THE EFFECT OF VERBAL PROSODY ON SPEECH PERCEPTION IN ADULTS WITH AND WITHOUT DOWN SYNDROME

THE EFFECT OF VERBAL PROSODY ON SPEECH PERCEPTION IN ADULTS WITH AND WITHOUT DOWN SYNDROME

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ABSTRACT

Emotion perception in speech has been shown to facilitate greater understanding and learning in adults as well as children. There is an atypical RH specialization for speech perception that exists in individuals with Down Syndrome (DS). Individuals with DS have a typical left hemisphere specialization for motor control and speech production, similar to those individuals from the general population which may cause a functional dissociation between speech perception and motor control for these individuals (Heath et al., 2000). What remains unknown is how this atypical lateralization may influence speech perception when emotional intonation is included with verbal stimuli. Using a free recall dichotic listening paradigm, it was found that individuals with DS process verbal stimuli similarly to mental-age matched peers (individuals with a developmental delay, and individuals for the general population.) To investigate this further, a directed attention paradigm was employed. Participants listened to a particular ear for either a particular word or emotion. It was found that individuals from the general population were more accurate than individuals from either of the other two groups for perception of the word. Also, an effect for Ear was found with the right ear being significantly more accurately perceived than the left for all three groups. When emotion was attended to specifically, the left ear was more accurately perceived than the right. These results are somewhat consistent with previous findings (e.g., Bulman-Fleming & Bryden, 1994) for participants from the general population however the expected lateralization in DS group was not evident. This lack of atypical RHA in individuals with DS may be related to the task itself.

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Section 1: Emotional Processing in Humans

1.1 General Introduction

The images of world disasters with great human suffering elicit something greater than just a simple a basic response to a visual stimulus. That we all feel emotion on a daily basis is not something that is specific to the human race, as Darwin discovered in his attempt to re-enforce the shared ancestry of animals. Different species all have common ways of expressing certain emotions (Mlot, 1998) however these subjective experiences can, not only trigger behavioural changes, but can also have lasting physical changes on the brain itself (Mlot, 1998). For example, individuals who are fearful not only exhibit certain predictable behaviours, but also show evidence of distinct patterns of brain activity (Mlot, 1998). Emotions have been traced to many areas of the brain including the prefrontal cortex and ventral striatum, but it is more difficult to define what these apparent "universal cognitions" are due to their subjective nature. What we do know about the emotional response is that it usually involves changes in large number of somatic parameters such as endocrine, visceral, autonomic, and musculoskeletal changes, (e. g., facial expression) that unfold in a complex fashion over time (Adolphs, 2005).

Neurobiologists and psychologists generally conceptualize emotions as concerted and usually adaptive phasic changes in multiple physiological systems (with both somatic and neural components), that are in response to the value of a stimulus (Adolphs, 2005). In other words, they believe that there is a distinction between an emotional reaction (physiological change) and actually feeling the emotion. An example would be how the subjective experience of anxiety represents the affective response to changes in the central nervous system brought about by arousal. How we perceive and derive meaning from the emotions of others is a complex process, however facial expressions and gaze patterns are powerful indicators of the dispositions and intentions (known as social cognitions) of others (Wicker et al., 2003). These are conspicuous aspects of human interaction and the eye region of the face is often used as a cue to predict emotional or mental states of others (Wicker et al., 2003).

Emotions themselves are thought to be representational states with the input or output having value or significance for the organism's particular homeostasis (Adolphs, 2005). An example of this would be anger, which an organism may exhibit at the threat of their food being taken by another organism. Because behaviour, physiological response, and feeling all affect each other it is often difficult to isolate and identify only one of these variables alone with a particular emotional state. We can, however, use these responses to observe emotional states, including some basic emotional constructs such as happiness, surprise, fear, anger, disgust, and sadness (Russell, 1991). Some of these emotions, such as fear and disgust, have obvious advantages at a basic level of survival, but others (shame, guilt or embarrassment) derive meaning only in a social context and thus, although anthropologic studies have suggested that different cultures have different emotions, there are distinctly different ways of categorizing, interpreting and naming the emotions across cultures (Russell, 1991). Thus, different stimuli in different cultures will elicit different emotions because they may have different social meaning. For example, when you see someone bowing to you in North America, we think of someone accepting praise from an audience, however in Japan, this is taken more as a sign of respect in a greeting to someone. We can be aware of much more than feelings when we experience emotions, however one thing is for certain, without feelings we do not have an emotional experience at all.

1.2 Face Processing

As noted earlier, facial expression and gaze patterns are powerful indicators of the emotional state of others. Indeed, the survival benefits of rapidly and accurately identifying facial affect are numerous. As such, humans are thought to have evolved particular modules for the processing of facial affect (Hugenberg, 2005). This process of recognition gives us many clues about the emotional state or intent of others, a concept formalized as 'theory of mind' (e.g., Baron-Cohen et al., 1996). The effects of this recognition can be observed when asking individuals to perform a visual scan task in which pictorial displays are scanned for certain expressions. Results from such studies suggest that not only do individuals identify angry facial expressions more readily, it appears that these types of facial expressions "pop out" of the display (Baron-Cohen et al., 1996). The angry face not only catches, but also holds attention more so than any other facial expression (Hugenberg, 2005). It is interesting, however, that this effect of an angry face is not true in all types of task. If, for example, we examine facial categorization tasks, it has been shown that happy expressions are categorized more quickly than all other expressions, including a neutral facial expression (Hugenberg, 2005). Research suggests that a set of 6 universal emotional facial expressions comprised of happiness, sadness, anger, disgust, fear, and surprise have emerged (Baron-Cohen et al., 1996). Because the production and recognition of these universal emotions are present very early in development, they are thought to be innate rather than culturally dependant. The research shows that children as young as 8 years of age have already developed face recognition skills, seeing more than just emotions, and are able to recognize the mental states of others (Baron-Cohen et al., 1996).

Regarding the locus of these effects within the brain, research into the specialization of certain neural areas implicates the amygdala, as damage to this structure has been consistently linked with deficits in the recognition of emotional expressions. As well, neuroimaging studies also seem to implicate this particular structure (Shaw et al., 2005). The specific contribution of the amygdala to the recognition of facial expressions is not just limited to social expressions however, but also appears to include cognitive expressions (Shaw, et al., 2005). Unlike cognitive expressions which display one's specific mental state at a particular time (i.e., thinking), emotional facial expressions (or social expressions) regulate our social behaviours and possess a feature of valance (Shaw et al., 2005), consisting of either a positive (such as a happy emotion) or a negative valance, (such as anger). This is an important point since emotions are thought to be processed differently depending on their valance value, with the right cerebral hemisphere (RH) thought to be more specialized for negatively valanced emotions, and the left hemisphere (LH) being more specialized for the positive ones (Collins & Cooke, 2005). The theory relating to the valance of emotional processing will be discussed in greater detail later. Of note however is that there is a marked effect of valance only as it relates to the impairment of right frontal groups confined to social expressions with a negative emotion (Shaw et al., 2005). Through studies investigating damage to the anterior temporal lobe, it has become apparent that this area is also implicated with the recognitions of both cognitive and social expressions (Shaw et al., 2005). Overall this suggests that there is a defined neural area that is very involved with the face processing of not just emotions, but other affective states as well.

1.3 Auditory Processing

As with other emotional processing, there is an evolutionary component to the processing of auditory emotional stimuli. Primates show some elements of semantic communication (such as differing cries of fear) which depend upon the specific situation (Bostanov & Kotchoubey, 2004). However, although emotional content has been identified in auditory expressions from birds and animals, humans are unique in that they are the only speaking creatures; more specifically, humans communicate using a vocabulary of verbal utterances (Bostanov & Kotchoubey, 2004). We do know however, that the underlying physiological mechanisms of nonverbal emotional expression are similar in all primates (Bostanov & Kotchoubey, 2004) suggesting that certain neural areas for emotion similar to those observed for visual emotions, are also present for auditory emotions, although not as easily examined (Bostanov & Kotchoubey, 2004).

Just like vision, touch, and motor control, speech has been found to be localized to one particular neural area of processing. In almost all right handed individuals, linguistic abilities (such as phonology, the lexicon, and grammar) are primarily specialized to the areas in the left hemisphere (Kendal et al., 2000). This laterality has been shown with studies involving brain lesion patients as well as with electrical and metabolic activity. The right cerebral hemisphere however, also plays a role in language processing (Kendal et al., 2000). Its role is to process communicative and emotional prosody (such as stress, timing and intonation) (Kendal et al., 2000). Prosody is the suprasegmental features of speech defined only on a large scale by pitch and loudness contours, as well as speech and articulation rates (Bostanov & Kotchoubey, 2004). Evidence of this right hemisphere specialization can be illustrated by individuals who have experienced damage to that area. A patient with a right anterior lesion, may produce inappropriate intonation in their speech, while those with posterior lesions have difficulty interpreting the emotional tone of others speech (Kendal et al., 2000).

Prosody (the addition of emotion to speech) aids with language acquisition and provides more than just semantic information. It may also provide information about more basic language features, such as structural bracketing and how the prosodic cues relate to prosodic structure (Gerken, 1996). It is believed to also provide cues to adult listeners about whether one word belongs to the same unit as the proceeding word (Gerken, 1996).

One example of prosodic laden speech is infant directed speech (ID). In this style the speaker is more "free" with their speech style than in the more constrained style of adult directed speech (AD) (Trainor et al., 2000). ID compared to AD has higher pitch contours, a larger pitch range, a slower tempo, is more rhythmic than AD, and is almost thought of as musical (Trainor et al., 2000). But what is most compelling when comparing ID and AD is that it is the widespread expression of emotions in ID that analytically differentiates it from AD (which is more constrained with regards to the expression emotions) (Trainor et al., 2000). Although the literature is limited, there is some evidence that emotional expression aids language acquisition. For example, it has been shown that when an adult is teaching other adults new or novel words, they will, without prompting, use more sentence focus and prosody on these words compared with the other words (Fernald & Mazzie, 1991). ID is also thought to influence acquisition by accommodating innate attentional biases that infants bring to language learning, and it is believed that through this and other mechanisms, the use of ID facilitates the speech processing learning in infants, and perhaps has a role in adult learning (Fernald & Mazzie, 1991).

Section 1.4 – Emotional Development

What is known about emotional development is somewhat limited (Herba & Phillips, 2004). However, despite the lack of a cohesive general theory, there is quite a large body of literature that examines emotional development, including evidence of accurate emotion perception at quite a young age. Most of the research in this area has focused on children's recognition of facial expressions. At just a few months of age, infants can discriminate happy and sad faces from surprised ones, and also can distinguish between different intensities of the expression of emotion. For example, one-year old infants are able to use facial cues from caregivers to evaluate potential threats (Herba & Phillips, 2004). Recognition increases in complexity with age, but it doesn't appear to emerge at only one stage in the infants or child's development (Herba & Phillips, 2004). For example, happiness appears to be the earliest emotion to be recognized, followed by sadness or anger, and then surprise and fear (Herba & Phillips, 2004). During development, the reliance on situational cues also emerges with age (Herba & Phillips, 2004). Infants in event-related brain potential (ERPs) studies attended more to a mother's face than a stranger's face and therefore appear to be sensitive to contextual information from familiar individuals. School aged children show the opposite effect (Shackman & Pollack, 2005). Also, from 3-5 years old, a child will rely on not just the vocal but also use facial expressions to help recognize an emotion, while at age 8-9 years, the children will also use situational cues (Herba & Phillips, 2004). Unfortunately, less attention has been directed towards understanding the role of vocal expression in emotion perception. Vocal expressions are important in developmental terms because auditory signals can capture attention from someone who is not visually attending. This is certainly the case with infants and toddlers who are still developing their attention skills (Shackman & Pollack, 2005). What we do know, however, is that listeners are able to accurately recognize joy, sadness, anger, and fear all based on prosody, and children do not exhibit preferences for either visual or auditory information (Shackman & Pollack, 2005).

It is interesting is that even though many disorders of different origins, from Williams Syndrome to Attention Deficit Hyperactivity Disorder, have been examined using what is known about emotional development, there is no evidence that individuals with Down Syndrome (DS) have defined problems with emotional development beyond those expected with the known etiologies of this disorder (Herba & Phillips, 2004). Although what is known about development of the actual neural circuitry of emotion is somewhat limited, the first two years of life are characterized by an increase in the mylenation of neural pathways, and therefore the efficiency of both cortical and subcortical pathways (Herba & Phillips, 2004). Amygdala development has not been looked at extensively, and its role in development remains unclear. However, it is known that the structural connections between the amygdala and cerebral cortex become more streamlined at 10 months of age with the mylenation of the capsula interna, that links these two areas (Herba & Phillips, 2004).

Section 1.5 – Valance and Prosody – Competing Models

When emotional valance is added to a word, prosody affects the processing of words. This is evident in explicit recall in which the recall is enhanced for emotionally-valanced words compared to non-emotional words. Furthermore, the recall is superior for positively valanced stimuli compared to negative with these biases seen in both clinical (e.g., individuals with depression) and non-clinical groups, (Collins & Cooke, 2005).

There are two competing models that attempt to explain how these higher order stimuli are processed but neither has yet been able to explain the processing of prosody. Specifically, the Right Hemisphere (RH) model contends that the RH is specialized for all emotional processing. This uses the knowledge of the RH's association with the substantial involvement in mechanics of autonomic and behavioural arousal (Collins & Cooke, 2005). The valence model, on the other hand, posits that emotional processing is mediated by each hemisphere depending on the valence of the emotion with the RH specializing in negative emotions and the left hemisphere (LH) specializing in more positive emotions (Collins & Cooke, 2005). In support of the RH model, it has been shown through lesion studies that those individuals with LH damage appear to have few problems with the perception of emotion, however, their RH damaged counterparts appear to have very profound difficulties with perceiving emotions (Smith & Bulman-Flemming, 2005). There is also evidence that also supports the Valance Hypothesis. For example, behavioural studies using neurologically intact individuals show inconsistent RH advantage results, usually related to the valance of the stimuli (Smith & Bulman-Flemming, 2005). However, the RH model of emotion perception appears to be quite salient with regards to predictions of specialization when it comes to the processing prosody, in particular with regard to processing during a dichotic listening task with prosody (Erhan et al., 1998).

Section 2 - Dichotic Listening Paradigm

2.1 Dichotic Listening Paradigm Overall

A dichotic task involves the simultaneous presentation of two different words to each of the two ears (such as "blue" to the left ear and "red" to the right ear). The participant is usually asked to repeat a target word, or identify if a target word was heard in a target setting. For example, a person could be asked to listen for the target 'red' in the right ear, and the correct response would be to indicate that it was present. Other responses could also include a movement to indicate what the participant heard, such as moving a finger to a red target on a display, to indicate what was heard in a particular ear. This type of paradigm attempts to assess the laterality of the process being examined.

Previous attempts at correlating reaction or response times did not correlate with the advantaged ear (or the other ear) when used with a vocal response. The dichotic listening paradigm is considered to be a reliable laterality paradigm, among the various measures that explore laterality of auditory perception (Voyer et al., 2002).

2.1.1 – Speech Perception and Dichotic Listening

With adults, a pattern of right ear advantage (REA)/left hemisphere (LH) specialization for speech perception emerges. Bulman-Fleming & Bryden (1994) showed that this speech perception effect is robust even when emotion as a characteristic is present. Participants listened for the words "Bower", "Dower", "Power" and "Tower" in angry, happy, sad and neutral tones. They were asked to listen for either a target word or emotion and indicate after the trial whether the target was present. So for example, a participant might have been asked to listen for the word 'Bower' and if he/she heard this target word presented to either his/her left or right ear then he/she would indicate that it was present. The REA/LH specialization was present for speech perception regardless of whether the stimuli contained emotion (happy/sad) or not (neutral). This indicates that this superiority effect consists of more than just attentional factors (since valance didn't have an effect,) and is perhaps a more innate effect (Bulman-Flemming & Bryden, 1994).

Children also appear to have a LH specialization for speech perception that is seen with a robust REA during a similar dichotic task (Saxby and Bryden, 1984). Saxby and Bryden (1984) illustrated this by having children listen to four dichotically paired phrases in 4 different intonations (such as 'The baker drinks the coffee' etc.) The phrases were all semantically and phonetically similar, and were spoken with happy, sad, angry, and neutral intonations. The children received a binaural presentation of one of the two phrases from the dichotic presentation following it, and they had to identify whether it was the same or different for both emotion and speech perception. It was shown that there was a significant REA for speech perception which did not depend on emotion. Specifically, the right ear (RE) more accurately identified the phrase than the left ear (LE) (Saxby and Bryden, 1984). This REA for speech perception appears to be deeply routed as it appears in early development, as early as 5 years of age (Saxby and Bryden, 1984).

2.1.2 – Emotion Perception and Dichotic Listening Paradigms

Opposite to speech perception effects, the recognition of emotion in verbal stimuli appears as a left ear advantage (LEA)/right hemisphere (RH) (Ley & Bryden, 1982). The LE (RH) has a significant advantage for the recognition of emotional sound (such as crying and laughing), along with emotional tone in speech (Ley & Bryden, 1982). Although Ley & Bryden (1982) demonstrated this LEA for emotion, the research to date has only looked at the specialization for perception and judgement, and not the expression of verbal emotion. The RH theory, as mentioned earlier, posits that there is a RH specialization for emotion perception, and although valance is sometimes seen in other non-verbal/non-dichotic/non-listening tasks, this RH specialization is consistently observed under a dichotic listening paradigm (Erhan et al., 1998). For example, one study used ERPs in a dichotic listening task and revealed a LEA with response accuracy to emotion perception was found for response accuracy, along with prominent ERP asymmetries for verbal perception (Erhan et al., 1998).

2.2 – Free-Recall versus Directed Attention

There are two types of dichotic listening paradigms. In the free-recall method, the experimenter will ask the participant to repeat (or recall) all the words heard during the trial. The directed attention method asks that participants listen for a target that could be a specific emotion, word, or even a specific ear. By asking the participant to listen for a target, it is thought that the participant will direct their attention to that aspect of the stimulus alone.

Attention is a critical issue to the free-recall response in a dichotic listening task (Bryden, 1978). Participants can choose where attention goes and any instructions that allow for participants to select how attention is deployed, exposes the paradigm to bias (Bryden, 1978). Although most of the early dichotic listening tasks elicited a significant REA (LH specialization), the effect is only seen in 85% of the population. This contrasts with the fact that 95% are right-handed, and so therefore should be LH specialized for speech perception (Bryden, 1978). Bryden (1978), hypothesized that attentional strategies may be employed by participants during a free-recall dichotic task, and might explain why even through 95% of the population is right handed, the REA/LH specialization is only seen in 85%. He also hypothesized that memory might also effect the results (e.g., studies where there is more then one word reported) with errors tending to appear on the second word. Overall, Byden (1978) suggested that attention, perception, memory, order of report, and starting bias could be factors that affect the efficacy of a free-recall dichotic listening task.

With these differences and factors affecting reliability, there are several ways to protect effects from contamination from them. For example, the ABX procedure asks that participants attend to both ears, by presenting the stimulus dichotically first, and then subsequently with a binaural probe and ask the participant to identify if they are the same or different. There are problems with this paradigm, however the ABX procedure adds another level of difficulty (Voyer et al., 2002).

Section 3: Emotion and Processing in Down Syndrome

3.1 Emotional and Face Processing in DS

Individuals with DS have a good social understanding and empathy for others. This is particularly so in the form of non-verbal communication (when considering these individuals' difficulties in understanding many aspects of the world around them) (Whishart and Pitcairn, 2000). Children with DS appear to be socially responsive and attentive to the emotions of others (Kasari et al., 2001). Not as much attention however, has been paid to the social and emotional development of these individuals. The most common method to assess emotions in younger individuals is by verbal reporting, and this has been suggested to be unreliable (e.g., Smith and Dodson, 1996). Although children with DS appear to be socially responsive and attentive to the emotions of others, adults with DS do less well in identifying emotions from facial expressions than their chronological-aged matched counterparts (Kasari et al., 2001). Through developmental studies we know that infants with DS are described as more muted, less intense, and less understood (Knieps et al., 1994). They appear to have delayed onset of smiling and laughing, and compared to more typically developing infants, infants with DS have been shown to be more affectively labile (Knieps et al., 1994).

It has also been shown that children with DS tend to focus on other faces more often than their peers (Kasari et al., 2001) and that children with DS perform similarly to their typically developing peers at a mental age of 4 year old in their recognition of emotions (Kasari et al., 2001). With a story vignette task however, differences began to emerge with individuals with DS at 4 years of age, despite no differences at the mental age of 3 years (Kasari et al., 2001). However, these differences are probably more related to their known verbal problems as they become more dependent on verbal language for emotional expression (Kasari et al., 2001).

Although adults with DS have been shown to exhibit difficulty with face processing, this is not consistent across all emotions (Smith & Dodson, 1996). In an emotional response task, for example, these individuals exhibited the same types of facial expressions in response to happy stimuli as the control participants did, highlighting that the facial expression of positive affect appears to be intact (Smith & Dodson, 1996). However, it has been shown that individuals with DS have demonstrated problems with identifying surprise and fear (Whishart & Pitcairn, 2000) in that as early as the toddler years, individuals with DS only differed for facial expression ratings in the fearful message condition (Knieps et al., 1994). What is interesting in this scenario is that it is also known that children with DS have a reduced volume in the temporal limbic cortex of the forebrain, which includes the amygdale structure (Whishart & Pitcairn, 2000). This may explain why these individuals have exhibited difficulties with identifying fear and surprise.

Toddlers with DS also differ with their mental aged matched peers in other ways. For example, DS tend to look longer and more frequently at their parents than toddlers without DS (Knieps et al., 1994). Also, the affective expressions of the toddlers with DS are more influenced by parental affect, but what remains unclear is what effect either of these (frequency of gaze at parents and increased influence of parental affect) might suggest theoretically and whether these differences are advantageous or not (Knieps et al., 1994).

3.2 Laterlization in DS

3.2.1 Progression of Research in Auditory Processing in DS

Children with DS show a higher incidence and greater diversity of speech and language disorders, than do typically developing children. These include either separate or concomitant articulatory, fluency or phonatory abnormalities (Sommers and Starkey, 1977). In the early work, the heterogeneity of some of these speech and language performances were only partially explained, and in no great detail (Sommers and Starkey, 1977). Most of the more original work, which was aimed at explaining some of these differences, was done with dichotic tests that either included triple pairs of digits (which have a lower linguistic complexity), and also more complex common single-syllable nouns (Hartley, 1981). In these studies, it was found that there was an atypical left ear advantage (LEA) for children with DS (Hartley, 1981). In a study employing more complex stimuli then just tones or digits, Hartley (1981) had DS and non-DS children listen to word pairs that were derived from the *Peabody Picture Vocabulary Test.* They found that individuals with DS had an opposite LEA for these words, compared with typically developing children (Hartley, 1981). In a similar study, this LEA was not found but neither was a REA for the individuals with DS suggesting little if any hemispheric superiority for speech perception (Sommers and Starkey, 1977). In this task, the stimuli again consisted of more complex word pairs, such as cat-bat, dig-pig, ball-doll, etc (Sommers and Starkey, 1977). Elliott et al. (1994) examined 9 different papers dealing with dichotic listening in individuals with DS and overall found 19 different dichotic procedures, with the general finding being that individuals with DS had a LEA for speech perception tasks.

There are also marked differences in individuals with DS with regard to their movements. For example, Hermelin (1964) found that individuals with DS reacted faster to light than they did to sound. As well, as individuals with DS reacted fastest with the shortest interval between a warning and the stimulus (2-4 seconds compared to 8-16 seconds). When reaction time was looked at specifically, individuals with DS were significantly slower when there was a tone present (either with or without a light) to signal the movement (Davis et al, 1991). In addition, Hodges et al, (1995) found that individuals with DS were less affected when vision of a target was removed during the movement phase of an aiming movement, and were more consistent with their aiming than were individuals without DS of a similar mental age. They also found that the individuals with DS adopted a more conservative speed-accuracy trade off strategy. Regarding manual asymmetries, individuals with DS exhibit a pronounced right hand advantage, for tasks such as finger tapping (Elliott et al., 1986), and a right hand advantage in a sequential finger tapping experiment (Elliott, 1985). These studies showing a right hand advantage suggest a typical left hemisphere advantage for the processing and planning of movements.

One movement that incorporates both language and movement is speech production. Stuttering in speech (or dysfluency) has been shown to be more prevalent in individuals with DS than in individuals without, and increased dysfluency was associated with a decrease in right handedness for individuals with DS (Devenny & Silverman, 1990). As well, Heath & Elliott (1999) have shown that a right mouth advantage has been found in individuals with DS with this side of the mouth opening wider than the left at the beginning and end of a speaking movement. Therefore it appears that a LH specialization for speech production exists in individuals with DS.

3.2.2 – A Model of Cerebral Specialization

It has been shown that the LH plays a more dominant role in organization and execution of limb and finger movements in individuals with DS (Elliott 1985; Elliott et al. 1986), so it is thought that they are similarly lateralized for movement control as is the general population (Elliott & Weeks, 1993). In terms of movement production, individuals with DS have shown that they are able to use advanced information to decrease movement preparation time, and show the same degree of programming flexibility, as are both their mental age and chronological aged matched counterparts (Welsh & Elliott, 2000 for review). This laterality for motor control also extends to oral movements, such as the case with language production (Heath et al., 2000). This has been shown across various tasks including manual asymmetry tests and inter-manual transfer training (Elliott & Weeks, 1993). When an individual with DS is learning a sequential movement task, there is greater transfer from the left hand to the right hand, than from the right hand to the left (Elliott & Weeks, 1994). This is perhaps because the motor programs are stored in the LH giving the right hand an advantage over the left, since it is readily able to access the motor program more easily (Elliott, 1985). Thus it has been shown that individuals with DS both organize and control movements with the LH, for both basic and more complex sequential movements. For the processing of speech perception, however, research has shown a consistent atypical RH specialization along with this typical LH specialization for movement control (Elliott & Weeks, 1993; Elliott et al., 1994). A model of biological dissociation developed by Elliott and colleagues suggests that this dissociation translates into greater difficulty for individuals with DS with regard to tasks that require perception of speech and the execution of sequential movements based upon this auditory information. In other words, these two processes remain functionally separated from each other thus making them more difficult to integrate (Elliott & Weeks, 1993). The prediction was confirmed by Elliott & Weeks (1993), who found a significant, although not strong, relation between the results on a dichotic listening task and verbal motor deficiencies. Specifically, the larger the LE/RHA found in an individual with DS, the greater the difficulty the individual exhibited with performing to verbal instruction (Elliott & Weeks, 1993). Perhaps the separation of the two systems (motor and language) results in a loss of information during the interhemispheric communication that now must occur for the two systems to integrate their information (Elliott & Weeks, 1993).

As mentioned, most people in the general population exhibit a greater REA (LHA) for sounds in dichotic listening tasks however individuals with DS perform differently with a LEA for these same stimuli. Although there has been an attempt to explain these differences through a lower number of right-handed individuals in the DS population, we know that 75% - 85% of these individuals are right handed (Batheja & McManus 1985), and so this is an unlikely alternative (Heath et al., 2000). In fact, these individuals exhibit right hand preference asymmetries on unimanual tasks (such as rapid finger tapping, finger sequencing, etc.) (Elliott, 1985; Elliott et al, 1986). The biological dissociation model incorporates all these differences, and is a model that is unique to only individuals with DS. It posits that there is a RH specialization for speech perception that is combined with a LH specialization for the organization movement control and organization, and also for speech production (Heath et al., 2000 for review). What this translates into for these individuals is increased problems with learning a task with verbal instructions, as they can not seem to use these verbal cues to rapidly structure a motor program (Welsh & Elliott, 2000). This different pattern of cerebral specialization is evident in verbal/motor integration studies in which, for individuals with DS, reaction time delays with audition, seem to be related to their unique lateralization (Welsh & Elliott, 2000). For example, LeClair & Elliott (1995) showed that individuals with DS have problems with preparing movements on the basis of advanced information when that information consists of verbal information. This also extends past the motor verbal/integration studies, into studies of training or instruction for these individuals. Broadley & McDonald (1993), found that visual training for memory had far greater improvements in memory *than* auditory training.

3.2.2.2 – Implications (Theoretical and Practical)

Most individuals with a developmental disability are able to participate in society as active contributing members. Most of them will hold down a job at some point in their lives and are encouraged to integrate into their communities and everyday life. However, when learning and working, individuals with DS tend to be grouped with their other peers with mental delays. It is therefore important to understand if these individuals benefit from the same type of instruction both in a working and learning environment, and to see if the same principles of processing apply across the board to maximize everyone's potential by addressing their unique instructional needs (Welsh & Elliott, 2000). What is also important is that this atypical specialization also gives us a unique understanding of the implications of the genetic basis of cerebral specialization and what its repercussions are (Elliott et al., 1987). By understanding one of their difficulties, perhaps we can help facilitate their integration into society.

Section 4 – Research Question and Hypotheses

4.1 – Development of the Research Question

Although we know that individuals with DS display an atypical lateralization outlined in the biological dissociation model (Elliott & Weeks, 1993; Elliott & Weeks, 1994; Heath et al., 2000 for review), what is still unknown is how these individuals process more complex (i.e., higher order) stimuli such as emotion. As well, little is known regarding how they lateralize auditory emotional processing. Exploring this dimension, will further our understanding of cerebral specialization in DS (Elliott et al, 1987). It will also add more to the base of knowledge of how these individuals process emotions, and whether there are any atypical characteristics with the perception of verbal emotion.

4.2 – Predictions of the Lateralization Model

Given past research in this regard with individuals from the general population, we can predict that in both the mental and chronological aged matched controls a LEA/RH specialization for emotion perception (Saxby & Bryden, 1984; Bulman-Fleming & Bryden, 1994; Erhan et al., 1998; Ley & Bryden, 1982) combined with a REA/LH specialization for speech perception. As the research is not as extensive in the area of emotion perception, the individuals with DS are expected to show an atypical lateralization for speech perception with a LEA/RH specialization for speech perception however, how they perceive emotion is unclear. We do know, however, that there does not seem to be a pronounced specific difficulty with the perception of emotions in these individuals since they appear to be socially responsive and also attentive to the emotions of others (Kasari et al., 2001; Smith and Dodson, 1996; Whishart and Pitcairn, 2000; Knieps et al., 1994). We can therefore tentatively predict that they will show a typical lateralization of emotion perception in the dichotic listening paradigm since they are not showing specific problems with emotion.

4.3 – Predictions of the Valance/Prosody Models

Since it has been shown that the RH model of emotion perception is dominant in the dichotic listening paradigm, we would expect a robust RH specialization for emotion perception in all three groups (Saxby and Bryden, 1984; Bulman-Fleming and Bryden, 1994; Erhan et al., 1998; Ley and Bryden, 1982). However, should the Valance hypothesis hold under this paradigm, we would expect to see that the more negative emotions (sad) will mediate the lateralization to a LH specialization, or a weaker RH specialization.

4.4 – Significance

This research is expected to provide a more complete picture of speech perception in individuals with DS. These individuals live, work, and play in a world filled with emotions, and more specifically emotional speech. Understanding how they process emotions in speech perception may offer an intervention method, aside from that of using visuals instructions.

EXPERIMENT 1

In the first experiment, the use of a free recall dichotic paradigm was used to examine the effects of emotion on adults with and without Down Syndrome. This study borrows from Bulman-Fleming and Bryden (1994). In this free recall task, individuals are typically asked to listen to dichotically-paired stimuli, and recall the stimuli heard after the trial. By recording their responses and tallying up the correct response by ear, it is believed that this will illustrate how each group of individuals, and in particular those with DS, are processing these more complex stimuli and where hemispheric specialization lies. The recording of vocal RT was also examined to determine if it could also be used as a variable that would be sensitive enough to hemispheric specialization or ear advantage in this type of paradigm. Overall, this research investigates how the model of biological dissociation predicts hemispheric specialization with regard to the processing of verbal affect.

Method

Participants

For the experimental group (DS), 10 individuals with Down syndrome with an average CA of 31.6 years (26-38 years) and average MA of 7.9 years (4.7-11.1), were recruited from the *Dundas Learning Centre*, as well as the *Etobicoke* and York *Community Living Centres*. Ten individuals from the McMaster University community were used as a representation of the general population (CG) and a chronological age (CA) similar group with an average CA of 23 years (18-26 years). Eight individuals with an undifferentiated developmental delay (unDD), served as the mental age (MA) similar controls with an average CA of 31.1 years (27-37 years) and average MA of 8.3 years (6.1-10.7 years). The individuals from the unDD group were also recruited from these centers. Each participant (and/or guardian where appropriate) provided informed consent prior to participating in the experiment and participated in a pure tone audiometry exam administered by the experimenter. This was to ensure that all participants had differences between their ears no greater then 5 dBs at the 250, 500, 1000, 2000, or 3000 Hz frequencies, and therefore any differences seen in the processing of stimuli in the form of an ear advantage would be due to hemispheric differences, and not that of differences in ear acuity. The information on the mental ages from the DS group and the unDD group were obtained using the *Peabody Picture Vocabulary Test, Form L.* Participants were right-handed, as determined by their use of objects such as a pen.

Apparatus

The *E-prime Version 1.1 software,* (by Psychological Software Tools © 2003), was used to deliver and randomize the presentation of the stimuli. The computer, on which *E-prime* was used, operated with a *Windows XP Professional* operating system. The sound card (*Realtek AC 97 audio)* ran the stimuli with an average variance of 8 ms for each trial, and had a standard deviation of 2 ms, making it a reliable source for presentation of auditory stimuli. The headphones used in the experiment were *Panasonic™ RP-HT227 Stereo Headphones* and were placed on the ears that corresponded with the ear indicated on the head phone (left ear with the left head phone and vice versa.) A *Lafayette Instrument Co. model 63040 A Voice Activated Relay* was used to record the reaction time (RT) after each trial. The *E-prime Version 1.1 software* was programmed to record each of these RTs to ensure that each RT corresponded to the appropriate stimuli and response. Each stimulus was 450 ms in duration, and consisted of the words *Bower, Dower, Power,* and *Tower* spoken in the neutral, sad, and happy intonations borrowed from Bulman-Flemming and Bryden (1994). After each trial, there was a one second delay to ensure that the effects from the previous trial were limited. The experimenter recorded each of the responses that the participant gave, and also the order in which they gave them for each trial. The experimenter also recorded any difficulties with the RT recording, (such as the microphone not picking up responses etc.,) so that these RTs could be excluded from the RT analysis. During each trial the participants were asked to fixate on a point that was located on the center of the screen, and was denoted by a '+' symbol.

Procedure

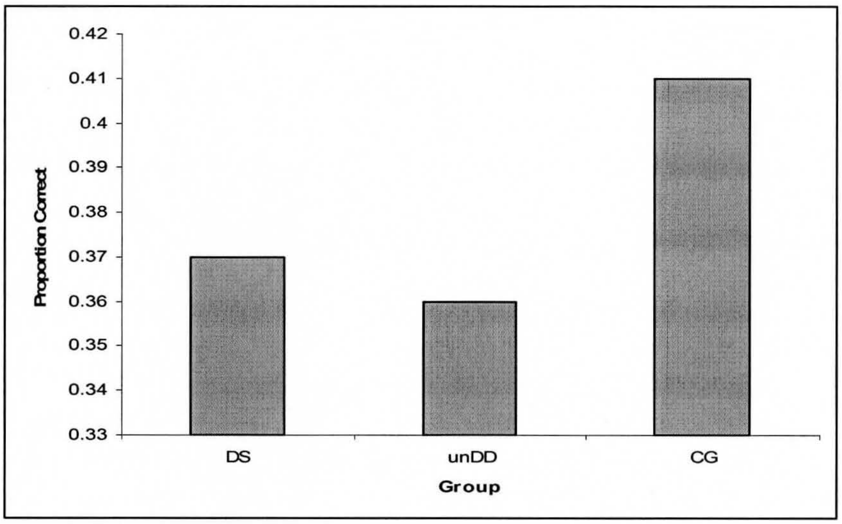
After informed consent was obtained and testing with the pure tone audiometer was completed, the participants were asked to participate in a practice session. They were shown a sheet with the words 'BOWER', 'DOWER', 'POWER', and 'TOWER', and were asked to repeat the words with the experimenter to ensure that they were familiar with all the stimuli. This sheet remained on the desk between the participant and screen for their reference. The participants were then asked to place the headphones on their heads and either hold the microphone in their hand or rest it on the stand on the table in front of them, which ever was more comfortable. The experimenter then began the practice session, and the participants were asked to listen to the words that they heard and repeat them into the microphone loud enough to trigger the voice RT box. The stimuli in the practice session consisted of each of the four stimulus words presented binaurally such that each pair of stimuli consisted of congruent words combined with congruent emotions. The stimuli were presented in a predetermined order, and consisted of the stimulus words spoken in neutral, happy, sad, and angry intonations, for a total of 16 trials. After one practice session, participants were allowed to continue practicing or proceed with the experiment.

During the experimental session, the participants were asked to keep the headphones on and were asked to repeat as many words as they could after each trial. The condition with emotional intonation (ES) was tested separately from the condition with a neutral intonation (NS) and the order was counterbalanced with each individual within each of the 3 groups. Each stimulus consisted of a dichotically paired set of target words (e.g., bower happy right, dower sad left), with each of the stimulus words being in conflict (for example *bower right* and *dower left*), while the emotion was either congruent (such as *happy right* and *happy left*,) or in conflict (such as *happy right* and *sad left*). However, since there was no emotion in the NS, only the words were in conflict. During the ES the words were in conflict for all the trials, but for half of the trials the emotional intonation was in conflict while for the other half were the emotional intonation was congruent. Since there were more possible combinations in the ES, participants completed 48 trials of three blocks for a total of 144 trials in the ES condition. In the NS condition participants were required to participate in 12 trials in 3 blocks, for a total of 36 trials in the NS. In considering the nature of the level of functioning of individuals with DS, it was thought that a directed attention dichotic paradigm with short testing sessions was more appropriate for these individuals. After testing the participants, the experimenter removed any trials in which there were difficulties with recording RT; as well any RTs that were over two standard deviations outside of the group means. Only the total correct responses were tallied, and made into a proportion so that the NS condition and ES condition could be compared to each other in a statistical analysis.

Results

Both of the dependent measures of RT and percent correct (% CT) were subjected to a 3 (group) x 3 (happy, sad, or neutral emotion) x 2 (ear) mixed analysis of variance. Tukey's *HSD* ($p<.05$) procedure was used to further investigate any significant effects involving more than two means. The %CT analysis revealed three main effects as well as a 2-way interaction of emotion and ear. The effect of group ($F(2, 25) = 4.89$, $p. < 0.05$) (*See Figure 1*) indicates that individuals from the CG had significantly more correct answers ($M = 0.41$) than the individuals either of the other two groups, ($M = 0.36$ and 0.36).

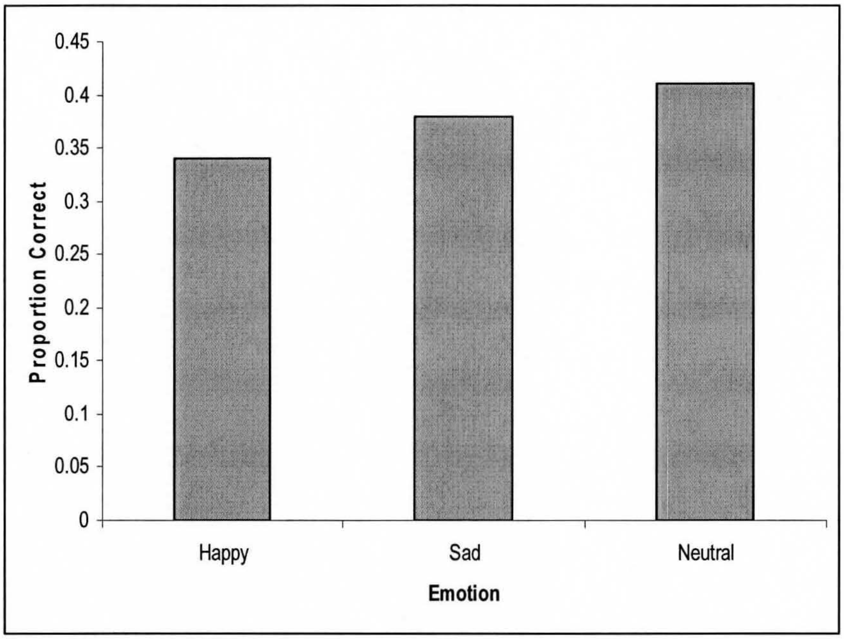
Figure 1: Proportion Correct as a function of Group



The main effect for ear ($F(1, 25) = 6.70$, $p. < 0.05$), revealed that the RE information ($M = 0.43$) was significantly more accurate than the LE information($M = 0.33$). The main effect for emotion ($F(2, 25) = 11.47$, $p. < 0.01$) (*See Figure 2*), suggests that in the neutral

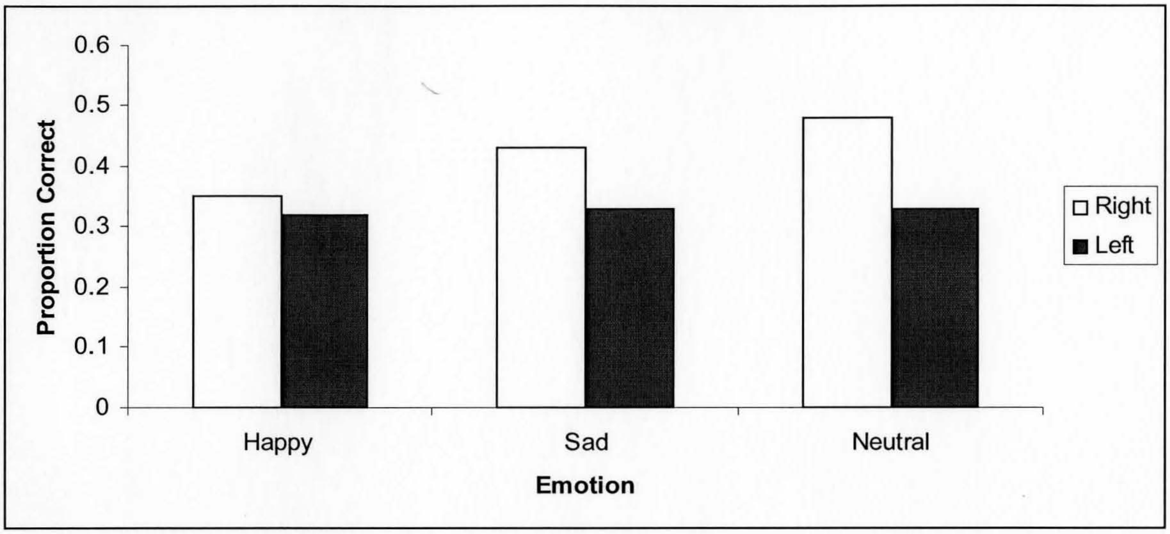
($M = 0.41$) and sad condition ($M = 0.38$) all individuals were significantly more correct than in the happy condition ($M = 0.34$).

Figure 2: Proportion Correct as a function of Emotion



Further to the main effect of emotion, there was an interaction of emotion and ear ($F(2, 25) = 5.71$, $p. < 0.01$) (*See Figure 3*), in which the overall ear advantage was revealed such that RE responses were significantly more accurate in the neutral condition ($M = 0.49$) than in the happy condition ($M = 0.36$). The RE responses in the sad condition ($M = 43$) did not significantly differ from either the happy or neutral conditions. The LE information was not affected by emotion in that the neutral ($M = 0.33$), happy (0.32), and sad (0.33) conditions did not significantly differ from each other.

Figure 3: Proportion Correct as a function of Emotion and Ear



A trend toward a Group by Ear interaction was also evident ($F(2, 25) = 5.71$, $p. = 0.09$), with evidence of the individuals from the CG exhibiting a greater REA than the individuals from either the DS or unDD groups. With regard to RT, there were no significant main effects or interactions found. RT was perhaps not sensitive enough to pick up differences, and so it was excluded from analysis in the subsequent two experiments. A 2 (emotion) x 4 (word) x 3 (group) ANOVA was also conducted on the proportion of how often participants reported certain words. The one main effect of interest is for Word ($F(2, 25)$, $p. < 0.01$) suggesting that participants responded correctly with significantly more frequency to the words 'POWER' ($M = 0.268$) and 'TOWER' ($M = 0.308$).

Discussion

Overall the results show some findings consistent with what has been previously reported in the literature. As expected, the main effect for group suggests that the CG had significantly more correct answers than the other two groups (unDD and DS). The main effect for ear, suggesting that there was a REA or a LH specialization for speech perception, is consistent with most theories in which semantic content is thought to be processed in the LH (Ley & Bryden, 1982; Saxby & Bryden, 1984; Bulman-Fleming & Bryden 1994). There is one aspect, however, of this finding that is not consistent with the functional dissociation model, and that is that the main effect for ear existed across all groups. The biological dissociation model would have predicted a two-way interaction in which the individuals from the CG and DD groups would exhibit a LH/REA, while the individuals from the DS group would exhibit a RH/LEA, such as was found in Hartley (1981).

Although previous movement studies have shown that individuals with DS or unDD employ fewer strategies than individuals from the general population (e.g., Welsh & Elliott, 2000), one possible explanation for why a RH specialization for speech perception did not occur with individuals with DS is that they may have employed strategies that are contaminating the results. Contamination with the free recall method in a dichotic listening paradigm may occur (see Bryden, 1978) because attention is not being directed to a specific ear and consequently, individuals with DS may be directing their attention to their right ear. One way to overcome this difficulty is to direct attention in the dichotic listening task. For example, one could ask for responses only from one ear or ask participants to attend to one ear and indicate the presence or absence of a stimulus (i.e., Bulman-Fleming & Bryden 1994).

It was interesting to note that there was a main effect for emotion in conjunction with a two-way interaction of emotion and ear. This result revealed that emotion only affected right ear performance in that the responses from the right ear were more accurate in the neutral condition than in the happy condition. More specifically, these results suggest that the presence of emotion does not differentially affect the processing of stimuli across all three groups and shows that individuals with DS process stimuli with emotional content differently from neutral stimuli much like everyone else. The model of biological dissociation, does not speculate on how emotion is processed and although this experiment sought to examine emotional processing in DS, it is still not clear from this experiment how this happens. In order to further explore this issue, two additional experiments were conducted.

EXPERIMENT 2 (a & b)

Experiment 2a was conducted to see if directing attention would reveal different laterality effects for individuals with DS than was observed in Experiment 1. It was expected that since attention will be directed in Experiment 2a, that the participants with DS will show a differential laterality effect in that they will not display a REA/LH specialization for speech perception. How emotion is being processed will also be examined simultaneously in Experiment 2b in which participants will be asked to focus on the emotional intonation of the stimuli, and not the semantic content as in Experiments 1 and 2a. This should provide a more complete picture with regard to emotional verbal perception in DS since there is both an emotional and semantic component to the stimuli. The results are expected to show no differences with regard to the processing of emotion in individuals with DS, since they appear to have limited difficulties with the perception of emotion.

Method

For the two experiments in which the participants were asked to direct their attention (Experiments 2a and 2b), the same equipment and stimuli were used as in Experiment 1. These two experiments ran consecutively. In order to keep learning effects to a minimum, the order in which the participants performed these two experiments was counterbalanced.

Participants

The individuals that comprised the experimental group were 9 adults with DS (3 females, 6 males). This group had an average CA of 31.4 years (25-38 years) and a MA of 7.16 years (3.58-11.08 years). A CA similar group (CG) was used which consisted of 10 individuals (6 females, and 4 males), from the McMaster University community, with an average CA of 22.9 years (19-34 years). As a MA similar control, 9 individuals with an unDD with an average CA of 32.2 years (25-42 years) and MA of 8.32 years (6.08-10.58 years, 5 females, 4 males) were recruited to participate. The participants from the unDD and DS groups were recruited form the Dundas Learning Centre, as well as the Etobicoke and York Community Living Centres. The mental age of these two groups of participants was found using the *Peabody Picture Vocabulary Test, Form L.* Each participant (or their parent/guardian where appropriate,) was required to provide informed consent prior to their participation. They also completed a pure tone audiometry exam prior to participating in either experiment. Only those participants with threshold differences between their ears of no greater then 5 dB at the 250, 500, 1000, 2000, and 3000 Hz frequencies were used. Again the threshold differences were evaluated to ensure that any differences seen in the results would be due only to laterality effects, and not due to differences between the acuity of ears. All participants were right handed, as determined by their use of objects, such as a pen.

Apparatus

The apparatus used was identical to Experiment 1.

Stimuli

The stimuli used in this experiment were 450 ms in duration and consisted of the same dichotic pairs of words (*Bower, Dower, Power,* and *Tower)* spoken in either a happy, sad or neutral intonation. The pairs of stimuli consisted of incongruent words, and, for one half of the trials either incongruent (e.g., *Power happy right ear, Tower sad left ear,*) or congruent intonations (e.g., *Bower happy right ear, Power sad left ear.*) For the practice session, the same stimuli were combined binaurally. In the experimental condition, participants listened to the dichotically-paired stimuli, in which 2 different stimuli were delivered to each ear simultaneously. In the trials in which emotional intonation was excluded (the neutral condition) the words were always incongruent (e.g., *Bower right ear, Tower left ear.*) With all possible combinations of stimuli included, there were 48 different stimuli in the emotion condition, and 12 for the neutral condition.

The 12 mono stimulus words were recorded using a woman's voice, different from the stimuli from Experiment 1. A low pass 3000 Hz frequency filter was applied to ensure that there were no frequencies above 3000 Hz present in the stimuli. In order to ensure the intonation (happy, sad, or neutral) was reliable, 204 undergraduate students from the McMaster University Department of Kinesiology, first year Psychomotor Behaviour class were asked to listen to each of the stimuli 3 times, and record for each stimulus whether they perceived it as happy, sad, or neutral. Each stimulus was presented in mono format, and the order in which they were presented was randomized. It was found that the emotional intonation of each of the stimulus was perceived accurately at a 60% confidence level.

Experiment 2a

Procedure

After informed consent was obtained and the pure tone audiometry was completed, those participants who failed to show a difference between the two ears were asked to participate first in a practice session to familiarize the individual with both the task and the stimuli. The participants were instructed to listen to a specific ear and for a specific word. They were then presented with binaural stimuli through the headphones, and were asked to indicate whether they had heard the target word in their target ear for 12 trials. For the practice session, the stimuli were presented in a predetermined order, and participants were given the opportunity to try the practice session as many times as they wished before continuing on to the experimental session.

During the experimental session each individual was asked to listen for either of the target words *Tower* and *Power* in a particular ear (left or right). The order of which word and ear they were asked to attend to was counterbalanced within group. Since there were 4 possible combinations of the words and ears to listen for, each participant completed 4 blocks to ensure that each combination was used. The words with neutral intonation were presented in a separate condition (NS) from those with an emotional intonation (ES). Order was counterbalanced across participants to ensure minimal learning effects. In the NS condition there were 12 trials in each block, for a total of 48 trials in this condition. The ES condition contained more possible pairs of stimuli and therefore had a total of 48 trials in each block for a total of 192 trials in this condition.

After testing, the participants' responses were matched with the stimuli presented. The proportion of incorrect responses was calculated overall for each participant and subsequently for each ear. The proportion of false positives, false negatives, and intrusion was also calculated for each participant and also each ear. A false negative occurred when a participant indicated that the target word was not present in the target ear when in fact it was. A false positive consisted of a participant indicating that the target word was present, when in fact it was not. Intrusions occurred when the stimuli presented to the opposite ear were reported. For example, the participant is asked to listen for "tower" in the right ear and their response is a false positive it would considered an intrusion error only if tower was presented to the left ear during this trial.

Experiment 2b

Procedure

Each participant wore the headphones and proceeded with a practice session prior to the experimental session. The practice session was similar to Experiment 2a in that it allowed the participants to become familiar with both the stimuli and the procedures. However, in this session participants were asked to practice listening to the voice intonations (i.e., happy or sad), in either their LE or RE, and asked to indicate when they heard the target emotion in their target ear. After one practice block, participants were given the opportunity to continue with more practice blocks or to start the experiment.

In Experiment 2b, each participant was instructed to indicate to the experimenter after each trial whether they heard the target emotion in the ear that they were asked to attend to. Which ear and emotion that they were asked to listen to was counterbalanced within each group. Since there were 4 different ear/emotion combinations, 4 blocks of 48 trials were conducted for a total of 192 trials. After participants finished the experiment their responses were matched up with the stimulus for each trial as in Experiment 2a. The proportion of incorrect responses was calculated for each participant, as well as for each of the ears. The proportion of false negatives, false positives, and intrusion as defined in Experiment 2a were also calculated for each participant.

Results

Experiment 2a

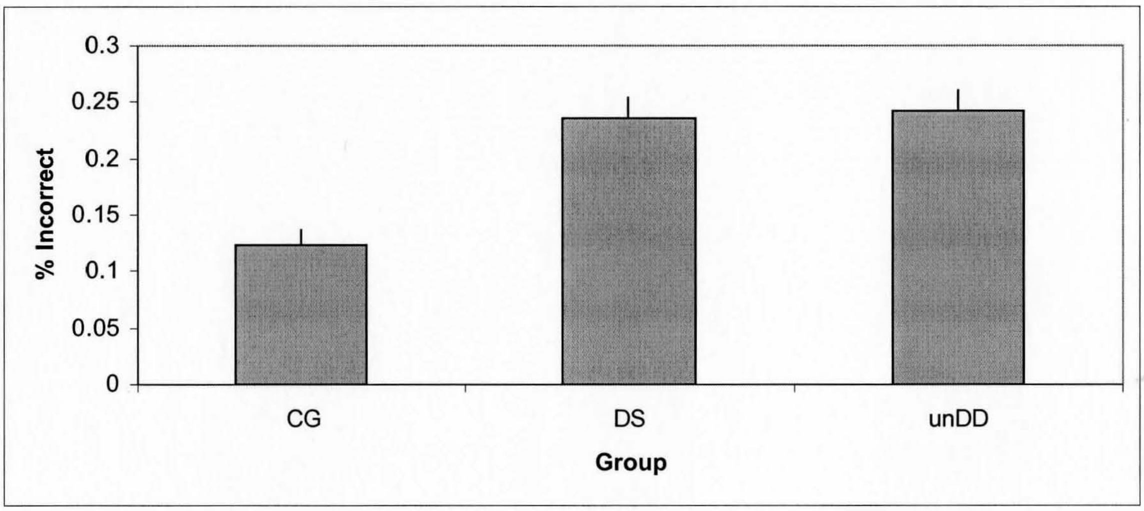
A 3 (group) X 2 (ear) X 2 (word) ANOVA was performed on each of the four variables of Percent Incorrect, False Negative, False Positive and Intrusion for both the

NS and ES conditions. A 2 (emotion) factor was also included in the ANOVA in the ES condition. A Tukey's Honestly Significant Difference test was performed on each of the significant effects involving more then 2 means. As well, a Hartley's F-Max test ($p. <0.05$) was used to test the homogeneity of the variance revealed that the data were homogeneous for each of the significant effects.

NS Condition

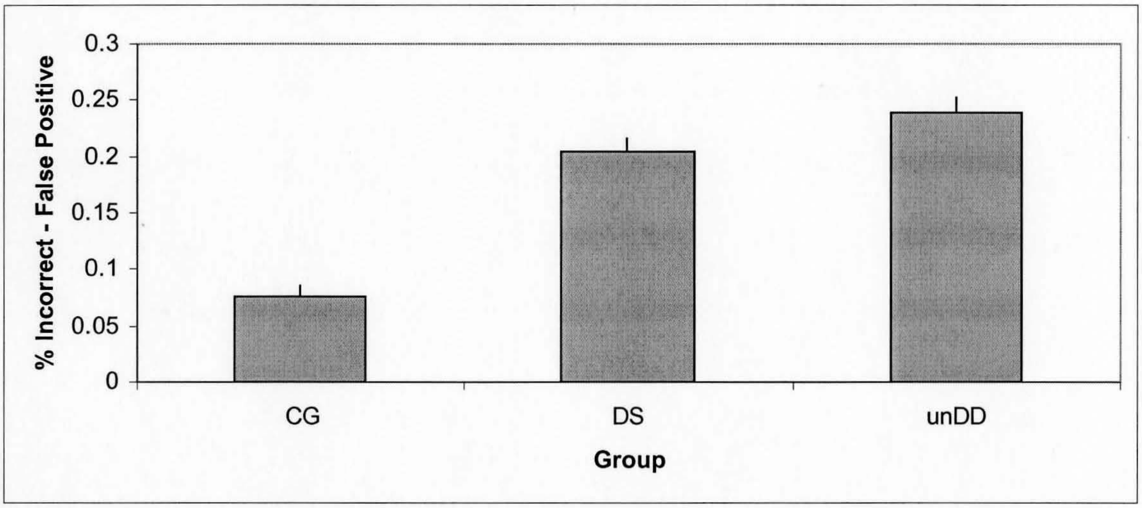
For Percent Incorrect, a main effect was found for both the Group (F (2, 25) = 15.62, $p. < 0.01$) (*See Figure 4*) and Ear (F (1, 25) = 5.57, $p. < 0.05$). With the Group main effect, it was found that the DS (M=34%) and unDD (M=32%) groups were both significantly more incorrect than the CG group (M=15%), and that the left ear (LE) (M=31%) was significantly more incorrect than the right ear (RE) (M=23%).

Figure 4: Proportion of Incorrect as a function of Group



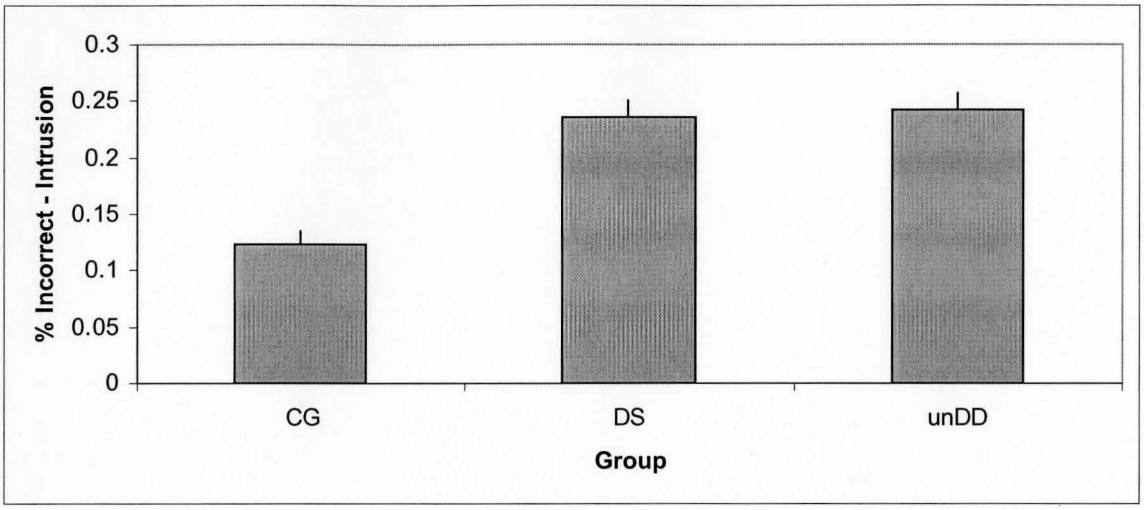
The main effect for Ear carried over into the False Negative variable (F (1,25) = 8.70, $p. < 0.01$). The same effects were found with the RE (M = 8%) having significantly fewer false negative responses than the LE ($M = 12\%$). The Group main effect was also found in the False Positive variable (F (2, 25) = 16.81, p. < 0.01) (*Figure 5*), with the CG (M =75%) having significantly fewer false positives than either the DS ($M = 24\%$) or unDD ($M = 20\%$) group (which were not significantly different from each other).

Figure 5: Proportion of False Positive as a function of Group



For intrusion, a main effect for both Ear (F (1, 25) = 10.75, p. < 0.01) and Group (F (2, 25) = 12.66, p. < 0.01) was evident (*See Figure 5*). The Group and Ear main effects again suggest that the CG ($M = 12\%$) exhibited significantly less intrusion than the DS (24%) or unDD (23%) groups. As well, the LE ($M = 24\%$) exhibited significantly greater intrusion than the RE ($M = 16\%$). No interactions were observed between the variables.

Figure 6: Proportion of Intrusion as a function of Group



ES Condition

For each of the variables, there were main effects of Group (*See Table 1*). These Group effects included: Proportion Incorrect (F (2, 25) = 34.23, p. < 0.01), (*See Figure 7*), False Negative (F (2, 25) = 21.59, p. < 0.01), False Positive (F (2, 25) = 28.97, p. < 0.01), and Intrusion (F (2, 25) = 24.37, p. < 0.01), and Ear [(F (1, 25) = 17.42, p. < 0.01), (F (1, 25) = 13.22, p. < 0.01), (F (1, 25) = 12.65, p. < 0.01), (F (1,25) = 19.88, p. < 0.01), respectively]. These effects were similar to those found in the NS condition in which the CG were significantly less incorrect (M = 10%), responded with fewer false negatives (M = 3%), fewer false positives (M = 7%), and exhibited less intrusion (M = 10%) than the individuals in the DS (M = 34%, 10%, 23%, 24%, respectively) and unDD groups (M = 35%, 12%, 24%, 24%, respectively).

Figure 7: Proportion of Incorrect as a function Group

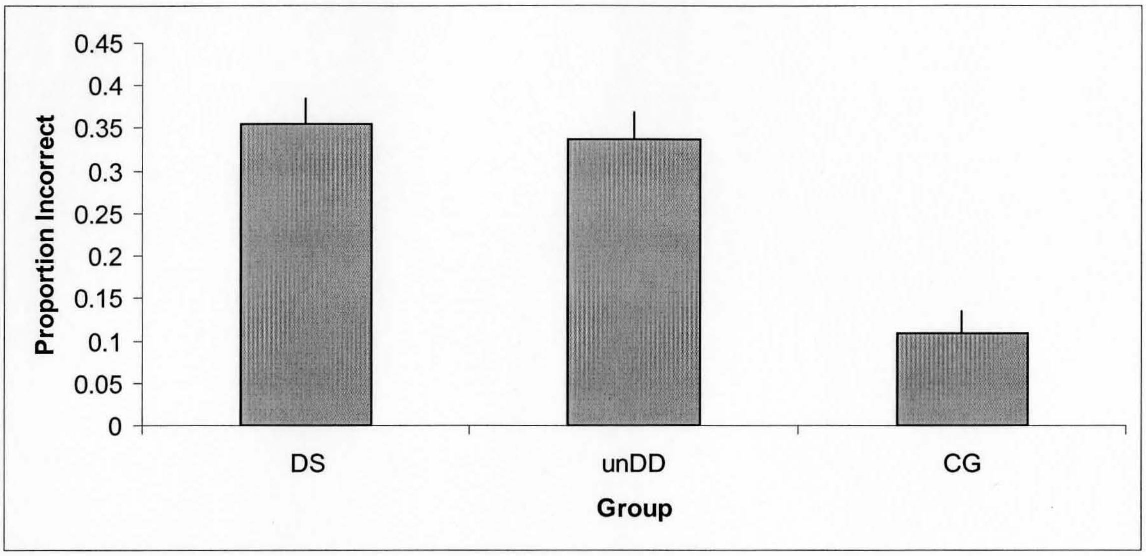


Table 1: Mean Proportion of each factor as a function of Group

	% Incorrect	False Negative	False Positive	Intrusion
DS	0.35	0.12	0.24	0.24
unDD	0.34	0.10	0.23	0.24
CG	0.11	0.04	0.07	0.10

To further explore the effects of emotion, two conditions (NS and ES) were analyzed together for all of the variables and, in the ES condition, the different emotions were broken down into happy and sad stimuli. This resulted in a 3 (emotion) X 3 (group) X 2 (ear) 2 (word) ANOVA which suggested that the factor of emotion had no effect on any of the variables or results for the semantic perception of a word.

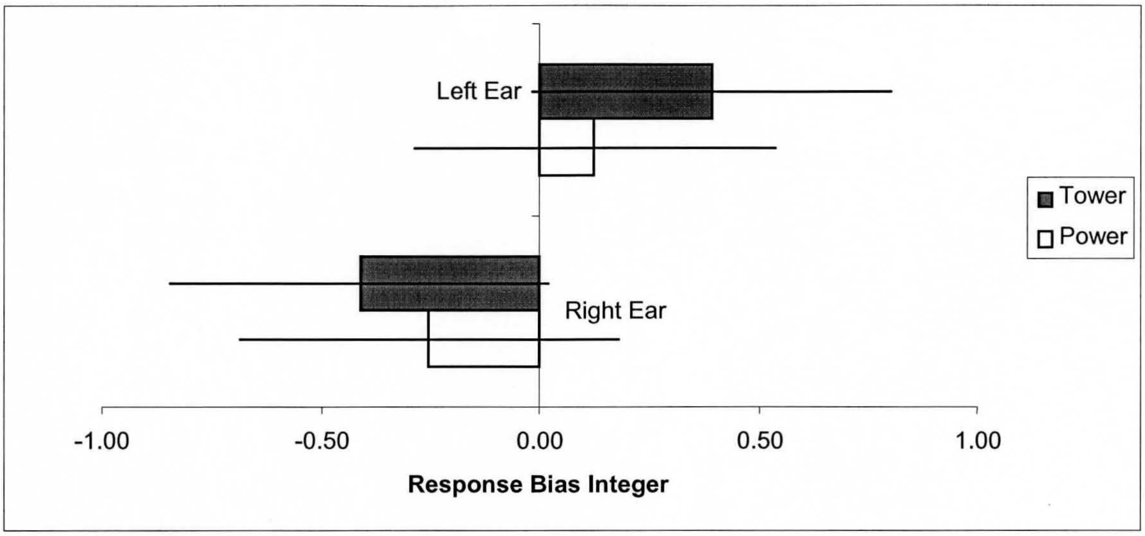
Signal Detection Analysis

In order to determine if the participants were exhibiting general response biases that existed independent of the variables of interest, a signal detection analysis was performed. Initially, Hit and False Alarm rates were calculated for each participant in each condition. The Hit Rate reflects how well the participant was able to correctly identify when the stimulus was present. The False Alarm rate is an indication of how often the participant indicated when the stimulus was present when it was, in fact, not present. A 3 (group) X 2 (ear) X 2 (word) factor ANOVA was performed on these response biases for both the NS and ES conditions. A 2 (emotion) factor was also included in the ANOVA in the ES condition.

NS Condition

The results in the NS condition are similar to those for proportion incorrect with an effect for Ear (F (2, 25) = 13.227, $p. \leq 0.01$) becoming evident. Specifically, the RE (M = -0.3) had a significantly higher hit rate than the LE (M = 0.3), which had a higher rate of false alarms. There was also a 2-way interaction between Ear and Word (F (1, 25) = 4.46, $p. < 0.05$) in which the RE still has a significantly higher hit rate than the LE. The LE however, has a significantly higher false alarm rate depending on which word was perceived (*See Figure 8*).

Figure 8: Response Bias Integer as a function Group and Ear



ES Condition

A Main Effect for Ear (F (1, 25) = 23.8, $p. < 0.01$) was observed, (RE: M = -0.3, LE: M = 0.3), as well as an interaction of Emotion and Word (F (1, 25) = 22.28, $p. < 0.01$) (*See Figure 9*), and a 3 way interaction of Group, Ear and Word (F (2, 25) = 5.12, $p. < 0.05$) (*See Figure 10*). Essentially, these interactions speak to the relative differences in the perception of the two target words. Although this might be problematic in terms of the overall interpretation of the data, it is evident in Figure 10 that the likely locus of this interaction lies in the tendency of the DS participants to respond to the word "Tower" on a disproportionate percentage of trials. This bias is most likely a reflection of DS participants adopting a strategy to simply repeat the word that has the most meaning, and/ or greater salience, to them.

Figure 9: Response Bias Integer as a function of Emotion and Word

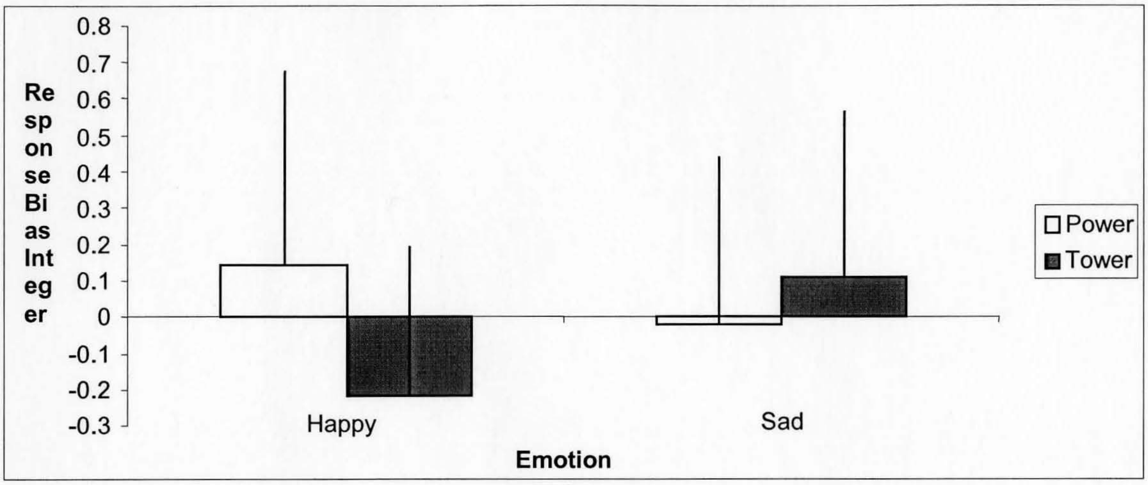
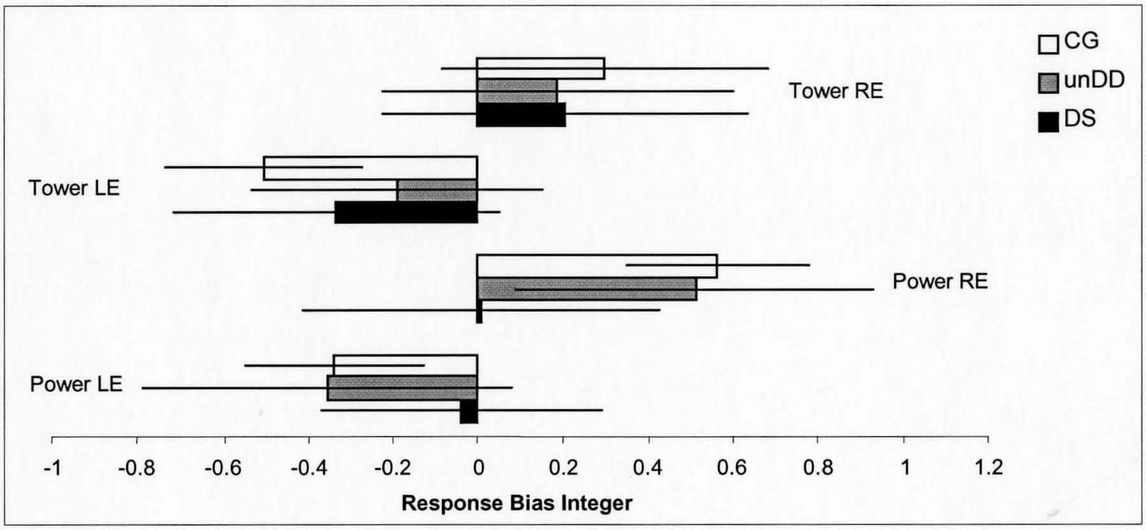


Figure 10: Response Bias Integer as a function of Group, Ear and Word



Results

Experiment 2b:

A 3 (group) X 2 (ear) X 2 (emotion) ANOVA was performed on the same four variables as before: percent incorrect, false negative, false positive and intrusion. With each significant effect, a Tukey's Honestly Significant difference test was performed at a significance of $p. < 0.05$, along with Hartley's F-max test to ensure homogeneity of variance for each effect.

For the Percent Incorrect condition, there were three main effects for each of the factors of Group ($F\,(2, 25) = 59.66$, $p < 0.01$) (*See Figure 11*), Ear ($F\,(1, 25) = 8.29$, $p. < 0.01$) and Emotion ($F\,(1, 25) = 4.29$, $p. < 0.05$). These suggest that the CG (M=10%) was significantly more accurate than either the DS (M=42%) or unDD (M=43%) groups: the LE (M=30%) was more accurate overall than the RE (M=34%), and that the happy emotion (M=30%) was more accurately perceived than the sad (M=33%). There was also a significant interaction ($F\,(2, 25) = 59.66$, $p. < 0.05$) of Group and Ear (*See Figure 12*), suggesting the CG are significantly more accurate than the DS and unDD in both the LE (M = 5%, 40%, and 44%, respectively) and the RE (M = 15%, 44%, and 43%, respectively) and that the two developmentally delayed groups are essentially bilateralized in this regard.

Figure 11: Proportion of Incorrect as a function of Group

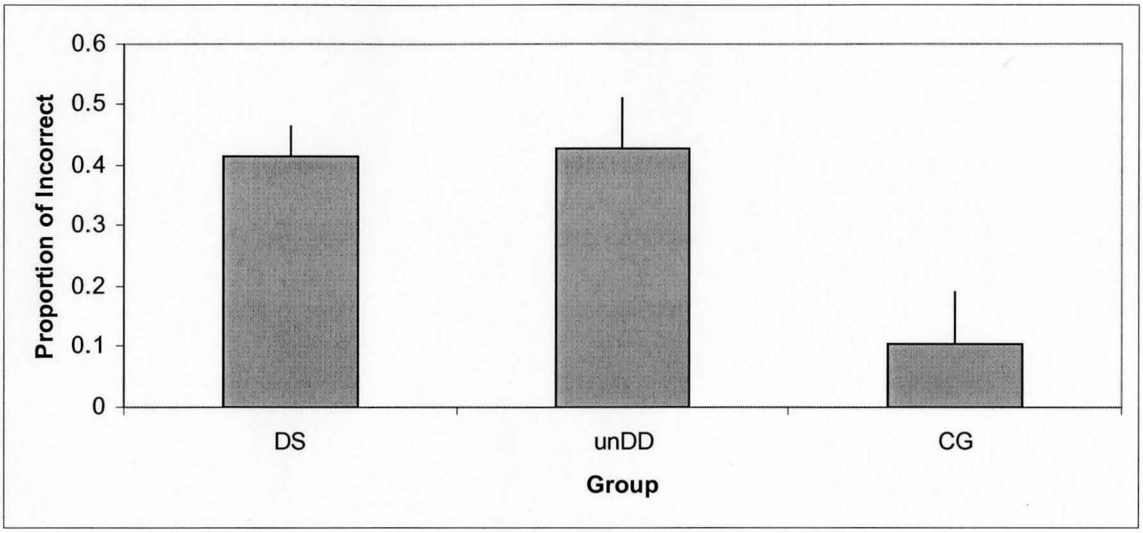
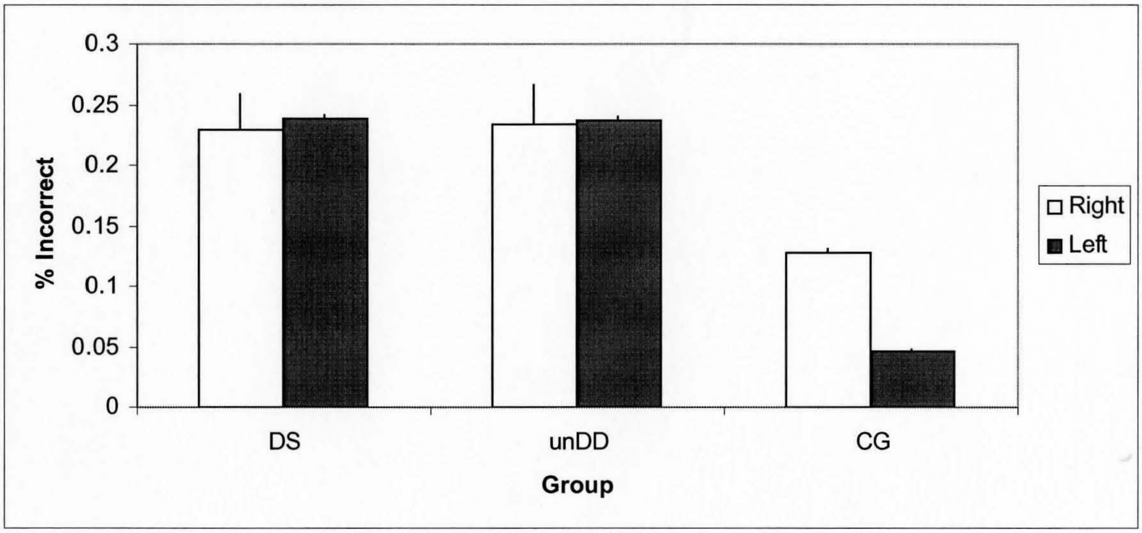


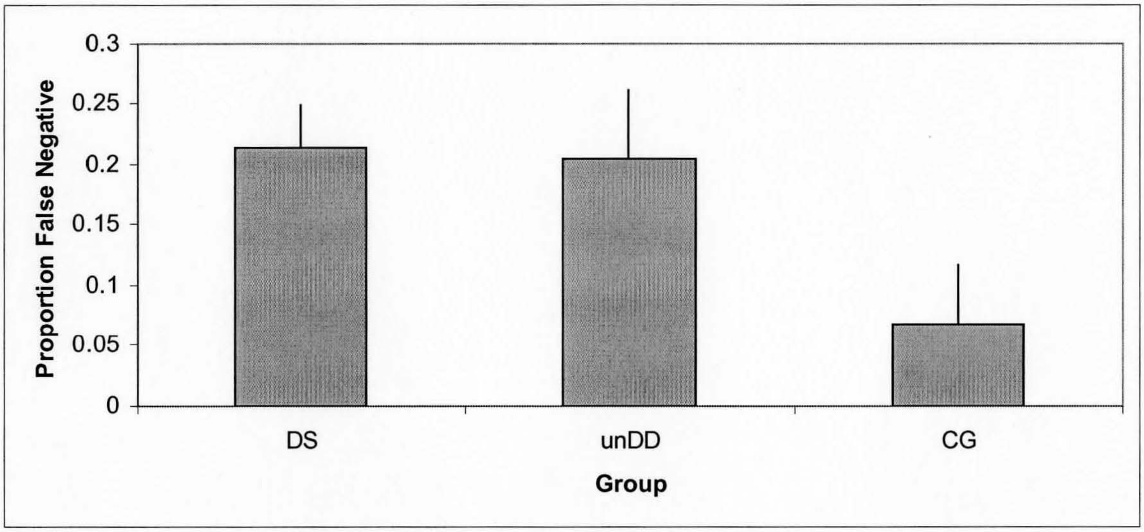
Figure 12: Proportion Incorrect as a function of Group and Ear



With the False Negative variable, there was a significant main effect for Group (F (2, 25) = 23.3, p. < 0.01) (*See Figure 13*) (CG: M=7%, DS: M=21%, unDD: M=20%).

There was also a main effect for Ear ($F(1, 25) = 6.4, p. < 0.05$) with the RE ($M = 18\%$) being less accurately perceived than the LE ($M = 15\%$), as well as a main effect for Emotion ($F(1, 25) = 5.8, p. < 0.05$) with the happy emotion ($M = 13\%$) being more accurately perceived than the sad emotion ($M = 19\%$).

Figure 13: Proportion of False Negative as a function of Group



Results for the False Positive variable demonstrate a main effect of Group ($F(2, 25) = 91.96, p. < 0.01$) (*See Figure 14*) and a three-way interaction ($F(2, 25) = 5.1, p. < 0.05$) of Group, Emotion and Ear (*See Figure 15*). The main effect for Group is similar to that which has been evident throughout, with the CG (M = 0.04) being more accurate with their responses than the DS ($M = 0.20$) or unDD ($M = 0.22$) Group. The 3-way interaction demonstrate some other differences between the groups, with the individuals with DS being significantly more correct when the emotion was sad in their LEs ($M =$

0.18), than the DD group in the left and right ears in the happy condition (M = 0.26, M = 0.26).

Figure 14: Proportion of False Positive as a function of Group

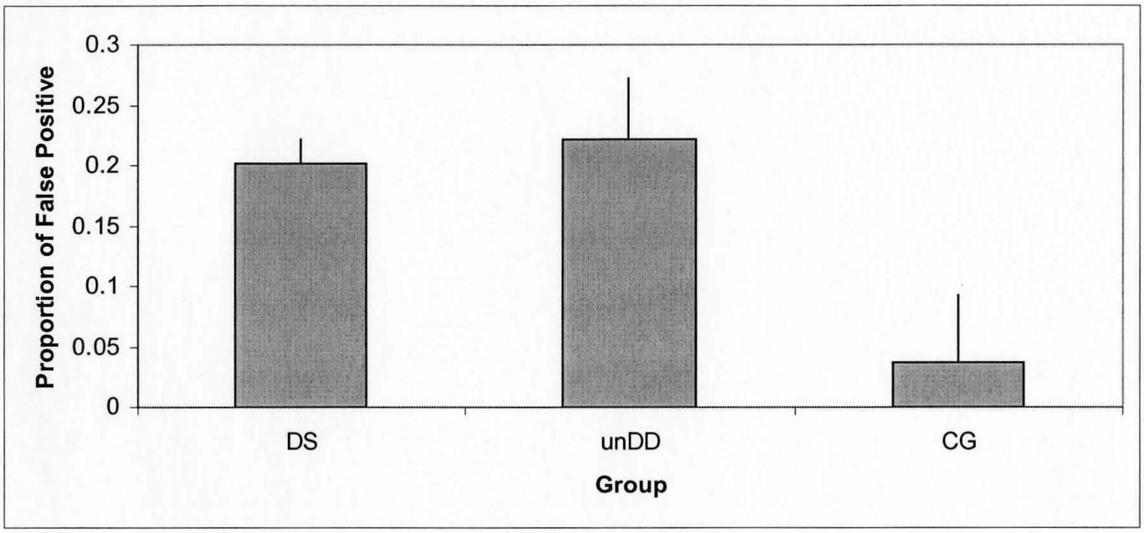
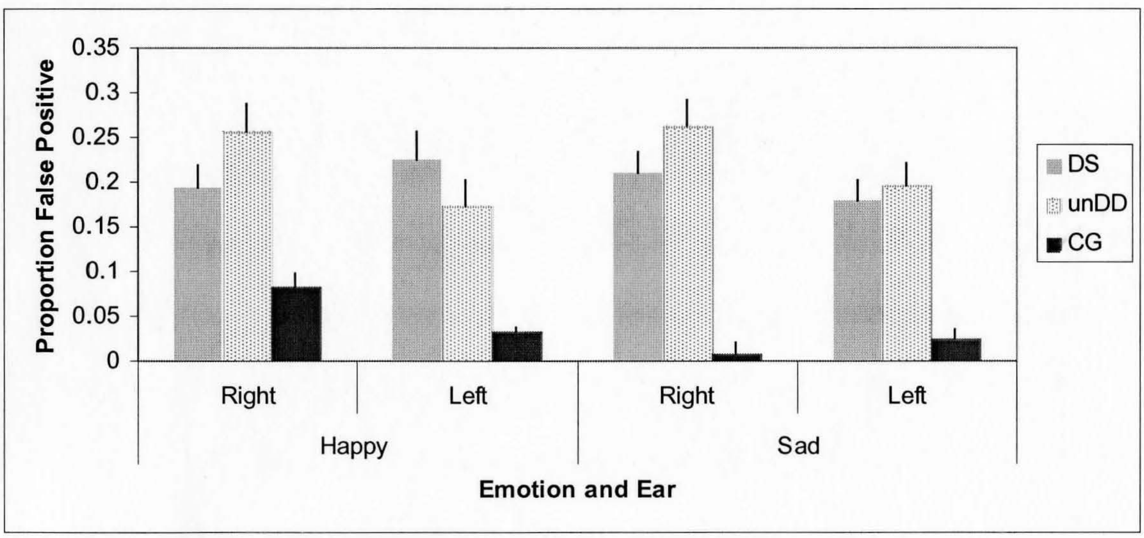


Figure 15: Proportion False Positive as a function of Ear, Group, and Emotion



For the variable of Intrusion, a main effect for Group (F (2, 25) = 26.34, $p.$ < 0.01) (*See Figure 16*) and an interaction of Group and Ear (F (2, 25) = 3.39, $p.$ < 0.05) (*See Figure 17*) were found. The main effect for Group was similar to all the other ME`s for Group with the CG (M = 9%) exhibiting significantly less intrusion than the DS (M = 23%) and unDD (M = 24%) groups. The interaction of Ear and Group suggests that, whereas intrusions are just as likely to occur in the LE or RE for DS (M = 23% and 24%, respectively) and unDD (M = 23% and 24%, respectively), the CG exhibits significantly higher incidents of intrusion for the stimuli presented in the RE (M = 13%) compared to the LE (M = 5%).

Figure 16: Proportion Intrusion as a function of Group

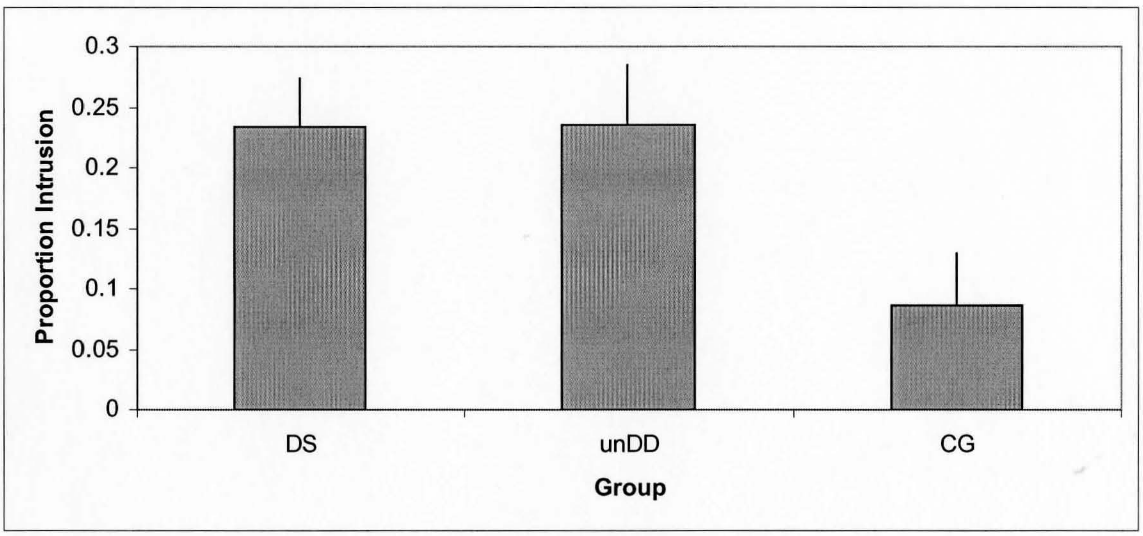
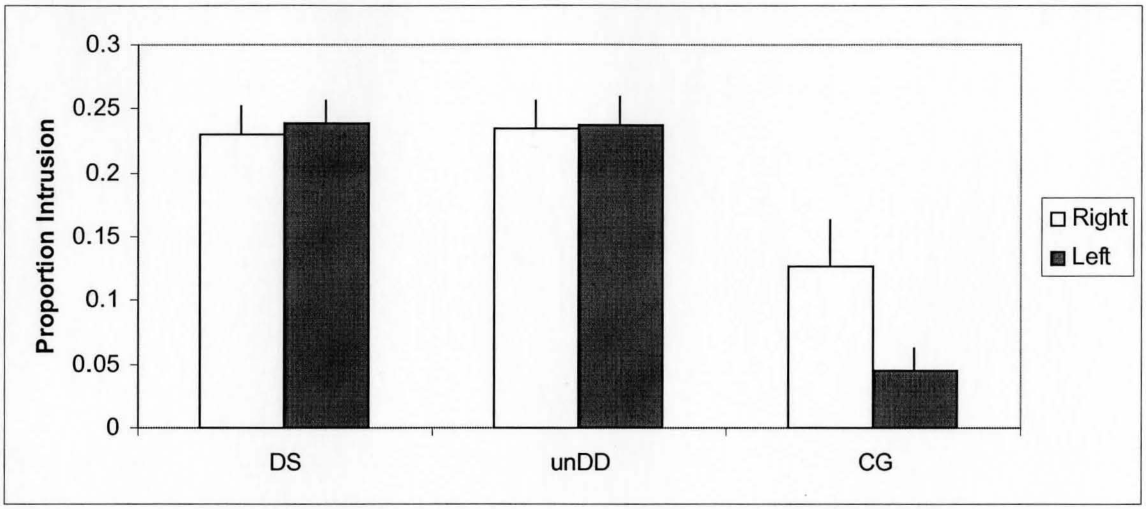


Figure 17: Proportion Intrusion as a function of Group and Ear



Signal Detection Analysis:

As with Experiment 2a, a 3 (group) X 2 (ear) X 2 (emotion) signal detection analysis was carried out to determine if the response bias differed across any of the 3 factors. A main effect for Emotion (F (1, 25) = 9.71, p. < 0.01) was evident in the happy emotion (M = 1.4) had a significantly lower false alarm rate than the sad condition (M = 1.6).

Discussion

<u>Section 1</u> – General Conclusions

1.1 – Experiment 2a

There was an expected group main effect in both the ES and NS conditions with the control group exhibiting significantly fewer incorrect responses across almost all variables. This was not unexpected since individuals with a higher mental age (i.e., control group) would be expected to out perform those with a lower mental age

(considering that it is assumed that the mental age of the CG are considered to be the same as their chronological age.)

With regard to ear, however, effects were consistent (i.e., a REA or LH advantage for speech perception) with the results of others (Ley & Bryden, 1982; Saxby & Bryden, 1984; Bulman-Fleming & Bryden 1994). This lack of effect of emotion was expected because it had not been observed previously in studies of this nature.

These findings suggest that the testing conditions were valid (i.e., replication of previous findings: Ley and Bryden, 1982; Bulman-Fleming and Bryden 1994; Saxby and Bryden, 1984). However, an expected interaction between ear and group was not revealed (Heath et al., 2000 for review). This could be due to many factors, especially with regard to the nature of the task/response and the complexity of the stimuli. These possibilities will be discussed in greater detail later.

The participants were also more accurate in Experiment 2a when compared to Experiment 1. This may be partially explained by the participants receiving information as to where to direct attention. When attention was not directed, participants may have attempted to split their attention between two ears as a strategy to compensate for the disadvantaged hemisphere.

1.2 – Experiment 2b

We again found that the CG, as expected, out performed the other 2 groups. There was also a reversed ear advantage with the LE or RH now having lower number of incorrect responses in all but the false positive variable.

The effect of emotion suggests that the happy emotion is more accurately perceived than the sad. This is not surprising since it has been shown that positive emotions are more accurately categorized (Hugenburg, 2005). This effect of "happy" being perceived more accurately was also evident in the signal detection analysis (i.e., more hits).

1.3 – General Conclusions

Generally, the results for the experiment 1, 2a, and 2b suggest that the expected group differences in terms of response accuracy are both evident and consistent (with the CG out performing the DS and DD groups.) As well, Ear effects are consistent with other research suggesting that the RE is more accurate with speech perception per se whereas the LE is more susceptible to the perception of emotion (e.g., Ley & Bryden, 1982; Saxby & Bryden, 1984; Bulman-Fleming & Bryden 1994).

The results from Experiments1 and 2b, appear to be somewhat consistent with the RH model for lateralization of emotion. In Experiment 1, the interaction of ear and emotion showed that it was the neutral stimuli in the right ear that was mediating a more accurate response *than* the happy emotion. The Valence hypothesis suggests that positive emotions are processed in the LH, and therefore should have mediated a more accurate response by the right ear. Further to this in E*xperiment 2b,* a significant LEA (RH specialization) was found for emotion perception which again coincides with the RH model. In other words, whereas the Valence Hypothesis would have predicted a LEA for negative (sad) stimuli and a REA for positive (happy) stimuli, this was not the case.

What remains unexplained however, is why the DS group did not display a LEA/RH advantage for speech perception with this task. This may call into question the degree of generalisability of the laterality effects typically exhibited in DS. Specifically, there was no evidence to suggest that DS individuals should be lateralizing these types of stimuli any differently from those in the general population. Rather, there is some evidence to suggest that persons with DS seem to process emotion laden speech in a manner that is similar to the general population but in a way that is delayed by the specific problems of speech perception in these individuals. We can therefore tentatively suggest that individuals with DS appear to show similar lateralization for emotion perception as do both the MA and CA peers, however further work would be needed to confirm this finding. An example of one such study might use a dichotic listening study with just sounds such as a crying versus laughing (i.e., no semantic content).

Section 2 – Lack of Atypical Lateralization in DS

2.1 – Nature of Task Response

The most striking result in these studies was the lack of a LE/RH advantage in DS participants particularly in the neutral stimulus conditions in which no affective content was present. Although the absence of this usually robust effect may cast some doubt on the validity of the testing procedures used in these studies, there are two important issues to consider before drawing this conclusion: 1) With the exception of this one effect, results from these studies are generally quite consistent with others with respect hemispheric specialization in the general population in terms of both response accuracy and the processing of emotion and; 2) Others have also had difficulty in eliciting atypical lateralization effects in DS (e.g., Sommers and Starkey, 1977) with relatively complex verbal stimuli. As well, although Hartley (1981) did find an atypical LEA for verbal stimuli, the words used were derived from the PPVT and were not matched for alignment nor any other potentially mediating phonetic properties such as rhyming.

That being said, the question remains as to *why* these effects were not present. Perhaps the lack of atypical lateralization in this study can be related back to the nature of the task or the response dimensions. For example, in face processing studies with emotion, differences emerge with regard to the nature of the response being asked. Angry faces are more easily and quickly responded to in a search paradigm (Baron-Cohen et al., 1996), versus a categorization task in which the happy response is faster to be categorized than angry, sad or neutral (Hugenberg, 2005).

As well, in one study that did look at rhymed meaningful dichotically paired one-syllable words (Somers and Starkey, 1977), no ear preference was found for these individuals. However, it should be noted that this involved a pointing response and so the differed from Hartley's work (1981) in which a verbal free-recall response was required. More recently, a study by Heath et al. (2005) investigated inter-hemispheric integration by using a directed attention dichotic listening paradigm in which the response was to point to the target word, displayed as a picture in front of the participant. It is interesting that Heath et al. (2005) found a similar REA in adults with DS. One possible explanation for why several studies have revealed REA advantages in DS (e.g., Heath et al., 2005; Sommers and Starkey, 1977) might involve specific methodologies, specifically the use of a manual pointing task rather than a simple verbal response.

2.2 – Complexity of Stimuli

In this study, two syllable words that were similar in many phonetic properties were used for the dichotic stimulus presentation. These stimuli also contained emotional intonation thereby resulting in two levels of complexity that have not been used with this population when investigating lateralization. The most complex stimuli used in previous studies were, as mentioned, single syllable emotion impoverished words, whereas these studies increased the potential complexity of these stimuli significantly thereby increasing the difficulty of the task.

Section 3 – Future Directions

3.1 – Increase Level of Difficulty

As Voyer et al. (2002) have suggested, increasing the difficulty of a task may increase the laterality effects. The ABX paradigm adds a level of difficulty by having participants utilize their short term memory. Participants are first presented with two dichotically paired stimuli, and *then* a probe which is binaurally presented. The participant is required to compare the probe with the dichotic presentation and indicate whether the stimuli were present in the dichotic presentation. This should add difficulty for the individuals with DS, as it is known that these individuals display particular deficits for verbal short-term memory as compared to other individuals with a developmental delay (such as Williams Syndrome), (Jarrod et al., 1999). Even with greater vocabulary knowledge then other chronological and mental age similar participants, individuals with DS still show a significant verbal short term memory deficit *than* their other peers (Brock and Jarrod, 2004). As mentioned before, it is believed that as difficulty increases, so too does sensitivity laterality effects. Since the individuals with DS and DD did not display floor effects, it would be prudent to examine, using a more difficult paradigm, whether these effects can be elicited relative to affective content.

3.2 – Changing the Paradigm or Response

Perhaps using only words that have been used before in a dichotic listening task (such as that of Hartley, 1981) may be more comparable and thus elicit the atypical verbal perception when emotion is present. If atypical lateralization is evident, then it is likely that it is the complexity of the stimuli that changes how individuals with DS literalize verbal stimuli. However, if these atypical lateralization patterns do not emerge, a stronger case could be made for the mediating influence of emotional delivery on lateralization in DS. Further to changing the stimuli, perhaps it would also be of benefit to employ some of the paradigms used the movement control studies, and change the response by having the participant respond with a button press. This would allow for a more direct assessment of issues of verbal-motor integration by not, only looking at the accuracy of the response, but also the reaction/response time of the participant. It may also diminish any interhemispheric advantage, by using different ears and response hands, and in effect forcing intrahemispheric integration of the information.

It is important to carry out this type of research not only for our understanding of how individuals with DS process verbal stimuli, but also to look at how different factors maybe affecting the performance of individuals in the dichotic listening paradigm. As mentioned before, the implications of researching the biological dissociation model not only enhance our knowledge of individuals with DS, but also may, in this case, help to understand better some of the factors that affect the dichotic listening paradigm. Overall, what can be concluded from this work is that individuals with DS appear, at least for dichotically presented two- syllable emotional words, to exhibit patterns of cerebral lateralization that are similar to non-DS controls for verbal stimuli. Such a result is not predicted by the biological dissociation model but further investigation in this vein is required before adaptations to this model can be suggested.

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