Verbal and Visual Instruction in Motor Skill Acquisition for Persons With and Without Down Syndrome

Brian K.V. Maraj
University of Alberta

Li Li, Rebecca Hillman, and Jennifer J. Jeansonne
Louisiana State University

Shannon D. (Robertson) Ringenbach
Arizona State University

This study examined motor learning in persons with Down syndrome (DS), persons with undifferentiated developmental disabilities (UnDD), and persons without disabilities (ND). Participants were instructed (either by verbal instruction or visual demonstration) to move a cursor to three items displayed on a computer screen. Results indicated that the ND group had superior performances to the other two groups for both instruction conditions. Participants with DS performed the task with both longer response and movement times when instructed verbally. In a transfer condition, results revealed the UnDD group displayed poor transfer, while participants with DS showed positive transfer from visual to verbal protocols. These results provide some evidence that persons with DS may be able to consolidate visual information to facilitate verbal-motor learning.

Clinicians, teachers, instructors, parents, and coaches often use various modes of instruction when guiding individuals in the acquisition of various motor skills. Typically, modes of verbal instruction and visual demonstration are integrated in the learning environment to facilitate skill acquisition. However, the efficacy of instructional modes in guiding persons with disabilities is an ongoing area of concern for many researchers and educators (e.g., Butler, 1998; Stone, 1998). While
this is a general area of concern, there are instructional challenges that can be very specific to certain populations. For example, there is a body of literature indicating that persons with Down syndrome (DS) perform more poorly in tasks presented verbally as opposed to visually. This deficit in verbal-motor behavior has been supported through investigations by a number of researchers (see Maraj et al., 2002 for a review).

In addition to showing general problems in cognition, persons with DS have been shown to display difficulty in various aspects of motor performance (Sherrill, 1998). Specifically, in comparison to other persons with intellectual disabilities, persons with DS experience a greater degree of difficulty in performing tasks that involve the integration of perception of speech and production of movement (e.g., Elliott & Weeks, 1993; Weeks, Chua, & Elliott, 2000; Welsh & Elliott, 2001).

In attempting to understand the role of verbal and visual instructional procedures for cognitive and motor learning in persons with DS, researchers have undertaken several efforts to explore these learning modalities, drawing from different theoretical underpinnings. For example, short-term memory deficits have been shown to influence verbal task performance in persons with DS (e.g., Jarrold, Baddley, & Hewes, 2000). Jarrold et al. investigated how the phonological loop in a model of working memory might affect verbal short-term memory performance. Their results revealed that short-term verbal memory was impaired in persons with DS when compared to nonDS. Neuropsychological evidence has also supported verbal/visual differences for information processing in persons with DS. Wang and Bellugi (1994) examined verbal and visual spatial short-term memory dissociation and corroborated the finding that persons with DS perform significantly better on a visual-spatial short-term memory task. Wang and Bellugi presented their findings as evidence for a general distinction between short-term storage for verbal and visual-spatial stimuli. This finding may represent a salient factor for the deficits displayed by persons with DS when engaged in tasks utilizing a verbal mode of presentation.

One further account for the verbal/visual dissociation, put forward over the last fifteen years, proposes atypical (right hemisphere) specialization for speech perception in persons with DS (see Weeks et al., 2000 for a review). This position was based on some earlier research involving persons with DS, indicating that these individuals exhibit quite different performance on tests of dichotic listening (Hartley, 1981, 1982; Zekulin-Hartley, 1981). Indeed, the research generally revealed that persons with DS display a left-ear superiority. This pattern of atypical specialization exhibited by persons with DS, in conjunction with typical left hemisphere specialization for the organization and control of limb movements, (e.g., Elliott, 1985; Elliott, Weeks, & Jones, 1986; Edwards & Elliott, 1989) results in a functional dissociation that could be responsible for some of the specific verbal motor problems in this population (e.g., Elliott & Weeks, 1990; LeClair & Elliott, 1995; Welsh & Elliott, 2001). Specifically, persons with DS now have to integrate information for both hemispheres (the right for speech perception and the left for the organization of movement production) in a verbal motor task. Thus the inter-hemispheric integration requirements impose a far greater information-processing challenge than that required when processing occurs within a single hemisphere.

Based on this anomalous left-ear/right-hemisphere specialization for speech perception, Elliott and colleagues have developed a neurobehavioral model of cerebral specialization in persons with DS. The key feature of the model is the
dissociation of right-hemisphere speech perception from left-hemisphere movement organization in persons with DS (Elliott, Weeks, & Elliott, 1987). As a consequence, the model predicts that persons with DS will have unique difficulty in performing tasks that coinvolv the perception of speech and the organization of complex movement. Tests of the model have shown that persons with DS do indeed exhibit greater difficulty performing movements on the basis of verbal direction (compared to other individuals of a similar mental age) but exhibit no impairment when visually directed to perform the same movements. In addressing the area of verbal-motor behavior in persons with DS, many studies have focused attention on studying motor performance as opposed to motor learning. The distinction here is one that has been identified as critical in the motor behavior literature (Schmidt & Lee, 1999). Specifically, motor performance deals with the ability to perform the associated movement characteristics of a task in one testing session. Thus by definition, motor performance does not deal with the long-term retention of a motor skill. Motor learning, on the other hand, reflects the capacity to acquire, retain, and generalize a movement pattern after some training period. Measures of learning describe the stability of behavioral changes over time and can be viewed as a meaningful descriptor of learning. In this regard, proper assessment of motor learning provides more relevant insight into the effectiveness of instructional protocols for persons with DS.

The importance of the learning/performance distinction is particularly heightened when one considers that conditions that facilitate motor performance are not always optimal for long term retention of a motor skill or transfer of learning to a similar movement task (Salmoni, Schmidt, & Walter, 1984). Factors that can be detrimental for motor performance may actually enhance skill acquisition (motor learning). For example, when practice schedules are such that feedback is given on every trial, it has been demonstrated that performance can be optimized but the effect on learning can be detrimental. WInstein & Schmidt (1990) showed that decreased levels of feedback produced levels of performance that were poor but for which retention and transfer scores were facilitated. It is now generally accepted that feedback on every trial will not produce superior levels of motor learning (Schmidt & Wrisberg, 2000).

In an initial study on motor learning in adults with and without DS, participants were taught a novel three-element movement sequence using a verbal instructional protocol (Elliott, Gray, & Weeks, 1991). The goal was to complete the task as quickly as possible. During the acquisition phase of the study, participants were cued verbally about the movement sequence to be completed prior to each attempt and were given verbal feedback about their performance. Following 45 practice trials and a short rest interval, retention of the newly acquired skill was examined in a situation in which verbal cueing and feedback were no longer available. These retention conditions would approximate what happens in a learning situation where the instructor was no longer present to guide the learner. The main dependent measures were the time to initiate the movement sequence (response time), the time to execute the movement sequence (movement time), and the number of movement sequencing errors. The retention results revealed that while persons with DS executed their movements just as quickly and accurately as control participants of a similar mental and chronological age, they took longer to initiate each movement sequence. This finding was taken as an indication that some of the difficulties persons with DS have performing movements on the basis of verbal
direction (e.g., LeClair & Elliott, 1995) may also extend to influence their ability to learn a novel motor task.

Although the Elliott et al. (1991) study was concerned with verbal-motor learning, one experimental design feature that was not included is a control learning situation in which instruction is provided in another manner (i.e., visual instructions). This warrants consideration especially in light of the proposed model by Elliott et al. (1987) and the verbal/visual findings from other investigators (Jarrold et al., 2000; Wang & Bellugi, 1994).

Thus, the primary goal of the present study was to determine if the specific problems that persons with DS have exhibited when executing motor performances on the basis of verbal instructions would also generalize to motor learning. Specifically, the following experiment was designed to explore more fully the role of visual and verbal instructional protocols on the acquisition, retention, and transfer of motor skills in persons with and without DS.

Method

Participants consisted of three groups of children and young adults. Persons with DS (n = 10), persons with undifferentiated developmental disabilities (UnDD; n = 10), and persons with no disabilities (ND; n = 8) participated in the experiment. The mental ages were obtained from records of assessments made at each of the respective schools that the children attended in South Louisiana. The mean mental age for the DS, UnDD, and ND groups was 6.3, 7.8, and 8.0 years, respectively. There was no significant difference between the groups for mental age (p = 0.54).

There was no significant difference between the mean chronological ages for the DS and UnDD groups (18.2 and 16.8 years). The university IRB approved the protocol for this study and informed consent forms for participation were obtained for all participants.

Task

The task was a computer-based movement sequence in which the participants had to move the cursor (via a mouse) to three targets that were arranged vertically on the computer screen. Participants were seated comfortably in front of a computer screen. The seats were adjusted to allow each participant to get an unobstructed view of the screen as well as be able to manipulate the mouse. The screen showed the participants four vertically arranged boxes. The top rectangle was the home position and participants were required to make one of two distinct movement patterns. The movement patterns used started from the home position from which participants moved down toward the Middle/Top/Bottom or the Bottom/Top/Middle squares. The presentations of movement patterns in acquisition and retention/transfer trials were counterbalanced for each block.

Procedure

Each group of participants was divided such that half would receive the movement instructions verbally or visually and the other half, visually. All participants were instructed to move to the targets from the home position. For the groups receiving instructions verbally, a recorded audio file was activated for each trial in the verbal
condition. The experimenter would ask if the participants were ready and thereafter activate the audio file, which provided the movement sequence (e.g., middle, top, bottom). This procedure ensured that the delivery of verbal instructions was consistent for all participants. For the visual instructional condition, the participants were shown on the screen the movement of the cursor in the order in which they were to perform the movement. For this condition, the custom made program was designed to move the cursor automatically to the required locations in the order to be performed.

For both verbal and visual conditions, participants were required to reproduce the sequence they were shown or told as quickly and accurately as possible after the sound of a tone. The tone was the movement imperative and was presented to the participants following a variable foreperiod (0.5, 1.0, 1.5, 2.0 seconds). The dependent variables of interest in this study were response time (RT; time from the movement imperative to the initiation of movement) and movement time (MT) for the entire movement sequence.

Participants performed 60 trials in acquisition (3 blocks of 20 trials). One hour following the acquisition trials, participants performed 1 block of 10 trials in a retention test (using the same instructional mode as in acquisition) and 1 block of 10 trials in a transfer test (using the other instructional cue from that used in acquisition). Twenty-four hours later, participants performed another block of ten trials for each of the retention and transfer tests.

Results

For all analyses conducted, the two movement patterns revealed no significant difference. As such, the following analyses reported were conducted with the data collapsed across the two movement patterns.

Acquisition Data

The acquisition data for Response Time (RT) were analyzed using a 3 Group by 2 Instruction Condition by 3 Block analysis of variance with repeated measures on the last factor. The results indicated main effects for Group $F(2, 47) = 18.75, p < .001$ and Condition $F(1,47) = 4.76, p < .05$. Post hoc analysis (Tukey’s HSD $p < .05$) for the Group main effect revealed that the ND group was significantly faster ($M = 1.16$) than the other two groups ($MDS = 2.46, MUnDD = 2.45$) whose RTs were not different from each other. For the effect of Condition, shorter response times were seen in the visual instruction condition than in the verbal instruction condition ($M_{Visual} = 1.78, M_{Verbal} = 2.23$). Only one interaction, Group by Condition, was significant for this dependent variable, $F(2, 47) = 6.66, p < .005$. This effect revealed that in the visual condition the group with DS had shorter response times than the UnDD group. However, in the verbal condition, the DS group had significantly longer response times than the UnDD group (see Figure 1). The groups of DS and UnDD participants had significantly longer response times than the ND group for both the verbal and visual conditions.

The analysis for Movement Time (MT) showed a main effect for Group $F(2, 20) = 20.80, p < .0001$ and Block $F(2, 40) = 4.14, p < .05$. Post hoc analysis (Tukey’s HSD $p < .05$) revealed for the Group main effect that participants in the ND group ($M = 7.38$) were significantly faster than participants in the other two
groups (which were not different from each other; \(M_{DS} = 14.42, M_{UnDD} = 15.02\)). The Block main effect revealed that the first block had significantly longer movement times than blocks two and three (\(M_1 = 13.05, M_2 = 11.88, M_3 = 11.88\)).

As with RT, the only significant interaction was for Group by Condition: \(F(2, 20) = 6.71, p < .01\). Post hoc analysis (Tukey’s HSD \(p < .05\)) of this interaction revealed that the DS group was faster in the visual condition than in the verbal condition; but the UnDD group had the reverse outcome, slower in the visual condition and faster in the verbal condition. Participants in the ND groups were faster than both other groups regardless of condition (see Figure 2).

Retention and Transfer Data

Retention and transfer data were analyzed separately with each using a 3 Group by 2 Condition by 2 Time analysis of variance with repeated measures on the last factor.

Retention Data. The analysis of retention data for RT revealed only one significant effect, a main effect for Group: \(F(2, 50) = 9.37, p < .001\). Post hoc analysis revealed that the ND group was significantly faster than the other two groups (\(M_{ND} = 1.17, M_{DS} = 2.36, M_{UnDD} = 2.36\)).

The analysis of retention data for movement time also produced a main effect for Group: \(F(2, 22) = 12.66, p < .001\). Post hoc analysis of this effect again revealed that the ND group was significantly faster than the other two groups who were not significantly different from each other (\(M_{ND} = 7.10, M_{DS} = 13.40, M_{UnDD} = 14.89\)). The Group by Condition by Time interaction was significant: \(F(2, 22) = 7.89, p < .001\). This interaction revealed that at the 1-hour retention test, the group with DS had longer movement times for the verbal condition when compared to the group in the visual condition. This effect still persisted after 24 hours.
The UnDD group showed little difference between visual and verbal conditions at the 1-hour retention, but at the 24-hour retention test, the verbal condition group had a significant reduction in total movement time when compared to the visual condition group (see Figure 3).

Transfer Data. In the transfer test, participants were also tested at 1 hour and 24 hours after the acquisition trials. However, the participants who had acquisition trials in the verbal condition were switched to the visual condition, and those in the visual condition were switched to the verbal condition.

The data analysis for response time in the transfer condition revealed main effects for Group, $F(2, 50) = 13.59, p < .0001$ and Time, $F(1, 50) = 6.85, p < .05$. Post hoc analysis of the Group effect showed that the ND group was significantly faster ($M = 1.15$) than the other two groups (which were not different from each other; $M_{DS} = 2.09, M_{UnDD} = 2.24$). The main effect for Time showed that participants had shorter response times in the 24-hour session than in the 1-hour session ($M_{1\text{-hour}} = 1.91, M_{24\text{-hours}} = 1.74$; see Figure 4).

The data for movement time revealed a main effect for Group, $F(2, 22) = 11.02, p < .0005$. Post hoc analysis of the Group effect showed that the ND group ($M = 7.73$) had significantly shorter movement times than the other two groups (which were not different from each other; $M_{DS} = 13.55, M_{UnDD} = 14.69$). The only other significant effect was the 3-way interaction between Group, Time, and Condition: $F(2, 22) = 5.02, p < .05$ (see Figure 5). Post hoc analysis of this interaction showed that the group with DS had a superior performance (decreased movement time) in the verbal condition after having had acquisition trials in the visual condition in comparison to the group with DS in the verbal condition retention test. This positive transfer effect from the visual condition in acquisition to the verbal condition in transfer was even more pronounced after the 24-hour delay interval. By comparison, the UnDD groups showed the opposite effect with longer movement times for the verbal condition after having visual instruction in the

![Figure 2 — Significant two way interaction between Group and Condition for movement times in acquisition phase.](image-url)
acquisition trials. Participants in the two ND groups had consistently shorter movement times than the DS and UnDD groups, regardless of transfer condition or delay.

**Discussion**

Verbal–motor deficits in motor performance for persons with Down syndrome (DS) have been demonstrated in the research literature (see Weeks, Chua, & Elliott 2000 for a review). In addition, there has been evidence to support the notion that persons with DS show right hemisphere specialization for speech perception (Elliott...
et al., 1987). This atypical cerebral specialization in persons with DS has been hypothesized to result in difficulties for the production of motor skills when verbal instructions are given. Elliott et al. (1987) has specifically addressed this issue in their proposed model. The model posits that speech perception is associated with the right cerebral hemisphere, while the production of movements is organized in the left hemisphere. The inter-hemispheric processes involved in movement production would, therefore, be more problematic for persons with DS due to the
increased information processing demands. With the model as a theoretical basis, the present experiment examined persons with DS and control groups, using verbal and visual instructional protocols. Moreover, the present experiment allowed us to examine the effects of these procedures on the learning of a novel sequential motor skill.

In the acquisition phase of the present study, participants with DS were slower at initiating their movements in the verbal condition as compared to participants of a similar mental age with undifferentiated developmental disabilities and those who were nondisabled. However, in comparison to the ND group, the participants in the UnDD and DS groups were both slower to initiate movements. Further, persons with DS demonstrated faster initiation of movements when in the visual condition as opposed to when the movement cues were provided verbally. This pattern of performance results is consistent with other verbal-motor findings (Elliott et al., 1991). However, compared to the Elliott et al. 1991 study, the response times in the present study were much longer. This may be due to the fundamental task requirements utilized in each experiment. In performing the task used in the present experiment, participants appeared to have lingered with the cursor in the home position following the movement imperative rather than move directly to the first position in the sequence. In the Elliott et al. (1991) task, there was no spatial translation required between the hand and the object to which the movement was directed. The more direct mapping of the hand and the object in the Elliott et al. (1991) task may have contributed greatly to the shorter response times reported in that study.

The movement time findings during acquisition were consistent with the response time results. That is, persons with DS took longer to complete the movement sequence in the verbal condition. However, the DS group demonstrated slightly faster movement times than the UnDD group in the verbal condition. Again, both groups were slower than the ND group of participants. The reduction in movement
time for the movement sequences as a function of practice (i.e., trials in the acquisition phase) demonstrates that the acquisition trials had an influence on the participants of the groups to improve (i.e., perform the movement faster) in all conditions. This finding is consistent with other studies that have shown a performance effect in a sequenced movement for persons with DS (e.g., Elliott et al., 1991).

Of primary interest in the present study was how instruction condition affected the retention and transfer of the movement (i.e., motor learning). In the retention test, participants were tested at 1 hour and 24 hours after the acquisition trials in the same condition (visual/verbal) in which they practiced the movement sequence. Contrary to previous work on motor learning in persons with DS (e.g., Elliott et al., 1991), our results indicated that regardless of whether they were instructed visually or verbally, persons with DS were no slower than persons of a similar mental and chronological age at initiating movements during retention tests at 1 hour and 24 hours. Thus, at least in terms of response time, the verbal-motor performance problem did not generalize to motor learning. Moreover, persons with DS were able to initiate their movements just as rapidly as their peers of a similar mental and chronological age when they were required to perform movement sequences during transfer conditions. Control participants without intellectual disabilities initiated their movements more quickly than persons in the two other groups regardless of condition (i.e., acquisition, retention, or transfer).

Perhaps the most interesting results are evident in movement times during retention and transfer. The transfer test involved performing the movement sequence following cueing via the untrained modality (i.e., verbal cueing of the visually trained participants and vice versa). The results showed that participants with DS exhibited slower movement times in the verbal condition as compared to the visual condition. Persons with DS did not differ from participants in the UnDD group in the verbal condition at 1 hour, but at 24 hours, unlike other participants, persons with DS showed a significant increase in movement time. These group differences were not evident under the visual presentation conditions. These findings provide some support for the notion that the learning derived from conditions of verbal instruction may be more susceptible to decay in the persons with DS. In fact, the longer retention interval seemed to exacerbate the poor performance levels associated with an already challenging mode of information presentation in the group with DS.

The visual instructional mode resulted in an advantage in the acquisition trials for the DS and UnDD participants. The adaptability of participants who had practiced in the visual instructional condition to transfer to the verbal condition was also evident by the transfer data for these groups. The participants who had visual instruction also demonstrated superior levels of performance in comparison to the participants who practiced in the verbal situation and then switched to the visual condition. In fact, this effect was even more pronounced after 24 hours. The DS group that practiced in the visual condition was able to transfer to the verbal condition after 1 day with comparable levels of performance for both movement time and response time. In fact, their performance was significantly better after 24 hours relative to the 1-hour retention test.

From these results, we propose that the general difficulties persons with DS experience when attempting to perform movements on the basis of verbal instruction be offset by a relatively greater capacity to consolidate information that is
presented in a visual manner. Such a proposal is consistent with the model of cerebral organization proposed for persons with DS by Elliott et al. (1987) and makes an important extension to motor learning.

Further investigation is needed to determine if long-term effects in the transfer condition can be seen in other variations of movement task dimensions across different learning modes. Our future work will continue to explore the means by which long-term retention and transfer can be facilitated in the acquisition of movement skill for more functionally relevant activities.

References


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**Authors’ Note**

The working assumption here is that the mental and chronological ages for the ND group would be equivalent.

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