a motorist while walking.	H	S	A	F
23)	On your third meeting a man ignores you completely.	H	S	A	F

Please tell me a bit about yourself: Male or Female Age_____

Thank you for your help!!

Appendix F

Fused Dichotic Words Test Response Sheets

INSTRUCTIONS: On this tape you will hear a man's voice saying some words. The first page is a practice, check off each word as you hear it. Starting on the second page, circle the word that you hear on the tape.

Page 1

1. pill
2. bill
3. coat
4. goat
5. pig
6. dig
7. tear
8. deer
9. cage
10. page
11. pan
12. can
13. car
14. bar
15. tail
16. pail
17. kit
18. pit
19. pier
20. beer
21. ten
22. pen
23. cook
24. book
25. keg
26. peg
27. toy
28. boy
29. curl
30. pearl

Please turn page.

Page 2a

1.	gale	bale	pear	tail
2.	pan	tan	can	man
3.	page	cage	gage	rage
4.	keg	beg	peg	leg
5.	deer	beer	pier	tear
6.	rage	cage	gage	page
7.	took	cook	rook	book
8.	beer	tear	pier	deer
9.	boy	toy	coy	roy
10.	roy	coy	toy	boy
11.	man	pan	tan	can
12.	pier	tear	deer	beer
13.	den	ken	ten	pen
14.	curl	girl	pearl	burl
15.	bar	car	tar	par
16.	tan	pan	can	man
17.	cook	rook	book	took
18.	coat	tote	gage	page
19.	coat	tote	goat	boat
20.	roy	coy	toy	boy
21.	boat	goat	tote	coat
22.	cage	gage	page	rage
23.	tear	deer	beer	pier
24.	curl	pearl	burl	girl
25.	till	bill	pill	gill
26.	pail	gale	tail	bale
27.	tar	bar	par	car
28.	book	cook	took	rook
29.	leg	peg	beg	keg
30.	fit	pit	bit	kit

Please turn page.

Page 2b

1.	tear	pier	deer	beer
2.	tan	can	pan	man
3.	pit	bit	kit	pit
4.	ken	pen	den	ten
5.	beg	leg	keg	peg
6.	pier	deer	beer	tear
7.	dig	big	pig	rig
8.	pill	gill	till	bill
9.	rig	dig	pig	big
10.	kit	fit	bit	pit
11.	tail	pail	bale	gale
12.	rook	book	took	cook
13.	dig	rig	big	pig
14.	gill	bill	pill	till
15.	deer	beer	pier	tear
16.	burl	girl	pearl	curl
17.	girl	burl	curl	pearl
18.	bale	tail	pail	gale
19.	tote	coat	boat	goat
20.	coat	boat	goat	tote
21.	pig	rig	dig	big
22.	pier	tear	beer	deer
23.	par	tar	bar	car
24.	den	ken	ten	pen
25.	pill	till	gill	bill
26.	ten	ken	pen	den
27.	peg	keg	leg	beg
28.	tar	par	car	bar
29.	coy	boy	toy	roy
30.	bit	pit	kit	fit

Please turn page.

Page 3

1.	den	ken	ten	pen
2.	tear	deer	pier	beer
3.	kit	bit	pit	fit
4.	gill	bill	till	pill
5.	man	tan	can	pan
6.	coat	boat	tote	goat
7.	bar	car	tar	par
8.	ken	pen	ten	den
9.	cage	rage	page	gage
10.	leg	beg	keg	peg
11.	coat	tote	goat	boat
12.	leg	keg	beg	peg
13.	rook	took	cook	book
14.	cage	rage	gage	page
15.	big	pig	dig	rig
16.	bill	till	gill	pill
17.	tan	pan	can	man
18.	car	bar	tar	par
19.	coy	boy	roy	toy
20.	roy	toy	boy	coy
21.	tail	bale	gale	pail
22.	rig	big	dig	pig
23.	fit	kit	pit	bit
24.	cook	book	took	rook
25.	bale	tail	pail	gale
26.	pier	tear	deer	beer
27.	burl	pearl	girl	curl
28.	curl	girl	burl	pearl
29.	tear	beer	deer	pier
30.	beer	pier	tear	deer

Please REVERSE earphones and turn page.

Page 4

1.	tar	bar	par	car
2.	beer	pier	tear	deer
3.	gill	pill	bill	till
4.	can	man	tan	pan
5.	gale	pail	tail	bale
6.	coat	boat	goat	tote
7.	rook	cook	took	book
8.	keg	beg	leg	peg
9.	can	tan	man	pan
10.	coy	roy	toy	boy
11.	fit	kit	pit	bit
12.	pearl	girl	curl	burl
13.	tear	pier	deer	beer
14.	pail	gale	tail	bale
15.	roy	toy	coy	boy
16.	cage	rage	page	gage
17.	ken	pen	ten	den
18.	book	cook	took	rook
19.	cage	gage	page	rage
20.	pill	bill	till	gill
21.	tar	par	bar	car
22.	keg	peg	beg	leg
23.	fit	bit	pit	kit
24.	ken	pen	den	ten
25.	coat	goat	boat	tote
26.	pearl	girl	burl	curl
27.	rig	big	dig	pig
28.	big	pig	rig	dig
29.	tear	deer	pier	beer
30.	beer	pier	tear	deer

Please turn page.

Page 5

1	peg	leg	beg	keg
2	pail	tail	gale	bale
3	kit	bit	pit	fit
4	pen	ken	ten	den
5	took	rook	book	cook
6	rig	big	pig	dig
7	gage	cage	page	rage
8	till	bill	gill	pill
9	page	rage	gage	cage
10	beg	keg	peg	leg
11	pig	big	rig	dig
12	tan	pan	man	can
13	den	ken	ten	pen
14	gill	till	bill	pill
15	tail	pail	bale	gale
16	curl	burl	girl	pearl
17	tear	pier	beer	deer
18	can	pan	man	tan
19	beer	tear	deer	pier
20	coy	toy	roy	boy
21	girl	pearl	curl	burl
22	roy	toy	boy	coy
23	goat	coat	boat	tote
24	tar	par	bar	car
25	pier	beer	deer	tear
26	pier	tear	beer	deer
27	fit	bit	pit	kit
28	rook	book	cook	took
29	car	tar	par	bar
30	coat	tote	goat	boat

Please REVERSE earphones and turn page.

Page 6

1	coy	boy	toy	roy
2.	page	gage	cage	rage
3.	goat	boat	tote	coat
4.	den	ten	ken	pen
5.	deer	tear	pier	beer
6.	fit	kit	pit	bit
7.	deer	tear	pier	beer
8.	gale	bale	tail	pail
9.	cook	took	book	rook
10.	gill	till	pill	bill
11.	pan	tan	man	can
12.	boat	coat	tote	goat
13.	pit	kit	bit	fit
14.	man	can	tan	pan
15.	pill	gill	till	bill
16.	dig	big	pig	rig
17.	tar	bar	par	car
18.	leg	peg	keg	beg
19.	pearl	curl	burl	girl
20.	pier	deer	tear	beer
21.	toy	coy	roy	boy
22.	gale	pail	bale	tail
23.	cage	rage	page	gage
24.	pig	dig	big	rig
25.	pier	tear	beer	deer
26.	cook	rook	book	took
27.	leg	keg	peg	beg
28.	den	ten	ken	pen
29.	girl	burl	curl	pearl
30.	car	tar	par	bar

Appendix G

Beck Depression Inventory

On this questionnaire are groups of statements. Please read each group of statements carefully. Then pick out the one statement in each group which best describes the way you have been feeling the PAST WEEK, INCLUDING TODAY! Circle the number beside the statement you picked. If several statements in the group seem to apply equally well, circle each one. Be sure to read all the statements in each group before making your choice.

1. 0 I do not feel sad.
 1 I feel sad.
 2 I am sad all the time and I can't snap out of it.
 3 I am so sad or unhappy that I can't stand it

2. 0 I am not particularly discouraged about the future.
 1 I feel discouraged about the future.
 2 I feel I have nothing to look forward to.
 3 I feel that the future is hopeless and that things cannot improve

3. 0 I do not feel like a failure.
 1 I feel I have failed more than the average person.
 2 As I look back on my life, all I can see is a lot of failures.
 3 I feel I am a complete failure as a person.

4. 0 I get as much satisfaction out of things as I used to.
 1 I don't enjoy things the way I used to.
 2 I don't get real satisfaction out of anything anymore.
 3 I am dissatisfied or bored with everything.

5. 0 I don't feel particularly guilty.
 1 I feel guilty a good part of the time.
 2 I feel quite guilty most of the time.
 3 I feel guilty all of the time.

6. 0 I don't feel I am being punished.
 1 I feel I may be punished.
 2 I expect to be punished.
 3 I feel I am being punished.

7. 0 I don't feel disappointed in myself.
 1 I am disappointed in myself.
 2 I am disgusted with myself.

- 3 I hate myself.
8. 0 I don't feel I am any worse than anybody else
1 I am critical of myself for my weaknesses or mistakes
2 I blame myself all the time for my faults
3 I blame myself for everything bad that happens
9. 0 I don't have any thoughts of killing myself.
1 I have thoughts of killing myself but I would not carry them out
2 I would like to kill myself
3 I would like to kill myself if I had the chance
10. 0 I don't cry any more than usual
1 I cry more now than I used to
2 I cry all the time now.
3 I used to be able to cry, but now I can't cry even though I want to
11. 0 I am no more irritated now than I ever am
1 I get annoyed or irritated more easily than I used to
2 I feel irritated all the time.
3 I don't get irritated at all by things that used to irritate me
12. 0 I have not lost interest in other people
1 I am less interested in other people than I used to be
2 I have lost most of my interest in other people
3 I have lost all of my interest in other people.
13. 0 I make decisions about as well as I ever could.
1 I put off making decisions more than I used to.
2 I have greater difficulty in making decisions than before
3 I can't make any decisions at all any more.
14. 0 I don't feel I look any worse than I used to.
1 I am worried that I am looking old or unattractive
2 I feel that there are permanent changes in my appearance that make me look unattractive.
3 I believe that I look ugly.
15. 0 I can work about as well as before.
1 It takes an extra effort to get started at doing something
2 I have to push myself very hard to do anything
3 I can't do any work at all.
16. 0 I can sleep as well as usual.
1 I don't sleep as well as I used to.
2 I wake up 1 - 2 hours earlier than usual and find it hard to get back to sleep.

- 3 I wake up several hours earlier than I used to and cannot get back to sleep.
17. 0 I don't get more tired than usual.
1 I get tired more easily than I used to.
2 I get tired from doing almost anything.
3 I am too tired to do anything.
18. 0 My appetite is no worse than usual.
1 My appetite is not as good as it used to be.
2 My appetite is much worse now.
3 I have no appetite at all anymore.
19. 0 I haven't lost much weight, if any, lately.
1 I have lost more than 5 pounds.
2 I have lost more than 10 pounds.
3 I have lost more than 15 pounds.
- I am purposely trying to lose weight by eating less: yes / no
20. 0 I am no more worried about my health than usual.
1 I am worried about physical problems such as aches and pains, or upset stomach, or constipation.
2 I am very worried about physical problems and it's hard to think of much else.
3 I am so worried about my physical problems, that I cannot think about anything else.
21. 0 I have not noticed any recent change in my interest in sex.
1 I am less interested in sex than I used to be.
2 I am much less interested in sex now.
3 I have lost interest in sex completely.

Appendix H

Toronto Alexithymia Scale (TAS)

INSTRUCTIONS: Using the scale provided as a guide, indicate how much you agree or disagree with each of the following statements by placing an X in the appropriate place. Give only one answer for each statement: (1) Strongly Disagree, (2) Moderately Disagree, (3) Neither Disagree nor Agree, (4) Moderately Agree, (5) Strongly Agree.

	Strongly disagree	Moderately disagree	Neither disagree nor agree	Moderately agree	Strongly agree
	1	2	3	4	5
1. When I cry I always know why.	—	—	—	—	—
2. Daydreaming is a waste of time.	—	—	—	—	—
3. I wish I were not so shy.	—	—	—	—	—
4. I am often confused about what emotion I am feeling.	—	—	—	—	—
5. I often daydream about the future.	—	—	—	—	—
6. I seem to make friends as easily as others do.	—	—	—	—	—
7. Knowing the answers to problems is more important than knowing the reasons for the answers.	—	—	—	—	—
8. It is difficult for me to find the right words for my feelings.	—	—	—	—	—
9. I like to let people know where I stand on things.	—	—	—	—	—
10. I have physical sensations that even doctors do not understand.	—	—	—	—	—
11. It's not enough for me that something gets the job done; I need to know why and how it works.	—	—	—	—	—
12. I'm able to describe my feelings easily.	—	—	—	—	—
13. I prefer to analyze problems rather than just describe them.	—	—	—	—	—
14. When I am upset, I don't know if I am sad, frightened, or angry.	—	—	—	—	—
15. I use my imagination a great deal.	—	—	—	—	—
16. I spend much time daydreaming whenever I have nothing else to do.	—	—	—	—	—
17. I am often puzzled by sensations in my body.	—	—	—	—	—
18. I daydream rarely.	—	—	—	—	—
19. I prefer to just let things happen rather than try to understand why they turned out that way.	—	—	—	—	—
20. I have feelings that I can't quite identify.	—	—	—	—	—
21. Being in touch with emotions is essential.	—	—	—	—	—
22. I find it hard to describe how I feel about people.	—	—	—	—	—
23. People tell me to describe my feelings more.	—	—	—	—	—
24. One should look deeper for explanations.	—	—	—	—	—
25. I don't know what's going on inside me.	—	—	—	—	—
26. I often don't know why I am angry.	—	—	—	—	—

END

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FIN