# MOVEMENT PREPARATION AND DOWN SYNDROME:

# THE COSTS AND BENEFITS OF ADVANCE INFORMATION

# MOVEMENT PREPARATION AND DOWN SYNDROME: THE COSTS AND BENEFITS OF ADVANCE INFORMATION

BY

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Thank you for being a special part
of my journey

*To Kathy LeClair, thank you for your love and encouragement*

*to continue the journey*

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## Foreword

This thesis has been written in a format suitable for publication. The introduction section has been written in APA style and to meet publication requirements and as such only addresses those issues central to the study hypotheses. Additional background information is found in Appendix A under the appropriate headings.

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# Movement Preparation and Down Syndrome:
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Running Head: Costs and Benefits of Advance Information

**Abstract**

This study attempts to resolve to what extent individuals with Down syndrome benefit from advance information provided visually, versus the same information provided verbally when performing a manual aiming task. Adults with Down syndrome and undifferentiated developmental handicaps, as well as control subjects without a developmental handicap, performed manual aiming movements to targets 10.5 cm. away. On a particular trial, subjects were cued about the specific movement either visually or verbally. The cue provided either 50% or 80% certainty.

Nonhandicapped control subjects initiated and completed their manual aiming movements more quickly than subjects with mental handicaps. As well, individuals with Down syndrome were found to be slower and more variable in reaction time than individuals in the other mentally handicapped group when valid information was provided verbally but not when the cue was provide visually. These results provide support for the Elliott and Weeks (1990) model of biological dissociation. Specifically, the atypical hemispheric lateralization for speech perception exhibited by individuals with Down syndrome results in a disruption in communication between functional systems responsible for the processing of verbal langauge, and the organization of complex movement.

## Movement Preparation and Down Syndrome:
## The Costs and Benefits of Advance Information

### OVERVIEW

During the past decade a number of studies have been conducted on cerebral specialization and the information processing abilities of individuals with Down syndrome. It has been noted in studies using a dichotic listening paradigm, that these individuals have an atypical hemispheric lateralization for the perception of speech (Hartley, 1981; Pipe, 1983; Zekulin-Hartley, 1981, 1982). Specifically, they exhibit a left ear right hemisphere advantage. It has been further shown that individuals with Down syndrome have a left hemisphere lateralization for the production of complex movements including speech (Elliott, 1985; Elliott, Weeks, & Elliott, 1987; Elliott, & Weeks, 1990; Elliott, Weeks, & Gray, 1990; Elliott, Weeks, & Jones, 1986; Piccirilli, Alessandro, Mazzi, Sciarma, & Testa, 1991). This left - right structural dissociation between speech perception and speech production is the main feature of a neurobehavioural model proposed by Elliott and Weeks (1990). The model posits that there is a dissociation between the functional roles of the two hemispheres in individuals with Down syndrome. Specifically, it proposes that individuals with Down syndrome depend on processes within their left hemisphere for the production of complex movements, while they depend on their right hemisphere for the perception of speech.

This dissociation is also thought to be responsible for the difficulties exhibited by these individuals in the processing of verbal information when attempting to accomplish a motor task.

The purpose of this study was to examine how individuals with Down syndrome employ advance visual and verbal information to parameterize goal-directed movements. Our hypothesis was that individuals with Down syndrome would be flexible in their ability to organize movements on the basis of visual information (Le Clair, Pollock, Elliott, 1993), but would exhibit difficulty relative to other mentally handicapped individuals when advance information was provided verbally.

## BACKGROUND

Specific differences have been noted between individuals with Down syndrome and individuals with other developmental handicaps. It has been shown that individuals with Down syndrome perform more poorly than other people who are developmentally handicapped on sequential language processing tasks (Hartley, 1985). Marcell and Armstrong (1982) examined auditory and visual memory and found that individuals with Down syndrome had greater difficulty with auditory sequential memory tasks than individuals with other developmental handicaps. It has been suggested that some of these specific problems may have a neurobiological base. Specifically, persons with Down syndrome appear to have an atypical pattern of cerebral specialization. Most of this evidence comes from studies employing dichotic listening procedures.

## DICHOTIC LISTENING AND DOWN SYNDROME

The dichotic listening technique involves the presentation of different sources of auditory stimuli to each ear. After the simultaneous presentation of this information, the subject is required to report and/or recall the information that they have heard. The accuracy of the subject's report and/or recall for information presented in the left and right ear is associated with the proficiency of the contralateral cerebral hemisphere in processing that type of information. It has been shown that right handed individuals without developmental handicaps generally demonstrate a right ear advantage for verbal information (Darwin, 1971) and a left ear advantage for non verbal information (Knox & Kimura, 1970).

Despite a number of limitations (e.g., Bradshaw & Nettleton, 1983), the dichotic listening research has provided relevant information on the cerebral specialization of individuals with and without developmental handicaps. Mosley and Vrbancic (1990) summarize three consistent findings on dichotic listening and individuals with developmental handicaps. First, they note that individuals with developmental handicaps, excluding those with Down syndrome, demonstrate typical ear advantages, though the magnitude of performance is variable. Second, individuals with developmental handicaps and those with Down syndrome demonstrate the same pattern of intrusion errors as do individuals who are nondevelopmentally handicapped and matched for mental age. Finally, individuals with Down syndrome exhibit atypical ear advantages for the perception of speech sounds (Giencke & Lewandowski, 1989; Hartley, 1981, 1985; Pipe, 1983; Pipe & Beale, 1983; Sommers & Starkey, 1977; Zekulin-Hartley, 1981, 1982). Specifically, persons with Down syndrome display a left ear advantage, indicating an atypical right hemisphere specialization for receptive language (cf. Tannock, Kershner, & Oliver, 1984).

## HEMISPHERIC SPECIALIZATION AND DOWN SYNDROME

Although persons with Down syndrome do appear to process speech sounds better with their right cerebral hemisphere, little was known about cerebral specialization for other types of information processing. To remedy this situation, Elliott and colleagues decided to examine manual asymmetries in persons with Down syndrome. Following the rationale taken with nonhandicapped persons, Elliott et al. (1987) proposed "that hand differences in the performance of specific motor tasks are related to the differential ability of the two cerebral hemispheres in processing certain types of information" (p. 266). Thus, by comparing the manual performance of individuals with Down syndrome to persons without Down syndrome, Elliott (Elliott, 1985; Elliott, Weeks, & Jones,

1986) attempted to gain additional insight into the processing characteristics of the two cerebral hemispheres.

In an initial study, Elliott (1985) used a finger tapping task to compare the performance of adolescents and adults with Down syndrome to chronologically age matched developmentally handicapped and nonhandicapped individuals. Only subjects with a preference for their right hand were used in the study. His initial findings showed that individuals with Down syndrome demonstrated no significant difference in performance for hand, unlike the individuals in the nondevelopmentally handicapped group who displayed a right hand advantage. Subjects in the developmentally handicapped group tended to have either a distinct right or left hand advantage. These findings suggested that individuals with Down syndrome were less specialized for the production of sequential movements than developmentally handicapped and nondevelopmentally handicapped persons.

Elliott, Weeks and Jones (1986) used a similar methodology to examine frequency of finger tapping, and also introduced a measure of finger tapping variability. They accomplished this by dividing the tapping response into two measurable components. By separately examining the depression and release portions of the tapping movement and deriving standard deviations for each component, they were able to evaluate the variability in finger tapping for each hand. This measurement technique was based on the work of Todor and Kyprie (1980) and Todor, Kyprie and

Price (1982), who had associated greater variability in finger tapping with the left hand with a less sequential and more pre-programmed type of processing within the right hemisphere. Though Elliott, Weeks and Jones (1986) found no hand differences in finger tapping rate for individuals with Down syndrome, these subjects exhibited a pattern of asymmetry similar to nondevelopmentally handicapped subjects. That is, they exhibited greater variability with the left hand than the right hand. Thus, contrary to the mean performance findings (Elliott, 1985), the variability data suggest left hemisphere specialization for the organization of sequential movements.

Other evidence for the left hemisphere specialization for motor control in persons with Down syndrome comes from studies examining intermanual transfer of training for sequential movement tasks. Both Elliott (1985) and Edwards and Elliott (1989) found greater transfer of training from the left hand to the right hand than the reverse, in Down syndrome and control subjects. Following Taylor and Heilman (1980), this pattern of transfer is thought to reflect left hemisphere specialization for the organization and control of movement. Thus while persons with Down syndrome may exhibit reversed cerebral specialization for the perception of speech sounds, like most non-Down syndrome persons, they appear to be left hemisphere specialized for the control of limb movements.

Elliott, Edwards, Weeks, Lindley and Carnahan (1987) used yet another approach to examine cerebral specialization in individuals with

Down syndrome. Specifically, they used a dual task paradigm to examine cerebral specialization for speech production. Previous literature (e.g., Kinsbourne, & Hiscock, 1983) has noted that when a right-handed individual is required to speak while performing an unimanual movement task, speech is likely to interfere with right hand performance more than left hand performance. Elliott et al. (1987) found the same pattern of lateralized interference in subjects with Down syndrome as in other developmentally handicapped and non-handicapped subjects. That is, all groups exhibited more right hand than left hand interference. Picirilli, D'Alessandro, Mazzi, Sciarma and Testa (1991) have reported similar results. This would indicate that like most non-handicapped persons, individuals with Down syndrome, are left hemisphere specialized for speech production. The consistency of the movement asymmetry findings indicate that a simple model of cerebral specialization in individuals with Down syndrome is not viable (cf. Hartley, 1982).

## MODEL OF BIOLOGICAL DISSOCIATION

Based on dichotic listening and motor asymmetry findings, Elliott et al. (1987) proposed an initial model of biological dissociation, suggesting that individuals with Down syndrome depend on processes within their left hemisphere for the production of complex movements including speech. At the same time, they accepted the position proposed by dichotic listening researchers that individuals with Down syndrome depend on the right cerebral hemisphere for the perception of speech. This lead Elliott et al. (1987) to postulate that "a left - right structural dissociation disrupts the interaction between cerebral mechanisms responsible for speech perception and speech production"(p. 268). Specifically they proposed that it is "a breakdown in communication between functional systems that normally overlap that is responsible, at least in part, for the general and specific language based problems exhibited by these individuals"(p. 268). The biological dissociation model (Elliott et al., 1987) predicts that individuals with Down syndrome will exhibit specific deficits on tasks that involve both speech perception and the production of complex limb and oral movements including speech movements. Thus, the model also predicts that individuals with Down syndrome will have greater difficulty in performing movements that are verbally directed as compared to individuals without Down syndrome who have been matched for mental age. If these movements are visually demonstrated however, no significant differences should be evident. The recent studies by Elliott and Weeks (1990) and Elliott, Weeks and Gray (1990) support the dissociation model.

Elliott and Weeks (1990) studied a group of adults with Down syndrome and a group of developmentally handicapped individuals matched for chronological age and mental age using a 40 item apraxia battery. This battery was divided into two categories, with movement cues being provided visually or verbally. They reported a significant group by type of cue interaction. Unlike other subjects with developmental handicaps, who perform equally well on the visual and verbal portions of the battery, subjects with Down syndrome demonstrated poorer performance when given verbal instructions than when the limb and oral movements were demonstrated.

In a second study, examining movement sequencing, Elliott and Weeks (1990) had two groups of subjects perform a task that required the individual to move from a home switch, and sequence three different movements. The order of the three movements was randomly varied and specified visually or verbally. Their findings revealed a right hand performance advantage in subjects with Down syndrome. As well, individuals with Down syndrome performed better when movement cues were given visually than when they were provided verbally. Elliott and Weeks (1990) proposed that the difficulty individuals with Down syndrome have in sequencing movement based on verbal instruction versus visual instruction, is due to biological dissociation between the cerebral areas responsible for speech perception and those responsible for the organization and execution of complex movements.

Recently, Elliott, Weeks and Gray (1990) replicated and extended these findings by demonstrating that the verbal-motor difficulties associated with Down syndrome become more pronounced as the length of a movement sequence increases. The difficulties of persons with Down syndrome do not appear to be due to verbal encoding or verbal memory problems, since subjects with Down syndrome did as well as control subjects when they were simply required to point to pictures of a verbally specified movement sequence. Thus the results of this study were consistent with Elliott's (1990) proposal that individuals with Down syndrome are adversely affected by a dissociation between the areas of the brain responsible for speech perception and those that govern the organization of complex movements.

The proposed model of biological dissociation raises a number of specific questions. One important question is the role of handedness in cerebral specialization of individuals with Down syndrome. Though, this study was not specifically designed to address this question directly, it is important to consider this issue. Kimura (1966) notes, that 70% of individuals who are left-handed exhibit the same patterns of cerebral specialization as individuals who are right-handed. Unfortunately, no specific information exists on the relation of hand preference to cerebral specialization in individuals with Down syndrome. Thus, the degree to which left-handed and right-handed individuals with Down syndrome differ remains unknown.

Another important question is the effect that verbal and visual advance information has on individuals with Down syndrome while they are preparing a motor task. Elliott, Gray and Weeks (1991) examined this question by studying whether verbal-motor performance deficits noted in persons with Down syndrome interfered with the ability to learn a novel motor task on the basis of verbal instruction. The task was a three element movement that was verbally cued. Elliott et al. (1991) found that when they withdrew the verbal cue during retention, reaction time increased for subjects with Down syndrome more than for the other subjects. At the same time, movement time did not differ between the subject groups. This indicates that subjects with Down syndrome took more time to plan and initiate their movements when the verbal cue present during acquisition trials was removed. One purpose of this study was to more closely examine the use of advance verbal information in movement preparation by persons with Down syndrome.

## ADVANCE INFORMATION AND MOVEMENT PREPARATION

There are several ways to manipulate advance information. Rosenbaum (1980), studying the sequential order of movement programming, introduced a technique to examine how movements were programmed prior to execution. This pre-cue technique involved providing subjects with varying levels of information about the movement to be performed prior to the movement imperative. The usefulness of a particular type of information was determined by comparing conditions in which that information was available, to conditions in which it was not available. The time taken to prepare the movement, or reaction time, was the primary dependent variable. In a manual aiming task, Rosenbaum provided his nonhandicapped subjects with either full, partial, or no information about the hand to be moved, direction of movement, and the extent of movement. These manipulations were made with the assumption that the reaction times of subjects under these conditions would indicate the advantages, in time, for those movement parameters that could be prepared in advance. His findings suggested a fixed order for movement preparation (hand, direction, distance), noting that advanced information about movement distance was not as useful in reducing movement preparation time, if advanced cues were not also given for hand and direction.

Goodman and Kelso (1980) adapted Rosenbaum's (1980) paradigm. Their main concern was to naturalize Rosenbaum's stimulus-response conditions. They argued that the conditions were too contrived. Goodman and Kelso (1980) considered the results of Rosenbaum's study an effect of stimulus-response translation processes. They naturalized the stimulus-response conditions by directly specifying the precue through vision and aligning the stimulus and response, within the physical structure of the task.

In their first experiment, Goodman and Kelso (1980) replicated Rosenbaum (1980). They found reaction time values similar to those of Rosenbaum (1980). In a series of three more experiments, Goodman and Kelso (1980) continued to naturalize the conditions. In experiment 2, the subjects' reaction times decreased as the precue information became more detailed, but no systematic pattern emerged. No evidence was found for a fixed order of movement preparation. When an ambiguous precue was added in experiment 3 and 4, again no systematic effect for reaction times were noted, even though this inclusion reduced task uncertainty. Goodman and Kelso (1980) concluded their results supported the parallel model of processing. Thus, these non-handicapped subjects were extremely flexible in their ability to use advance information.

If individuals without developmental handicaps are able to be flexible in their use of precue information, it is important to discover if the same flexibility exists with individuals with mental handicaps and Down syndrome. Le Clair, Pollock and Elliott (1993) used a four alternative target-aiming task, which required the subject to move with their right or left hand, to a near or far target. The precue information was manipulated by visually precuing hand, distance, both hand and distance or by providing no precue information. The results indicated that individuals with Down syndrome and developmental handicaps were in fact able to use precue information in a flexible manner during movement preparation.

## COST/BENEFIT PARADIGM

Another method of examining movement preparation is based on the cost-benefit paradigm (e.g., Posner, 1978). In this paradigm, subjects are typically given advance information that one response is more likely than another. On the majority of trials (e.g., 80%), this advance information is valid and subjects show a benefit in reaction time compared to conditions in which the two responses are equally probable (i.e., 50-50). Presumably, this is because subjects are able to use the advance information to prepare the movement prior to the movement imperative. On a small proportion (e.g., 20%) of trials however, the advance information is invalid and the movement imperative specifies the uncued response. On these trials, there is typically a reaction time cost compared to the neutral (i.e., 50-50) condition. Specific costs and benefits can be calculated by subtracting the mean reaction time on neutral trials from the mean reaction times on invalid trials (cost) and determining the difference between the mean response times for neutral trials and valid trials (benefit) (Posner, Nissen, & Ogden, 1978). The research reported here has employed this basic methodology to examine movement preparation in persons with Down syndrome.

## PURPOSES AND HYPOTHESES OF THE STUDY

This investigation attempted to resolve to what extent individuals with Down syndrome benefit from advance information provided visually versus the same information provided verbally, when performing a manual aiming task. The subjects were asked to perform the aiming task in the context of a cost / benefit paradigm. Testing was divided among four types of trial blocks. Specifically, subjects were cued about the upcoming movement either visually or verbally, and the cue provided either 50% or 80% certainty. Reaction times and movement times were collected for each trial.

In relation to the Elliott and Weeks model of biological dissociation and the findings of Elliott and Weeks (1990) and Elliott, Weeks and Gray (1990), it was hypothesized that individuals with Down syndrome would not benefit from advance information when it was provided verbally. Also, persons with Down syndrome were not expected to demonstrate any costs following the presentation of invalid verbal information. Secondly, it was hypothesized that individuals with Down syndrome would experience significant costs and benefits when advance information was provided visually. Furthermore, based on the Elliott and Weeks (1990) model of biological dissociation, the patterns exhibited by individuals with Down syndrome to verbal advance information should be unique to this group, when compared to individuals with and without developmental handicaps.

## METHODS

### Subjects

The subjects included 8 adults with Down syndrome (4 males, 4 females), 9 undifferentiated developmentally handicapped adults (3 males, 6 females), and 8 non-handicapped control subjects (4 males, 4 females) (Table 1).

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Insert Table 1 about here

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All subjects with Down syndrome and undifferentiated developmental handicaps were evaluated using the Peabody Picture Vocabulary test (form L) to establish a mental age. Audiological assessments were also conducted to establish normal hearing at a minimum level of 30 db within a range of 500 to 4000 Hz. Subjects were also tested for the ability to distinguish between the colours red and blue, using a seven colour chart. A simple assessment of hand preference was also conducted by having the subjects reach for a pencil.

Control subjects were screened for normal hearing at a minimum level of 30 db within a range of 500 to 4000 Hz and the ability to distinguish between the colours red and blue. Their chronological age and mental age were assumed to be equal.

Individuals with Down syndrome and undifferentiated developmental handicaps were recruited from the St. Thomas - Elgin County Association for Community Living, the Tillsonburg Association for Community Living, Hamilton Association for Community Living and the Brantford Association for Community Living. Nonhandicapped control subjects were recruited from the McMaster University undergraduate and graduate programme.

Apparatus and General Set up

The apparatus, depicted in Figure 1, consisted of two illuminating targets buttons (1 blue, 1 red) and one non-illuminating yellow home button. The buttons were arranged in an equilateral triangle.

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Insert Figure 1 about here

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The target buttons and home button were connected to a custom made control panel, an interval timer and power supply. The experimenter provided a visual precue by illuminating one or both of the target buttons for 1.5 s, or, a verbal cue (approximately equivalent time) by using the word 'red', 'blue', 'red or blue' or 'blue or red'. Immediately after the visual or verbal cues, the interval timer timed a foreperiod of 1.5 s, after which one of the target buttons was illuminated for 1.5 s. The illumination of the 'target' button started a digital timer, that stopped when the subject released the home button, providing a measure of reaction time. Removal of the finger from the home button, started a second timer that stopped when the target button was depressed, providing a measure of movement time. The task design was consistent with a cost / benefit paradigm.

To familiarize subjects with the procedure in the first testing session, the precue button (visual or verbal) was the imperative signal or target button 100% of the time. To discourage anticipation due to the constant foreperiod, catch trials were introduced randomly on 20% of the trials. On a catch trial, there was a precue but no imperative.

In the second and third testing sessions, two types of blocks of trials were employed. In the first type of trial block, both target buttons were precued (visually or verbally) for all trials. These trial blocks provided the subject with 50% certainty about the target button. In the second type of trial block, the precue button (visual or verbal) was correct 80% of the time. Each block of trials was evenly balanced between red and blue target buttons as the actual target, with the stipulation that no more than four consecutive responses were made to the same target.

Procedure

Three experimental sessions were conducted with subjects with Down syndrome and those with an undifferentiated mental handicap. The first session involved the administration of the Peabody Picture Vocabulary test (form L), audiological assessment, a colour recognition test, a simple reaction time test, and the 100% certainty trials. In sessions two and three, subjects were tested on the experimental tasks.

In the administration of the Peabody Picture Vocabulary test, subjects were seated in front of the desktop flipchart and were tested following the procedures outlined in the Peabody Picture Vocabulary Test (form L) administration manual.

The audiological assessment was conducted using Maico Hearing Instruments (Model MA-16). The subjects' hearing was evaluated for the right and left ears. The subjects were instructed to place the headset over their ears and to raise the hand corresponding to the ear in which they heard a tone. A mid range test of 45 db within a range of 250 to 4000 Hz was conducted to ensure that the subject understood the test instructions. Subjects were considered to have an acceptable hearing level for the purposes of this study if they responded to tones generated at 30 db in the 500 to 4000 Hz range, in either the right or left ear. Tones were generated in a random fashion for 5 second intervals to the right and left ear across db and frequency ranges. Catch trials were presented to discourage any anticipation.

A basic colour recognition test was also administered during the first session. It consisted of the subject identifying the colours red and blue by pointing to the colour requested on a seven colour chart. Control subjects were only tested for auditory requirements and colour recognition. To ensure that the subjects were comfortable with the experimental test procedure, a simple reaction time condition (100% certainty) was presented during their first session.

The second and third sessions were identical, consisting of the four blocks of trials (2 (visual/verbal precue) X 2 (50%, 20/80% certainty)). These experimental sessions lasted approximately 60 minutes. The session began with a brief explanation of the apparatus and subjects were instructed to respond only to the button that illuminated after the foreperiod. Both speed and accuracy were emphasized.

To familiarize the subjects with the apparatus, a minimum of 10 practice trials were given in the 4 trial blocks (2 (visual/verbal precue) X 2 (50%, 20%/80% certainty)). Practice trials were continued until the subject performed the task without error on 5 consecutive trials. A subject was not advanced to session 2 and 3 if they did not meet all the initial requirements. From a pool of 18 individuals with Down syndrome, 8 met the initial requirements and from a pool of 22 individuals with undifferentiated developmental handicaps, 9 met the initial requirements.

Each subject was asked to perform 640 trials in total, during the first, second and third sessions. These sessions consisted of 40 simple reaction time trials (20 precuing the blue target, 20 precuing the red target), 80 trials in the 50% target certainty condition (40 when the target is blue and 40 when the target is red) and 200 trials in the 80% target certainty condition, which were balanced between the red and blue targets according to a precue certainty of 80%. These trials were conducted twice, once with visual precues and once with verbal precues. Trial blocks were divided equally over the two sessions. Presentation of blocks and trials within blocks were randomized separately for each subject.[1]

Data Analysis

Data were analyzed using a 3 way mixed design ANOVA: Group (Down syndrome, undifferentiated developmentally handicapped, non-handicapped) X Precue (Visual, Verbal) X Certainty ( 50%, 20%, 80%). Tukey HSD post-hoc analyses (*p*<.05) were conducted to examine differences between groups on any significant main effects and interactions.

In accordance with the work of Posner (1978), the benefit of advance information was calculated using: the difference between the reaction time mean for the 80% certainty condition and the reaction time mean for the 50% certainty condition. The cost of invalid advance information was calculated using: the difference between the reaction time mean for the 20% uncertainty condition and the reaction time mean for the 50% certainty condition. These scores were then used to calculate the probable gain associated with precue using the following formula:

$$\text{Probable Gain} = (\text{probability of correct anticipation} \times \text{benefit}) - (\text{probability of incorrect anticipation} \times \text{cost})$$

A further analysis was conducted using a 2 way mixed design ANOVA: Group (Down Syndrome, undifferentiated developmentally handicapped, non-handicapped) X Precue (Visual, Verbal), using Probable Gain as a dependent measure for reaction time.

**Results**

Mean reaction time and mean movement time served as the primary dependent variables. In addition, reaction time means for both visual and verbal conditions were used to calculate probable gain in accordance with the work of Posner (1978). The number of target errors and false starts were also recorded for each subject in each condition. Though percent errors were higher in the Down syndrome and developmentally handicapped groups (see Table 2), these percentages still remained below 10% on average. Hence, no further analyses were conducted on errors. Reaction times and movement times were analyzed using a 3(groups) x 2(precue condition: visual, verbal) x 3(certainty: 20%, 50%, 80%) mixed analysis of variance. A further analysis was conducted for reaction time using the values calculated for probable gain. This analysis was a 3(group) x 2(precue condition: probable gain for vision, probable gain for verbal) mixed analysis of variance.

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Insert Table 2 about here

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Mean Reaction Time

Analysis of reaction time yielded main effects for group, $F(2,22) = 17.43$, $p < .001$, precue, $F(1,22) = 50.65$, $p < .001$ and certainty, $F(2,44) = 354.15$, $p < .001$. Interactions were found for group x precue, $F(2,22)$

= 7.13, $p < .005$, and group x certainty, $F(4,44) = 3.29$, $p < .02$. In addition, a three way interaction was found for group x precue x certainty $F(4,44) = 6.46$, $p < .001$. As predicted, the control subjects were faster than subjects with Down syndrome and subjects with undifferentiated developmental handicaps, and the two experimental groups did not differ from one another. Overall, subjects were faster when information was presented visually versus verbally. As would be predicted, the main effect for certainty confirms the distinct difference between the 20%, 50% and 80% certainty conditions. Overall, subjects were slower as certainty was reduced from 80% to 50% to 20% (Table 3, Figure 2).

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Insert Table 3 and Figure 2 about here

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For the group x precue interaction, though all groups had slower reaction times in verbal conditions as compared to visual conditions, subjects with Down syndrome experienced the greatest deficit in speed when utilizing verbal precue information (Figure 3). In the visual precue condition, subjects with Down syndrome and subjects with other developmental handicaps do not differ significantly. Within the verbal precue condition, a significant difference between the two groups did occur due to the slower performance of the subjects with Down syndrome when utilizing the verbal precue. In the group x certainty interaction, as certainty increased, all subjects benefited from advance information, though the gains made by the subjects with Down syndrome were not as substantial. In the 20% certainty condition, no significant difference was evident between the subjects with Down syndrome and those with other developmental handicaps. In the 50% and 80% certainty conditions, significant differences between these two groups did occur, again due to slower reaction times for subjects with Down syndrome (Figure 4).

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Insert Figure 3 and 4 about here

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In addition to these second order interactions, a third order interaction for group x precue x certainty was found. Post hoc analysis of this interaction revealed that significant differences exist between the way that groups use visual and verbal precue information across certainty conditions (Figure 2). Although all groups show less ability to utilize verbal precue information, this difficulty is more pronounced for subjects with Down syndrome. This is evident by the disparity between visual and verbal precue as certainty increases (Figure 2).

Another way of examining this three way interaction is to analyze the group differences between the verbal and visual precue on corresponding conditions of certainty (Table 4). In conducting this 3(group) x 3(differences: 20% visual/verbal, 50% visual/verbal, 80%

visual/verbal) mixed analysis, a main effect for group, $F(2,22) = 6.86$, $p < .01$ and an interaction of group x differences, $F(4,44) = 6.25$, $p < .001$ were found. The main effect for group shows that the differences between the visual and verbal precue are significantly less pronounced for the control subjects than those differences found in the Down syndrome and developmentally handicapped groups. It also shows that the differences in visual/verbal precue are significantly larger in the subjects with Down syndrome as compared to those with other developmental handicaps. The interaction found between group x differences gives a clearer indication of the inability of the subjects with Down syndrome to effectively utilize verbal precue information. It shows that the subjects with Down syndrome have significantly greater differences between verbal and visual precue than the developmentally handicapped and control groups. It also shows that the differences increase significantly as certainty increases. This indicates that the subjects with Down syndrome demonstrate a relative inability to utilize valid verbal information to prepare a target aiming movement in advance.

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Insert Table 4 about here

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Mean Movement Time

Analysis of movement time yielded a main effect for group, $F(2,22) = 29.3$, $p < .0001$ with no second order or higher interactions. As expected, based on previous research, control subjects were faster in movement time than the Down syndrome and developmentally handicapped groups. The two developmentally handicapped groups did not differ (Table 5).

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Insert Table 5 about here

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Within Subject Standard Deviation for Reaction Time

Analysis of within subject standard deviation means for reaction time yielded main effects for group, $F(2,22) = 15.28$, $p < .001$, precue, $F(1,22) = 33.4$, $p < .0001$ and certainty, $F(2,44) = 130.21$, $p < .0001$. Interactions were found for group x precue, $F(2,22) = 10.67$, $p < .001$, and group x certainty, $F(4,44) = 3.65$, $p < .01$. As predicted, the control subjects were less variable than subjects with Down syndrome and subjects with undifferentiated developmental handicaps. The two mental handicapped groups did not differ from one another. The main effect for precue indicates that subjects were less variable when information was presented visually versus verbally. As would be predicted, the main effect for certainty revealed that subjects became more variable as certainty was reduced from 80% to 50% to 20% (Table 6, Figure 5).

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Insert Table 6 and Figure 5 about here

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For the group by precue interaction, the Down syndrome and developmentally handicapped groups demonstrated greater variability in reaction time for the verbal precue conditions as compared to visual precue conditions. Subjects with Down syndrome experienced greater variability in reaction time when utilizing verbal precue information (Figure 6). Control subjects were significantly less variable than either developmentally handicapped group, but showed no significant difference in variability between visual and verbal precue. In the visual precue condition, subjects with Down syndrome and those with developmental handicaps do not differ significantly. Within the verbal precue condition however, a significant difference between the two groups did occur due to the more variable performance of the subjects with Down syndrome when utilizing the verbal precue. The group x certainty interaction revealed that as certainty increased, all subjects benefit from advance information by decreasing in variability, though the gains made by the subjects with Down syndrome were not as substantial. In the 20% and 50% certainty conditions, no significant differences exist between the subjects with Down syndrome and those with developmental handicaps.

In the 80% certainty condition, significant differences between these two groups were evident, again due to greater variability in reaction times for subjects with Down syndrome (Figure 7).

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Insert Figure 6 and 7 about here

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Within Subject Standard Deviation for Movement Time

Analysis of within subject standard deviations for movement time yielded a main effect for group, $F(2,22) = 22.1$, $p < .0004$ with no second order or higher interactions. As would be predicted, based on previous research, control subjects were less variable in movement time than subjects in the two handicapped groups, who did not differ (Table 7).

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Insert Table 7 about here

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Probable Gain for Reaction Time

The analysis of probable gain for reaction time yield a main effect for precue, $F(2,22) = 5.29$, $p < .03$ and an interaction for group by precue, $F(2,22) = 3.9$, $p < .04$. The main effect for precue again confirms that subjects regardless of group benefit more from visual precue information than verbal precue information. The interaction between group and precue is of particular interest as it confirms the study hypotheses that individuals with Down syndrome are less able to utilize verbal information. Specifically, they had greater difficulty achieving benefit from valid verbal precue information, yet at the same time were not as adversely affected by an invalid verbal precue information (Figure 8, Table 8).

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Insert Figure 8 and Table 8 about here

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## Discussion and Conclusions

There are a number of well established perceptual-motor differences between individuals with and without developmental handicaps. Baumeister and Kellas (1968) and Berkson (1960a,b,c) for example, have reported that adults with developmental handicaps are slower and more variable at initiating a response to simple sets of stimuli. As well, Brewer and Smith (1982) reported that these adults are also slower and more variable in movement time. In this investigation it was found that the individuals with Down syndrome and developmental handicaps were slower and more variable in reaction time and movement time.

In this respect our findings are consistent with previous investigations. Of greater interest, was the absence of an overall difference between the subjects with Down syndrome and undifferentiated developmental handicaps. Frith and Frith (1974) have suggested that persons with Down syndrome exhibit specific difficulties in motor programming compared to other individuals with developmental handicaps, and are therefore extremely dependent on feedback for motor control. The absence of overall reaction time and movement time differences between the two groups of subjects with developmental handicaps does not support this position. Thus, the differences in psychomotor speed that exist between individuals with and without developmental handicaps probably reflects neuromotor or strategic problems associated with mental retardation in general (see Brewer & Smith, 1982 and Hoover & Wade, 1985 for a review).

While there were no overall differences between subjects with Down syndrome and other developmental handicaps, recall that the purpose of this study was to examine the ability to utilize precue information presented visually and verbally for movement preparation by individuals with Down Syndrome, undifferentiated developmental handicaps and those without developmental handicaps. To examine this process, subjects performed manual aiming movements. On a particular trial, subjects were cued about the specific movement either visually or verbally. The cue provided either 50% or 80% certainty similar to the Posner (1978) Cost/Benefit paradigm.

Previous research (Goodman & Kelso, 1980; Rosenbaum, 1980) has shown that individuals without developmental handicaps are able to be flexible in their use of precue information. Le Clair, Pollock and Elliott (1993) showed that similar flexibility exists for individuals with mental handicaps and Down syndrome when advance information is presented visually. This study has also demonstrated that these three groups are able to use visual precue information in a flexible manner during movement preparation. That is, subjects were able to use advance information about both distance and hand to reduce their preparation time following a movement imperative. However, in the present study distinct differences in the ability to prepare for movements were evident between the three groups when precue information was provided verbally. It is these findings that are most relevant to the purposes of this study.

Elliott et al. (1987) proposed that a structural dissociation between the right and left hemispheres disrupts the interaction between cerebral mechanisms responsible for the perception and production of speech in individuals with Down syndrome. This breakdown in communication between functional systems that would normally overlap is responsible, according to Elliott et al. (1987), for language based problems exhibited by these individuals. This biological dissociation model (Elliott et al., 1987) predicts that individuals with Down syndrome will exhibit specific deficits on tasks that involve both the perception and the production of complex limb and oral movements including speech movements. The model also predicts that individuals with Down syndrome will have greater difficulty in performing movements that are verbally directed as compared to individuals without Down syndrome who have been matched for mental age. If these movements are visually demonstrated however, no significant differences should be evident.

Based on the Elliott and Weeks (1990) model of biological dissociation, this study investigated three hypotheses. First, it was expected that individuals with Down syndrome would not demonstrate the same costs and benefit from advance information when that information was provided verbally vs visually. Second, that individuals with Down syndrome would experience significant costs and benefits when information was provided visually. Finally, that the patterns exhibited by individuals with Down syndrome to verbal advance information would be unique to this group when compared to individuals with and without developmental handicaps.

The deficit that the subjects with Down syndrome experienced in speed when utilizing verbal precue information and the greater variability in reaction time when utilizing the same type of information is consistent with the idea that a reversed cerebral specialization for speech perception exists within this population. This implies that individuals with

Down syndrome depend on the right hemisphere for speech perception and the left hemisphere for the organization of goal directed movements (Elliott, 1985; Hartley, 1981; Pipe, 1983; Zekulin-Hartley, 1981, 1982), rather than the typical left hemisphere advantage for both functions seen in other populations.

While the biological dissociation model predicts that persons with Down syndrome will not benefit from advance information when it is provided verbally, it also predicts that an invalid verbal precue will entail little or no cost. Here the data are less clear. Specifically, although subjects with Down syndrome did exhibit verbal-motor deficits relative to other subjects in the 50% and 80% certainty conditions, they did not exhibit an advantage in the 20% verbal precue situation. This suggests that in verbal precue conditions, individuals with Down syndrome attempted to use verbal advance information, but were not able to do so effectively. Thus, even when the verbal precue was invalid, it took subjects with Down syndrome time to negate whatever programming had taken place before they could again prepare the movement on the basis of the visual imperative. Although not as clearly delineated as predicted, the reaction time results are consistent with the Elliott and Weeks (1990) model of biological dissociation between speech perception and movement organization in persons with Down syndrome. Moreover, they support the claim by Elliott et al. (1991) that the verbal-motor integration problem is related more to movement organization than execution.

In this study strict controls were placed on attention to reduce extraneous error. This was done in an attempt to minimize the effect that attention and motivation deficits have on the performance of individuals with Down syndrome and those with developmental handicaps, as noted in previous studies (e.g., Zelaznik & Aufderheide, 1986). These controls resulted in fewer outliers, hence, a smaller difference was needed to demonstrate significance. To better examine variability in these data differences in reaction time between visual and verbal conditions for corresponding conditions of certainty were analyzed. In this way, a clearer representation of the relation between group and certainty variables was given. This confirmed the inability of individuals with Down syndrome to utilize verbal precue information. Even though efforts were made to maximize attention and motivation, subjects with Down syndrome were still more variable in verbal situations regardless of certainty for the target. The model of Biological Dissociation's prediction that individuals with Down syndrome will have greater difficulty in performing movements that are verbally directed as compared to individuals without Down syndrome is consistent with these findings.

The use of probable gain (Posner, 1978) as a dependent measure was an effective tool in examining the differences between these specific populations. The analysis of reaction time provided information about the differences that exist in the way that individuals with Down syndrome utilize precue information, as compared to individuals with and without developmental handicaps.

The measure of probable gain indicated that individuals with Down syndrome are less able to utilize verbal information when compared to visual information. They are also less able to use verbal information when compared to the developmentally and nondevelopmentally handicapped groups, regardless of mode of information. Hence as has been stated, subjects with Down syndrome have greater difficulty obtaining benefit from valid verbal precue information, yet at the same time are affected negatively on invalid verbal precue. In examining this finding it appears that individuals with Down syndrome continue to process the verbal precue information during the first part of the reaction time period. Due to the dissociation in processes between the hemispheres of individuals with Down syndrome, communication between functional systems takes longer as demonstrated by the increase in reaction time within this paradigm. This is in contrast to individuals with undifferentiated developmental handicaps and individuals without developmental handicaps, who process both speech and organize goal-directed movement within the left hemisphere. Presumably the type of interhemispheric communication required by persons with Down syndrome not only takes more time, but can also result in information loss. Similar types of problems in information processing can be found in adults with brain injuries experiencing certain types of apraxia (Miller, 1986).

In summary, the inability of individuals with Down syndrome to utilize verbal information as effectively as they do visual information or in a manner consistent with developmentally and nondevelopmentally handicapped groups appears consistent, on the basis of these results, with the Elliott and Weeks (1990) model of Biological Dissociation. Their premise that the atypical cerebral specialization found in individuals with Down syndrome leads to a breakdown in communication is a reasonable explanation. The loss of information due to the interhemispheric transmission of right hemisphere speech perception with left hemisphere movement preparation is consistent with the specific difficulties experienced by individuals with Down syndrome in this study.

In future, models of cerebral specialization and models of movement preparation will have to consider, in situations of atypical lateralization, the length of interhemispheric transmission time as well as the path of communication when applying these ideas to individuals with Down syndrome. These findings also imply that it is important for research to look beyond normative data when formulating and evaluating models of motor control and cerebral function .

These findings suggest that serious consideration needs to be given to the specific cognitive and perceptual differences between individuals with Down syndrome and those with undifferentiated developmental handicaps. Specifically, that consideration should be given to the potential difference that arises in the way individuals with Down syndrome will process information visually versus verbally. Further, it may be useful for instructors to consider developing strategies that help accommodate for verbal-motor deficits. Strategies that help individuals with Down syndrome to visualize language versus verbally interpret information, might also be used.

Though this research has confirmed aspects of the Elliott and Weeks (1990) model of biological dissociation, further study is necessary to examine the role of gender and handedness in the information processing abilities of individuals with Down syndrome. Additionally, it would be useful to know to what extent of movement complexity the model of biological dissociation applies.

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## Author Notes

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## FOOTNOTES

1 In an effort to diminish the effect of variation in motivation and attention within the Down syndrome and developmentally handicapped groups, a strict and specific protocol was adopted to ensure that each trial reflected the best level of participation from the subject. In the event that any subject removed their attention from the apparatus after the command "ready" was given, the trial was cancelled and re-randomized later in the block cycle. In addition, any trial longer than 1200 ms was omitted and was re-randomized later in the block.

## Tables Captions

Table 1
Subject Characteristics

| | | CA(yr./mo.) | | MA(yr./mo.) | | Gender(f) | | Handedness(f) | |
|---|---|---|---|---|---|---|---|---|---|
| Group | n | Mean | SD | Mean | SD | Male | Female | Left | Right |
| Down Syndrome | 8 | 27-10 | 4-9 | 6-1 | 1-3 | 4 | 4 | 3 | 5 |
| Developmentally Handicapped | 9 | 29-10 | 5-8 | 6-5 | 2-1 | 3 | 5 | 2 | 7 |
| Control | 8 | 25 | 3-0 | - | - | 4 | 4 | 2 | 6 |

Table 2
Percent Target Errors and False Starts
as a function of Group, Precue and Certainty

| | Visual Precue | | | | | | Verbal Precue | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Certainty | 20% | | 50% | | 80% | | 20% | | 50% | | 80% | |
| Group | TARGET ERROR | FALSE START | TARGET ERROR | FALSE START | TARGET ERROR | FALSE START | TARGET ERROR | FALSE START | TARGET ERROR | FALSE START | TARGET ERROR | FALSE START |
| Down Syndrome | 9.6 | 10.9 | 5.4 | 8.4 | 3.9 | 5.4 | 9.4 | 13.1 | 5.8 | 9.5 | 3.4 | 5.0 |
| Developmentally Handicapped | 6.2 | 8.1 | 5.3 | 10.6 | 3.2 | 9.1 | 9.0 | 8.4 | 4.2 | 11.4 | 2.0 | 10.4 |
| Control | 0.0 | 0.9 | 0.0 | 1.2 | 0.0 | 0.7 | 0.0 | 0.3 | 0.0 | 1.6 | 0.2 | 0.5 |

Table 3

Means and Standard Deviations for Reaction Time (ms) as a function of Group, Precue and Certainty

| | Visual Precue | | | | | | Verbal Precue | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Certainty | 20% | | 50% | | 80% | | 20% | | 50% | | 80% | |
| Group | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Down Syndrome | 563 | 119 | 510 | 112 | 474 | 112 | 586 | 132 | 542 | 116 | 516 | 111 |
| Developmentally Handicapped | 554 | 103 | 502 | 97 | 467 | 92 | 576 | 112 | 520 | 106 | 484 | 100 |
| Control | 314 | 15 | 278 | 14 | 247 | 15 | 320 | 15 | 285 | 16 | 256 | 16 |

Table 4
Means and Standard Deviations for the Mean Reaction Time Difference (ms) between Precue Conditions

| | Reaction Time Differences Between Precue Conditions | | | | | |
|---|---|---|---|---|---|---|
| Certainty | 20% | | 50% | | 80% | |
| Group | Mean | SD | Mean | SD | Mean | SD |
| Down Syndrome | 23 | 19 | 32 | 18 | 42 | 22 |
| Developmentally Handicapped | 22 | 14 | 17 | 12 | 16 | 12 |
| Control | 7 | 5 | 7 | 6 | 8 | 4 |

Table 5
Means and Standard Deviations for Movement Time (ms)
as a function of Group, Precue and Certainty

| | Visual Precue | | | | | | Verbal Precue | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Certainty | 20% | | 50% | | 80% | | 20% | | 50% | | 80% | |
| Group | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Down Syndrome | 458 | 102 | 457 | 106 | 458 | 104 | 458 | 104 | 465 | 101 | 457 | 104 |
| Developmentally Handicapped | 484 | 101 | 483 | 100 | 489 | 102 | 488 | 102 | 482 | 100 | 490 | 102 |
| Control | 181 | 17 | 179 | 12 | 179 | 17 | 178 | 14 | 179 | 16 | 181 | 17 |

Table 6

Means and Standard Deviations for the Within Subject Standard Deviations for Reaction Time (ms) as a function of Group, Precue and Certainty

| | Visual Precue | | | | | | Verbal Precue | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Certainty | 20% | | 50% | | 80% | | 20% | | 50% | | 80% | |
| Group | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Down Syndrome | 117 | 31 | 102 | 28 | 89 | 26 | 124 | 30 | 113 | 26 | 102 | 23 |
| Developmentally Handicapped | 116 | 36 | 101 | 34 | 86 | 36 | 120 | 42 | 105 | 36 | 88 | 34 |
| Control | 49 | 8 | 36 | 5 | 31 | 3 | 51 | 9 | 36 | 4 | 32 | 3 |

Table 7
Means and Standard Deviations for the Within Subject Standard Deviations for Movement Time (ms) as a function of Group, Precue and Certainty

| | Visual Precue | | | | | | Verbal Precue | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Certainty | 20% | | 50% | | 80% | | 20% | | 50% | | 80% | |
| Group | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Down Syndrome | 90 | 25 | 93 | 26 | 90 | 26 | 88 | 21 | 90 | 26 | 91 | 22 |
| Developmentally Handicapped | 89 | 25 | 92 | 24 | 88 | 24 | 87 | 24 | 91 | 24 | 89 | 20 |
| Control | 32 | 4 | 33 | 3 | 32 | 4 | 32 | 5 | 32 | 4 | 30 | 4 |

Table 8
Means and Standard Deviations for Reaction Time (ms)
Probable Gain as a function of Group and Precue

| | Probable Gain Visual | | Probable Gain Verbal | |
|---|---|---|---|---|
| Group | Mean | SD | Mean | SD |
| Down Syndrome | 17.8 | 6.4 | 11.3 | 3.6 |
| Developmentally Handicapped | 17.6 | 5.7 | 17.2 | 6.0 |
| Control | 17.1 | 3.4 | 16.8 | 5.1 |

## Figure Captions

Figure 1. Experiment apparatus.

Figure 2. Mean reaction time as a function of group, precue and certainty.

Figure 3. Mean reaction time as a function of group and precue.

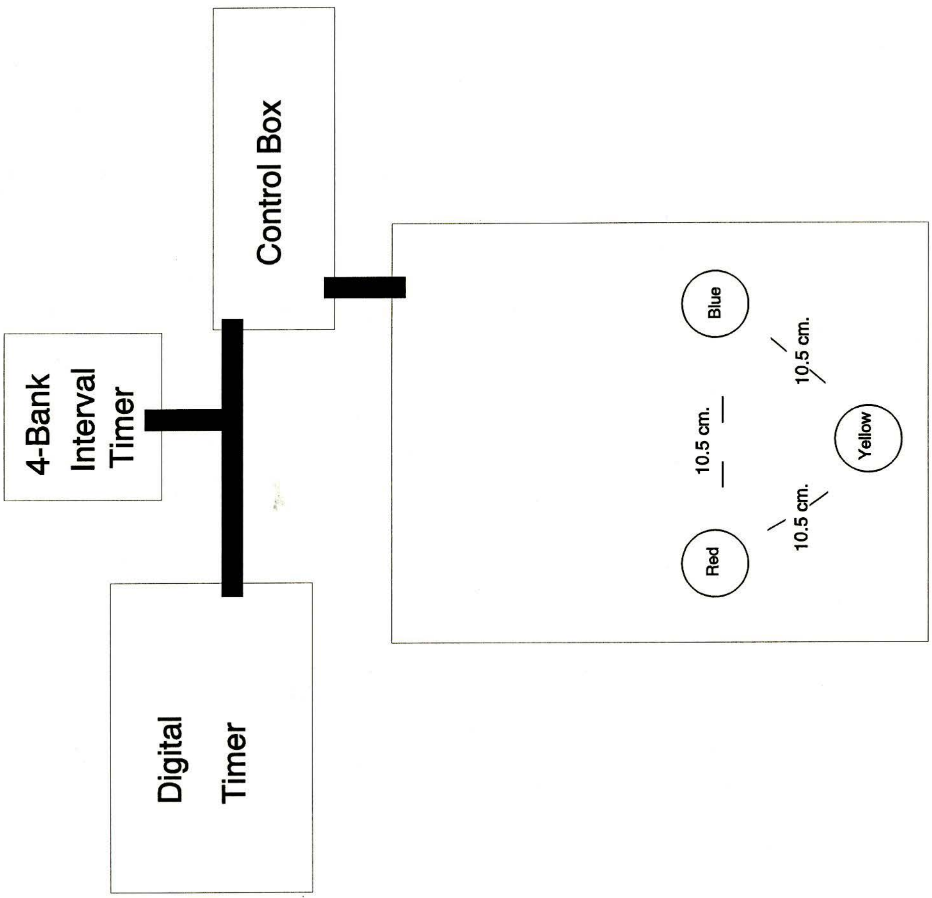
Figure 4. Mean reaction time as a function of group and certainty.

Figure 5. Mean standard deviation for reaction time as a function of group, precue and certainty.

Figure 6. Mean standard deviation for reaction time as a function of group and precue.

Figure 7. Mean standard deviation for reaction time as a function of group and certainty.

Figure 8. Mean probable gain reaction time as a function of group and precue.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Digital
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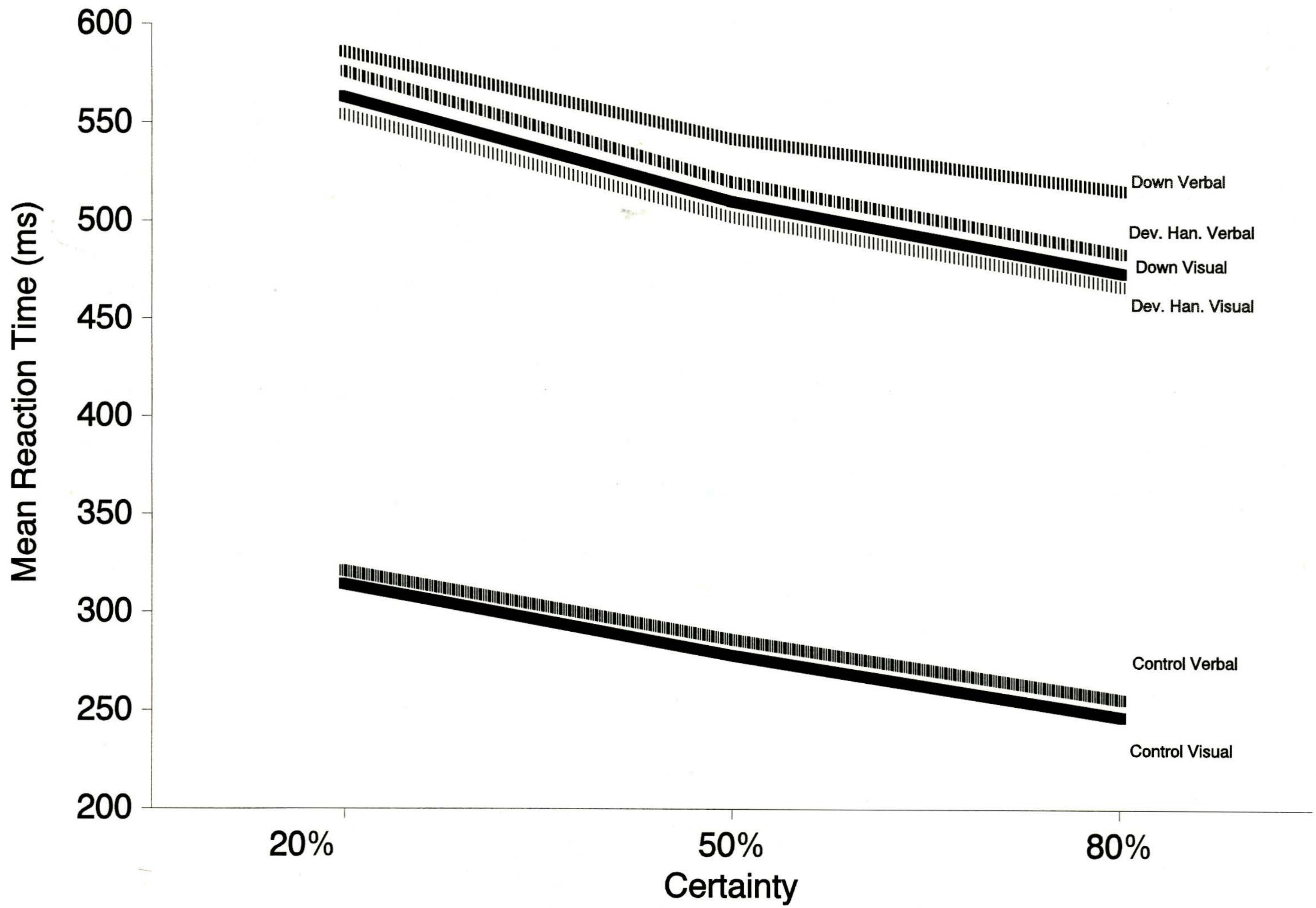
600
550
500
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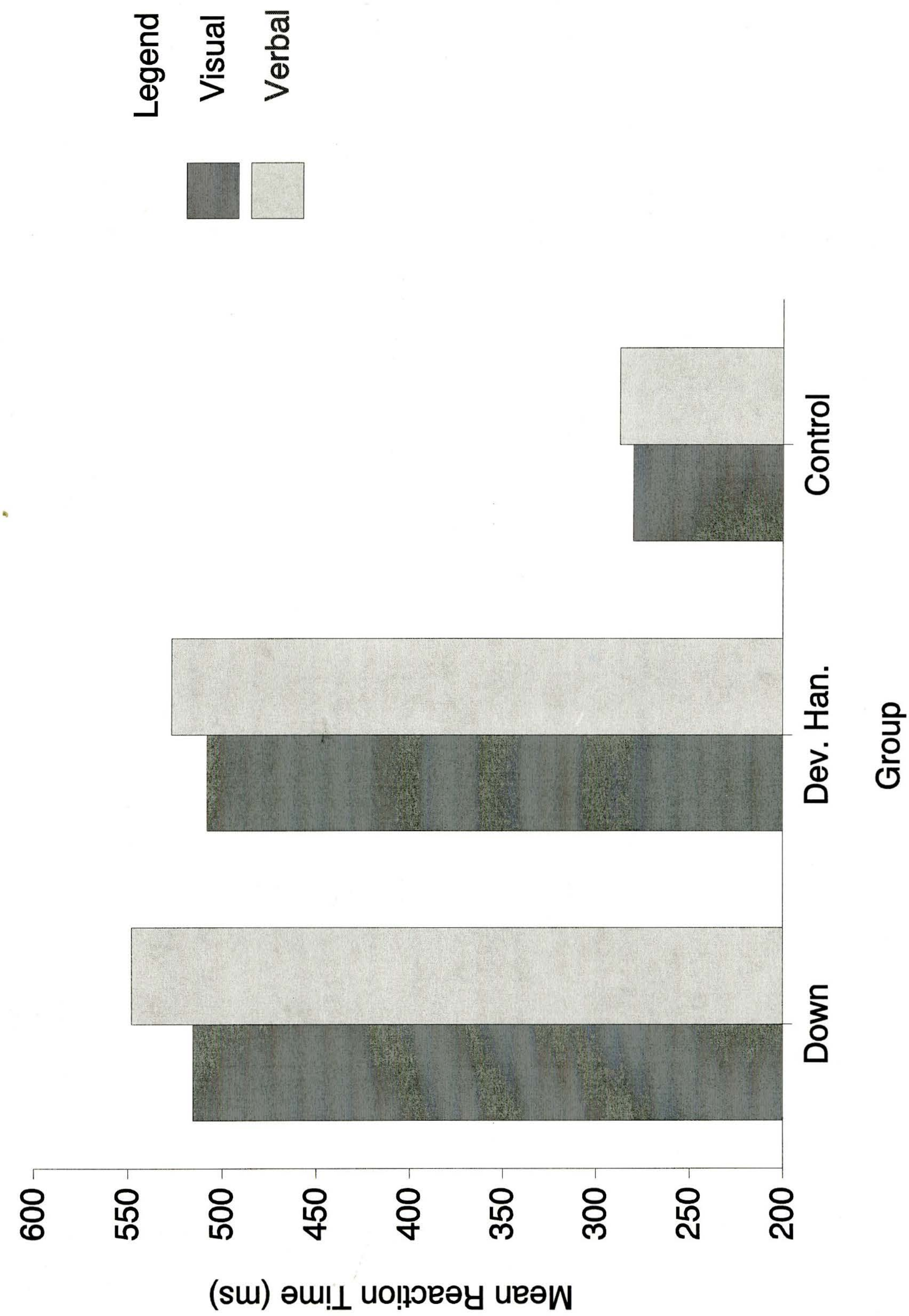
400
350
300
250
200
Mean Reaction Time (ms)
Down Verbal
Dev. Han. Verbal
Down Visual
Dev. Han. Visual
Control Verbal
Control Visual
20%
50%
80%
Certainty


Legend
Visual
Verbal
Mean Reaction Time (ms)
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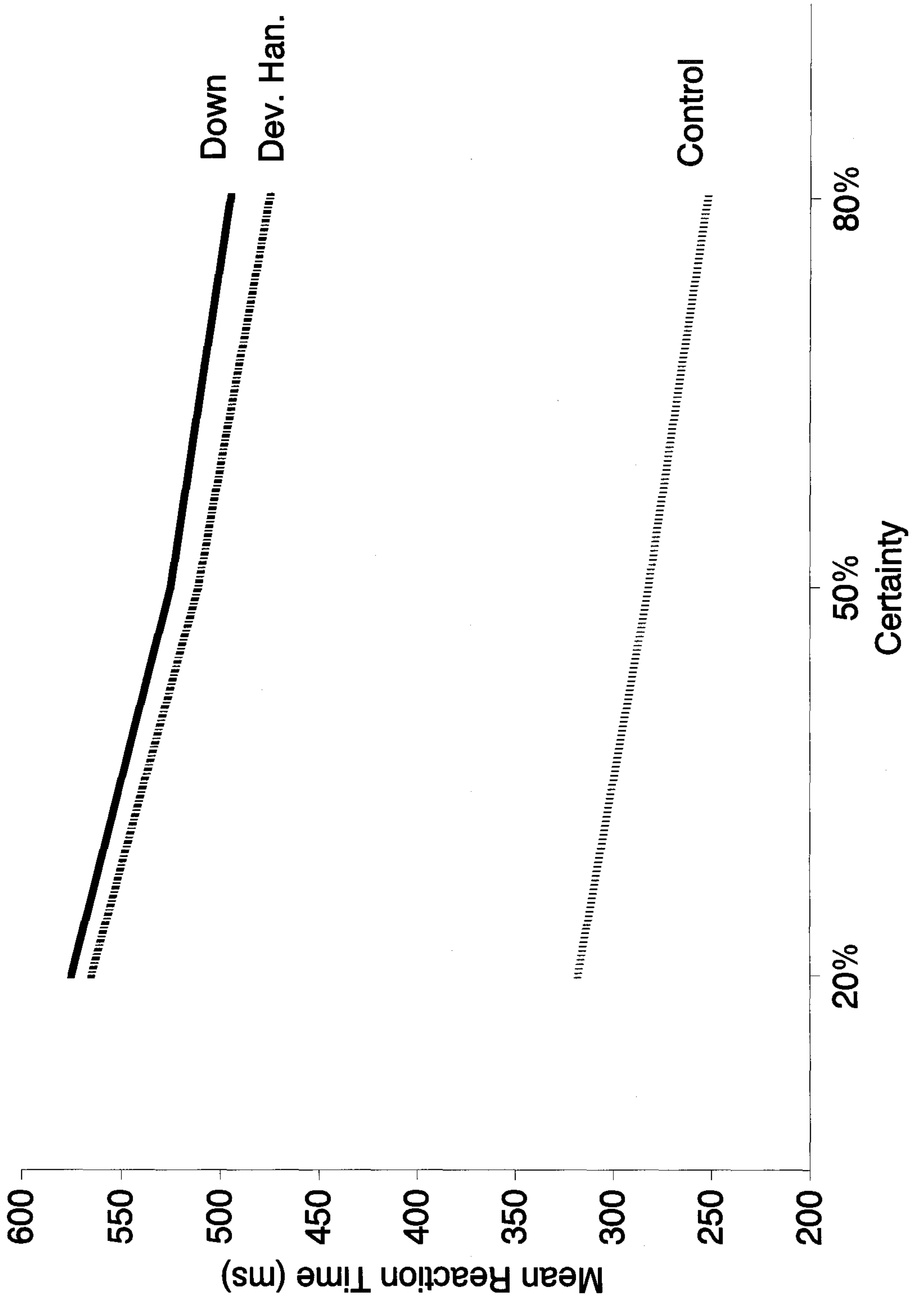
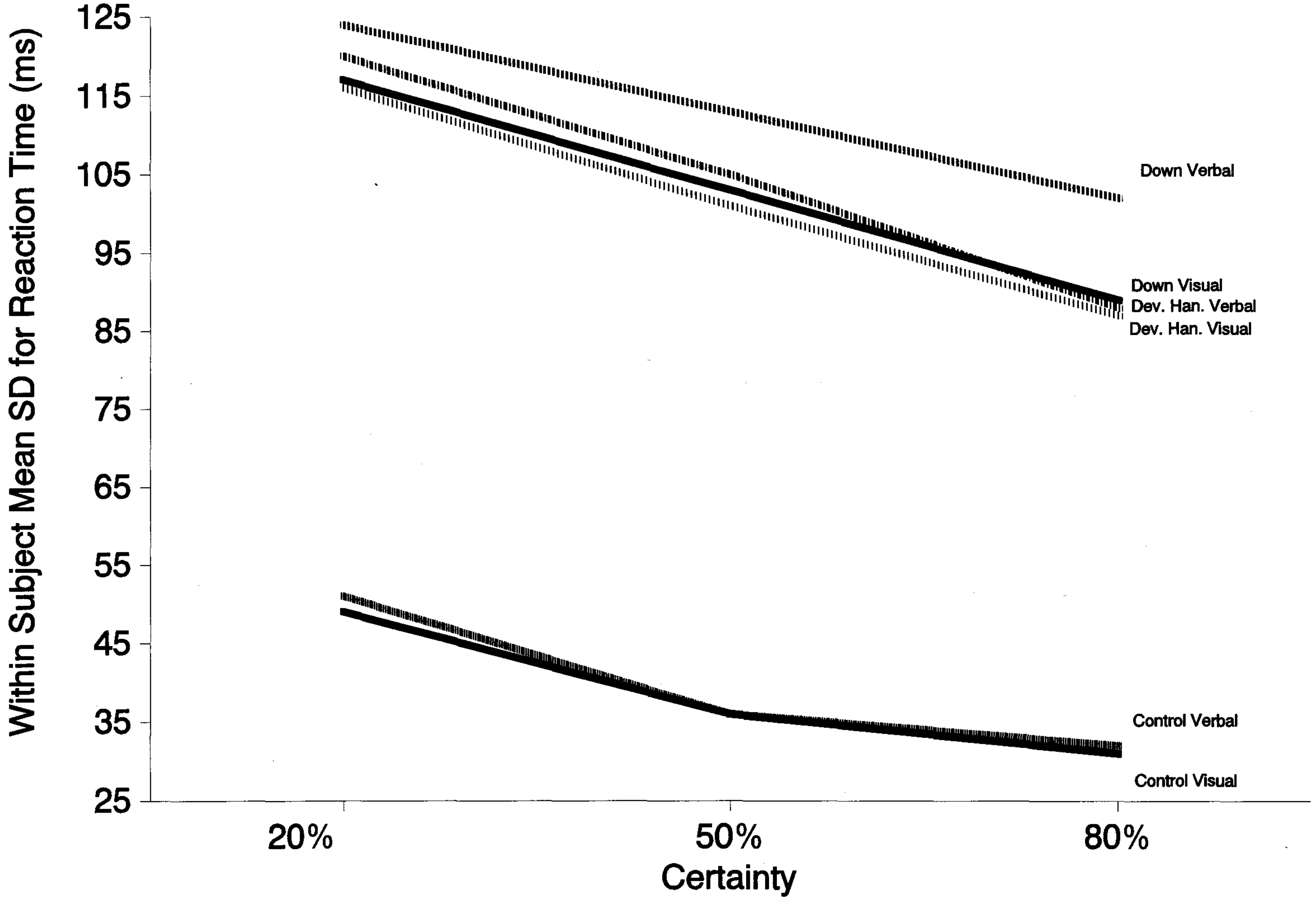
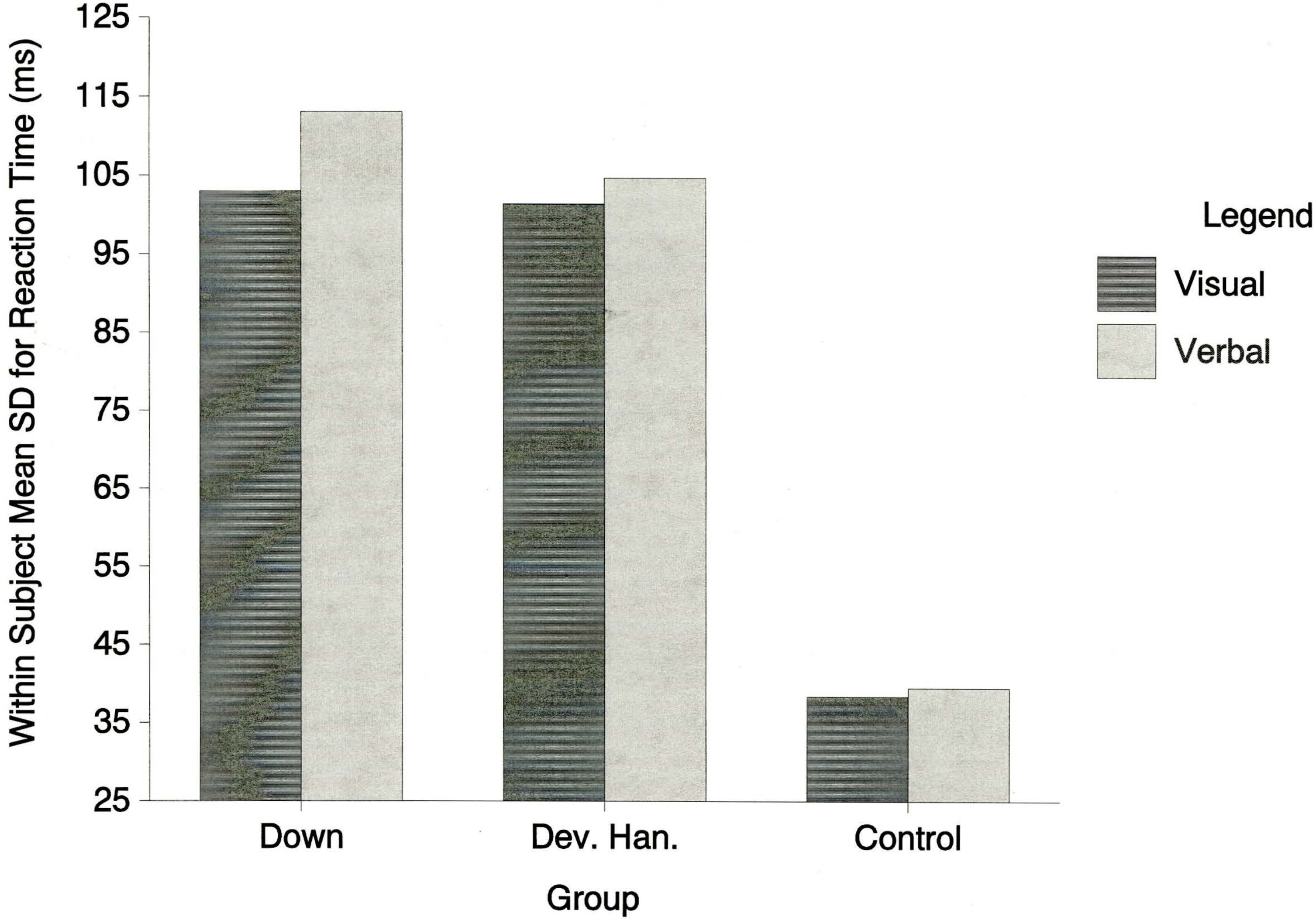
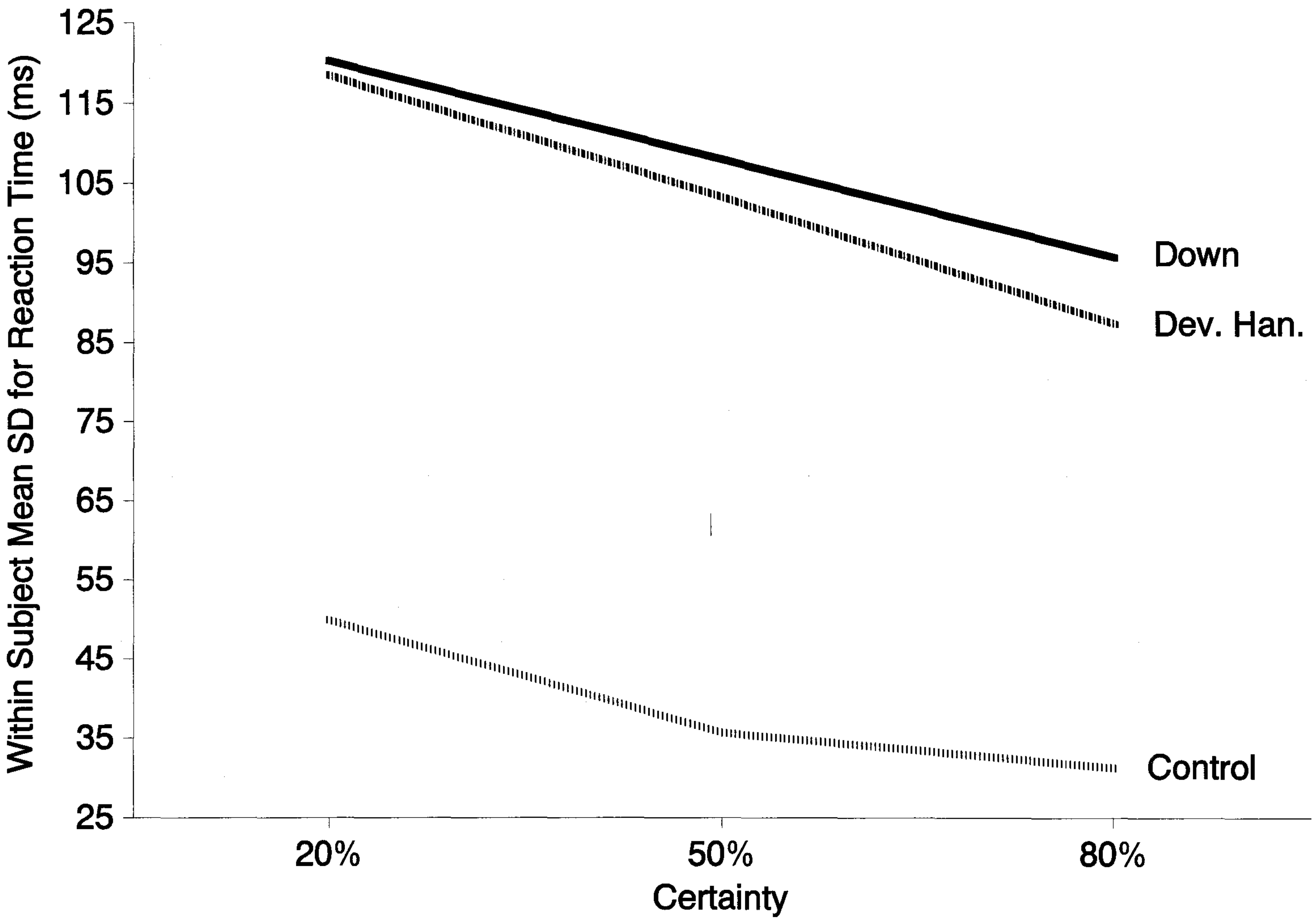
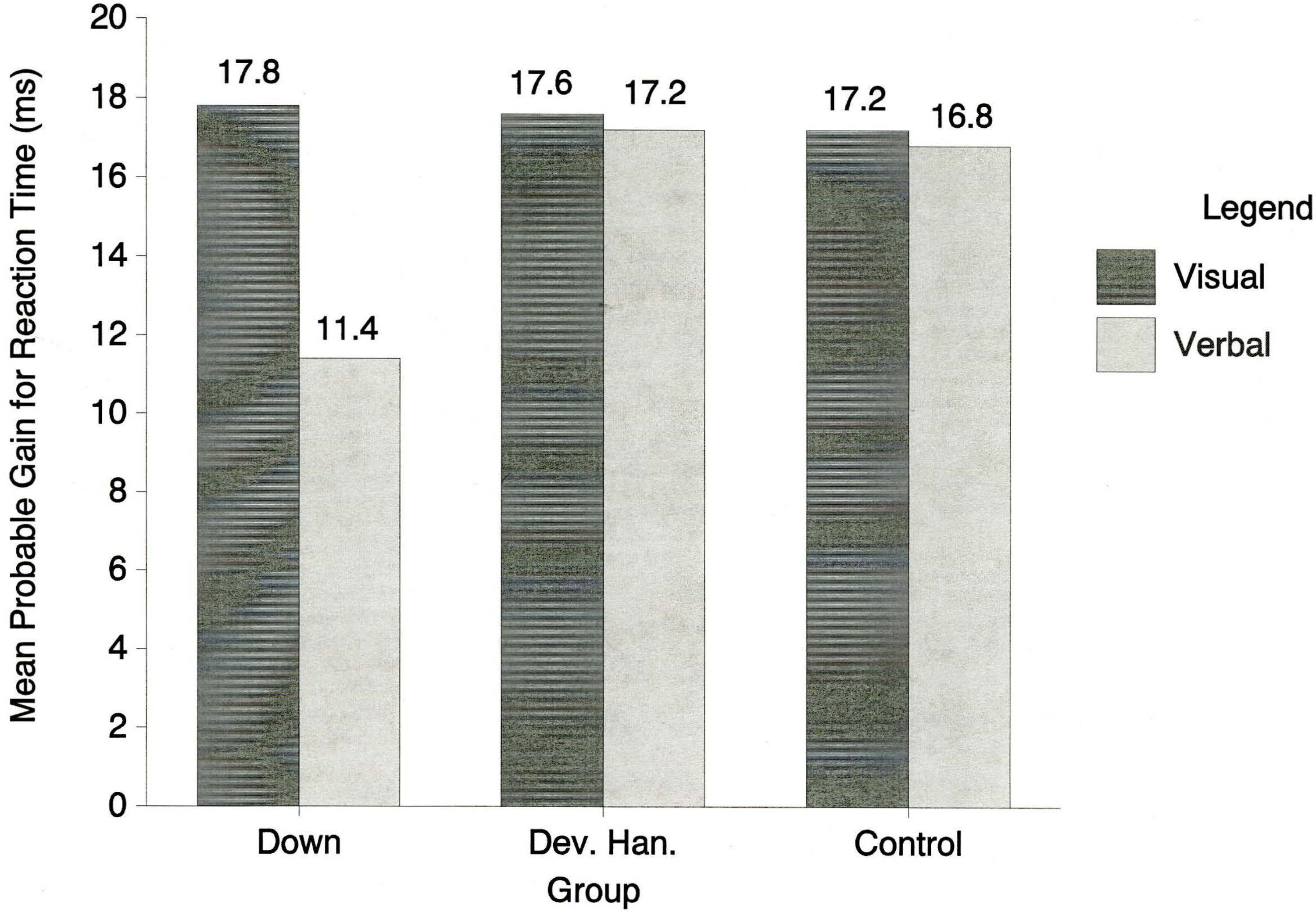
300
250
200
Down
Dev. Han.
Control
Group


Mean Reaction Time (ms)
600
550
500
450
400
350
300
250
200
20%
50%
80%
Certainty
Down
Dev. Han.
Control


Within Subject Mean SD for Reaction Time (ms)
125
115
105
95
85
75
65
55
45
35
25
20%
50%
80%
Certainty
Down Verbal
Down Visual
Dev. Han. Verbal
Dev. Han. Visual
Control Verbal
Control Visual


Within Subject Mean SD for Reaction Time (ms)
125
115
105
95
85
75
65
55
45
35
25
Down
Dev. Han.
Control
Group
Legend
Visual
Verbal


Within Subject Mean SD for Reaction Time (ms)
125
115
105
95
85
75
65
55
45
35
25
20%
50%
80%
Certainty
Down
Dev. Han.
Control



Mean Probable Gain for Reaction Time (ms)
20
18
16
14
12
10
8
6
4
2
0
17.8
11.4
17.6
17.2
17.2
16.8
Down
Dev. Han.
Control
Group
Legend
Visual
Verbal

# APPENDIX

## BACKGROUND ON DOWN SYNDROME

Down syndrome is the most frequent autosomal chromosome abnormality known to exist in humans. The incidence of Down syndrome is approximately 1 per 1000 live births (Hook, 1982). This syndrome was first noted by J. L. H. Down in his classic 1866 paper titled: Observations on an ethnic classification of idiots. However, it was not until the late 1950's when new cytogenic techniques allowed a more accurate study of chromosomes, that a team of French scientists discovered a supernumerary acrocentric chromosome in children with Down syndrome (Lejeune, Gauthier & Turpin, 1959). This abnormality in the 21st chromosome usually occurs during meiosis. At this time, one of the two sex cells contains an extra 21st chromosome, known as trisomy 21. In the event that the sex cells are used during fertilization, the resulting embryo contains forty-seven chromosomes.

There are three known causes of the chromosomal abnormality found in Down syndrome. In almost 95% of individuals with Down syndrome, the cause is trisomy 21. In less than five percent of the incidence of Down syndrome, the cause is translocation; the attachment of the long arm of chromosome 21 to the long arm of chromosome 22, 21, or 14. In the remaining percentage (between 1 and 3%), the cause is mosaicism (Thuline, 1982). In the case of trisomy 21 and translocation, the dysjunctional event occurs prior to conception. Whereas, the dysjunctional event for mosaicism occurs during one of the first mitotic cell divisions.

The American Association for Mental Deficiency (AAMD) defines Mental Retardation (hereafter referred to as Developmental handicap) as "significantly subaverage general intellectual functioning existing concurrently with deficits in adaptive behaviour and manifested during the developmental period" (Clifford, 1980 p. 367). Typically the person with a developmental handicap (DH) demonstrates deficits in adaptive behaviours, such as; independence, physical development, socio-economic activity, language development, basic concepts, self-direction, responsibility and socialization (Clifford, 1980). The degree to which individuals with mental retardation demonstrate these deficits depends on the severity of their intellectual impairment.

Individuals with Down syndrome share a number of similarities with other developmentally handicapped individuals. There are also a number of specific phenotypic, motor and perceptual characteristics which differentiate individuals with Down syndrome from those individuals with other developmental handicaps, as well as nonhandicapped individuals (Thuline, 1982).

## COGNITIVE AND PERCEPTUAL DIFFERENCES

There are a number of cognitive and perceptual differences that have been noted between individuals with undifferentiated developmental handicaps and individuals without developmental handicaps. It has been well established in previous literature, that individuals with developmental handicaps respond more slowly and with greater variability to environmental stimuli (Baumeister & Kellas, 1968; Berkson, 1960 a,b,c; Brewer & Smith, 1982; Hoover & Wade, 1985). In manual aiming tasks, it was noted that individuals with developmental handicaps, in situations of target uncertainty exhibit larger increases in reaction time and movement time, when the aiming movement is made more difficult (Wade, Newell, & Wallace, 1978). These disproportionate increases have been attributed to the extra time it takes for the individual with a developmental handicap to plan and initiate a more complex movement. Although it is likely that this extra time needed for planning and initiating complex movements can be explained by the temporal structure of movement preparation, little is known about the temporal order of movement programming in individuals with developmental handicaps.

In addition to differences in movement programming, strategic differences in movement preparation have also been examined. Strategic differences in reaction time tasks have been noted between individuals with developmental handicaps and nondevelopmentally handicapped individuals. Specifically, Berkson and Baumeister (1967) noted increased variability in reaction time of developmentally handicapped subjects compared to nondevelopmentally handicapped subjects, suggesting an inability of these individuals to choose a consistent strategy. In addition to noting that developmentally handicapped individuals were slower in reaction time, Baumeister and Kellas (1968) found different patterns of variability between the two groups. Developmentally handicapped subjects were found to have a greater degree of between subject and within subject variability than nondevelopmentally handicapped subjects.

Upon further examination, Baumeister (1968) hypothesized that the inability of developmentally handicapped children to reach comparable levels of performance in reaction time as nondevelopmentally handicapped children was due to their inability to perform consistently. Zelaznik and Aufderheide (1986) examined Baumeister's hypothesis based on their earlier work that compared the fastest reaction time trials of a group of educable developmentally handicapped males, with the fastest reaction times of 15 nondevelopmentally handicapped males. No significant differences between the two groups were reported for the fastest reaction time trials. It was concluded that the differences shown when reaction time trials are averaged and compared are due to the inability of the developmentally handicapped individual to maintain motivation and attention during the experimental task.

## DICHOTIC LISTENING AND CEREBRAL SPECIALIZATION

Since it has been suggested that inefficient right hemisphere language processing may be responsible for some of the specific information processing problems exhibited by persons with Down syndrome, a review of the dichotic listening work seems in order.

One of the first studies to use the task of dichotic listening to examine recall strategies and memory capacity in developmentally handicapped individuals, manipulated the length, rate and type of dichotic stimuli (Neufeldt, 1966). It was concluded that developmentally handicapped individuals had a short term memory capacity similar to that of an equal mental age group and lower than that of an equal chronological age group. The nonhandicapped groups displayed more flexibility in their recall strategies than did the developmentally handicapped groups. It was also concluded that recall was enhanced for the developmentally handicapped groups when they were requested to recall items by type, rather than by location of presentation. One of the problems that arose from early studies in dichotic listening was that they did not use a laterality index (formalized measure of ear advantage)[1]. If Neufeldt had used a laterality index it could have provided specific information about ear advantage by assessing dominance.

Sommers and Starkey (1977) used a laterality index to assess ear advantage in children with Down syndrome and nonhandicapped children. Employing a free recall dichotic listening task, using rhythmed meaningful words matched for vowel and final phoneme, subjects were asked to point to black and white photographs representing the words that they heard presented. Their findings indicated that children with Down syndrome had an atypical left ear advantage for speech perception.

Hartley (1981) examined dichotic listening in children with Down syndrome by using single syllable items that were selected from the Peabody Picture Vocabulary Test. A series of 38 word pairs were presented dichotically, using an automatic alignment method designed by Vincent and Bradshaw (1975). These word pairs were presented to a group of female children with Down syndrome and a group of nonhandicapped children of equivalent chronological age. Hartley (1981) noted that the children with Down syndrome exhibited a left ear advantage, whereas the nonhandicapped subjects exhibited a typical right ear advantage.

Zekulin-Hartley (1981) continued this line of investigation by dichotically presenting digit pairs by computer synthesized speech to three groups; twelve year old children with Down syndrome, chronological age equivalent children with developmental handicaps other than Down syndrome and five year old mental age equivalent nonhandicapped children. Over a series of ten experimental trials the children were told to listen and repeat the digits they heard. Zekulin-Hartley (1981) findings revealed the same left ear advantage for children with Down syndrome as had been noted in her previous study. She also noted a typical right ear advantage for the children with developmental handicaps and the nonhandicapped children.

Zekulin-Hartley (1982), using a priming technique, asked subjects to selectively attend to information presented in either their dominant or non-dominant ear. An ear advantage was noted when subjects were attending to information in their dominant ear while no ear advantage was noted when subjects attended to information in their non-dominant ear. This finding was consistent for subjects with Down syndrome, undifferentiated developmentally handicapped subjects and an equal mental age group of nondevelopmentally handicapped subjects. For individuals with Down syndrome, however, it was the left ear not the right ear that was dominant.

Pipe (1983) examined the influence of training on dichotic listening. Three groups (Down syndrome, undifferentiated developmentally handicapped and equal mental age subjects without developmental handicaps) were trained to point to a line drawing of the target word when it was presented monaurally. Training occurred over a six week period. Dichotic listening tests were conducted prior to and following monaural training. Again, a left ear advantage was reported for subjects with Down syndrome and a right ear advantage for all other subjects. It was also shown that training strengthened the ear advantages for all groups.

Hartley (1985) examined ear advantage and simultaneous / successive processing, using part 5 of the Token test for children with two groups of children (Down Syndrome and undifferentiated developmentally handicapped). Based on previous studies it had been hypothesized that individuals with Down syndrome have a right hemisphere specialization for language tasks. Since the right hemisphere is considered to be a less efficient system for the processing of language, Hartley (1985) hypothesized that subjects with Down syndrome would perform more poorly on verbal sequential (successive) processing tasks, but not on tasks requiring spatial (simultaneous) processing. Hartley (1985) reported that subjects with Down syndrome demonstrated a left ear advantage on dichotic listening tasks (though only 6 of the 12 subjects demonstrated a clear left ear advantage) and performed more poorly on tasks requiring an understanding of complex syntactical structures (successive processing) than undifferentiated developmentally handicapped subjects. Subjects were then regrouped based on ear advantage. Subjects with a left ear advantage, regardless of group, performed more poorly on syntactical tasks than subjects demonstrating a right ear advantage. Subjects with a left ear advantage did not perform more poorly on spatial tasks than subjects demonstrating a right ear advantage.

Other explanations for the findings of reversed cerebral specialization for language in individuals with Down syndrome have been proposed. Tannock, Kershner and Oliver (1984) used the Hiscock and Kinsbourne (1980) selective listening and attention switching paradigm and the same dichotic digits tape as Zekulin-Hartley (1982) to investigate the association between Down syndrome and reversed cerebral specialization for language. Results using this priming paradigm did not support a simple model of reversed cerebral specialization for individuals with Down syndrome. They contended that the atypical lateralization noted in previous studies could be explained by specific listening strategies adopted by individuals with Down syndrome, or as an artifact of the methodology in that priming was unintentionally present.

Bowler, Cufflin and Kiernan (1985) addressed the conflicting findings of earlier research on the direction of dichotic ear perference by conducting both verbal and nonverbal tests. The group of Down syndrome subjects did not show significant levels of lateralization for verbal or nonverbal conditions, but did have a greater number of subjects with left ear advantage. Based on these findings and earlier research on the mentally handicapped population, Bowler et al (1985) concluded the atypical ear advantage noted in individuals with Down syndrome was more likely associated with level of language ability.

In a more recent study however, Giencke and Lewandowski (1989) examined ear advantages in individuals with Down syndrome using free recall and priming conditions. Their results indicated an atypical left ear advantage for individuals with Down syndrome on four of their six experimental conditions, including conditions in which subjects were primed. The consistency of Giencke and Lewandowski (1989) results for attentional and memory demands and the use of a free recall and priming paradigm, indicates that these atypical patterns may be based in biological and neurological factors, rather than maturational lags, or methodological variation in the dichotic listening paradigm.

Attempting to determine a laterality index for the perception of speech sounds, Elliott and Weeks (1993) used a free recall dichotic listening procedure. They also had their subjects perform both visual and verbal sections of a standard apraxia battery. Elliott and Weeks (1993) found that subjects with Down syndrome did tend to show a left ear advantage, and performed better when cued visually versus verbally on the apraxia battery. Those subjects with greater left ear advantage also demonstrated greater disadvantage on the apraxia battery when verbally cued. This finding supports their model of cerebral organization for Down syndrome, since individuals exhibiting the greater dissociation between speech perception and movement organization also had more pronounced verbal-motor difficulties.

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## FOOTNOTES

1 A Laterality index is a measure of ear advantage used within the dichotic listening and other laterality paradigms. It represents the percent difference in the allocation of attention and/or sensitivity of the ears (Richardson, 1976).