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# Implicit Learning in Children With and Without Developmental Coordination Disorder

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## KEY WORDS

- dyspraxia
- motor learning
- perceptual learning

**OBJECTIVE.** The ability to use perceptual cues within the environment to guide movement accurately can be acquired implicitly in that skill may increase while the learner is not consciously aware of what cues are being used. In this study, the implicit learning capabilities of children with and without developmental coordination disorder were compared.

**METHOD.** Twenty-two children (11 with developmental coordination disorder, 11 without the disorder) played a computer game where they “caught” a descending ball image with a paddle on the screen. The dependent variable was accuracy of catch, as measured by the score on the computer game. On training trials, a visual cue appeared 50% of the time that signaled the direction of the ball. On probe trials, the visual cue was false. After completing the task, the children were interviewed about their conscious awareness of the cue. A mixed factorial analysis of variance (ANOVA) was used to analyze the data for group comparisons.

**RESULTS.** Of the 22 children, only 6 indicated that they were aware of the cue. A mixed factorial ANOVA was significant for greater error when the visual cue was false,  $F(1.12, 22.49) = 27.27, p = .000$ , indicating that the children responded to the cue. No difference was found between groups in game performance.

**CONCLUSION.** Children with developmental coordination disorder in this study were able to implicitly recognize and use a perceptual cue to enhance their performance on a computer game. Strategies that foster implicit learning may be relevant to occupational therapy intervention.

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**D**evelopmental coordination disorder is a condition that affects approximately 6% of all school-age children (Polatajko, 1999). The disorder presents as unexplained clumsiness and problems with tasks that require motor coordination. Of special concern to occupational therapists is the impact of this dysfunction on daily living tasks (American Psychiatric Association [APA], 1994). Children with developmental coordination disorder have trouble with skills such as writing, catching a ball, dressing, buttoning, tying shoes, or handling a spoon (Gordon & McKinley, 1980). These problems may translate into social and emotional challenges that can persist into the teen years (Cantell, Smyth, & Ahonen, 1994) and affect occupational choices made in adult life (Rasmussen & Gillberg, 2000).

Traditionally, occupational therapists have used treatment that is based on neuromaturational theories to address the occupational dysfunction of children with developmental coordination disorder. These treatments include sensory integration, process-oriented, and perceptual-motor programs. This bottom-up approach has been inconsistent with regard to improving occupational performance (Mandich, Polatajko, Macnab, & Miller, 2001). The challenge for children with developmental coordination disorder has recently been reconceptualized as one of motor skill acquisition (Missiuna, Mandich, Polatajko, & Malloy-Miller, 2001). This reconceptualization makes information about how children with developmental coordination disorder learn critical to intervention.

One crucial concept about motor skill acquisition is that a relationship must be forged between the learner and the task environment. Theories of motor learning that are based on the ecological approach forwarded by Gibson (1969) propose that certain aspects of the task environment are more important than others (Gentile, 1998). For example, an important perceptual cue to catching a ball is the angle of its descent. Children learn what the relevance of this cue is as they play catch. As the child gains experience in catching, finer discriminations of angles that signal good versus difficult catches are learned (Lefebvre & Reid, 1998).

Although perceptual discrimination in motor learning presents as a very complex process, evidence suggests that it occurs without conscious direction or awareness. The classic experiment in this line of inquiry was published by Pew (1974). Pew conducted an experiment in which participants were asked to track a randomly oscillating line. The first and third portions of the line's path were random from trial to trial. The line's path on the middle third, however, remained constant. When the participants' performances were compared, all showed better accuracy for the middle portion, yet none reported any awareness of the consistency of the line pattern during the middle third of the path. The results of these experiments and others have led to the conclusion that it is not necessary to specifically and consciously direct a learner to the cues critical for successful task performance; these cues can be learned implicitly (Magill, 1998).

In addition to the contention that perceptual cues are best learned implicitly, some researchers have argued that calling conscious attention to task-relevant features actually impedes performance. Green and Flowers (1991) hypothesized that providing learners with explicit information about a task on a computer and thus inviting them to engage in conscious routes of learning would produce an informational processing load that would lead to poor performance. The task consisted of using a joystick to intercept an image of a ball with a paddle image at the bottom of a computer screen. On half of the trials, a glitch, or a visible wiggle, in the falling ball appeared during the first third of its path. On 75% of these glitch trials, the falling ball subsequently moved sharply to the right when it approached the catching zone at the bottom of the screen, called a fade. The fade made the ball harder to catch. Sometimes the glitch accurately predicted a fade; other times, the glitch was a false predictor, and no fade appeared. Participants were divided into three groups: explicit, implicit, and control. Only the participants in the explicit group were informed about the glitch and fade probabilities.

At the end of practice, participants performed more poorly on trials involving a fade. The ball was harder to

catch in the fade condition. However, participants produced less error when the glitch accurately predicted a fade and more error when the glitch was false and not followed by a fade. The participants had learned the relevance of the glitch cue. In addition, the participants in the explicit group demonstrated greater overall error under all conditions. Knowing in advance that the glitch predicted a fade impeded rather than improved the performances of the participants in the explicit learning group.

The benefits of implicit learning are not readily apparent in the skill acquisition of children with developmental coordination disorder. A characteristic of the motor performance of these children is an inability to learn from their own errors and the persistence of incorrect strategies (Goodgold-Edwards & Cermak, 1990). Knowing how children with developmental coordination disorder go about learning the tasks important to their occupational roles thus becomes critical for occupational therapy intervention planning. The purpose of this pilot study was to seek evidence about how children with developmental coordination disorder compare with their peers without the disorder in their ability to unconsciously discern and respond to a perceptual cue important to motor performance.

## Method

This study used a split plot design (Maxwell & Delaney, 1990). Eleven children with developmental coordination disorder were matched to same-age peers without the disorder. The children played a computer game where they "caught" a descending ball image with a paddle on the screen. The dependent variable was accuracy of catch. On training trials, a visual cue that signaled the direction of the ball appeared 50% of the time. On probe trials, the visual cue was false. After completing the task, the children were interviewed about their conscious awareness of the cue.

### *Participants*

Twenty-two children participated in this study. Eleven children met the criteria for inclusion in the developmental coordination disorder group, and 11 met the criteria for the control group. Ages ranged from 6 years to 11 years, 11 months. Two girls and 20 boys participated.

*Developmental coordination disorder group.* Sixteen children with developmental coordination disorder were recruited through referral from occupational therapists. Inclusion and exclusion criteria were based on the definition of developmental coordination disorder established by the APA (1994). Inclusion criteria were (a) a total score in the lower 15th percentile of the Movement Assessment

Battery for Children (Movement ABC; Henderson & Sugden, 1992), (b) dysfunction in daily living skills or educational tasks per therapist or educator report, (c) no discrete deficit or diagnosis known to directly affect motor coordination, and (d) receipt of instruction in a general education setting with same-age peers. Exclusion criteria were (a) presence of mental retardation, pervasive developmental delay, or autism as identified by therapist, educator, or parent report and (b) educational goals differing by more than one grade level from same-age peers. Eleven of the recruited children met the criteria (see Table 1).

**Control group.** Fourteen children without developmental coordination disorder were recruited from elementary school afternoon care programs and youth organizations. Inclusion criteria were (a) a total score above the 15th percentile of the Movement ABC, (b) receipt of instruction in a general education setting with same-age peers, and (c) age and gender match to that of a child in the developmental coordination disorder group. Eleven of the recruited children met the criteria (Table 1).

Parents of the identified children were contacted. The purpose, risks, and procedures of the study were explained to the parents in accordance with the recommendations of the Institutional Review Board. Data collection was initiated upon documentation of informed consent.

### Instruments

The Movement ABC (Henderson & Sugden, 1992) is a standardized instrument that measures movement competence. It consists of eight tasks grouped under three headings: manual dexterity, ball skills, and static and dynamic balance. This assessment has been used extensively by researchers to identify children with developmental coordination disorder. The most frequent criterion for this identification is a movement impairment score below the 15th percentile (Barnett & Henderson, 1998). The test-retest reliability of the total impairment score ranges from 73% to

97% agreement over a 2-week period (Henderson & Sugden, 1992). The validity of the assessment has been compared with the Bruininks-Oseretsky Test of Motor Proficiency (Bruininks, 1978), with a resulting correlation coefficient of  $-.53$  (Henderson & Sugden, 1992). More recently, Crawford, Wilson, and Dewey (2001) compared the identification abilities of the Movement ABC to that of the Bruininks-Oseretsky Test of Motor Proficiency of a sample of 34 children with and 38 children without developmental coordination disorder. They found that the Movement ABC tended to underidentify children with motor problems and had an overall decision agreement of 67%. The researchers concluded that identification of developmental coordination disorder must combine test results with clinical observations.

The instrument used for the experimental task in this study was the Implicit Learning Software Configuration. The parameters of this software were selected to allow the programming of variations of the task described by Green and Flowers (1991). The software was custom designed for the Department of Kinesiology, Texas Woman's University, and used in other pilot work before the initiation of this project. The software program was installed on a 200 Hz Tangent microprocessor<sup>1</sup> with a 15-in. monitor, a keyboard, and a WingMan Attack joystick.<sup>2</sup> For this study, the image of a small red ball appeared at the top of the monitor screen. It descended the screen against a yellow background in an open reversed c-shaped curve, ending on the left. Descent time for the ball image was 2.5 sec.

On the monitor screen, a line twice as wide as the ball could be moved across the bottom of the screen by lateral manipulation of a joystick. The goal of the task was to "catch" the falling ball with this "paddle." The software pro-

<sup>1</sup>Tangent Computer, 197 Airport Boulevard, Burlingame, California 94010.

<sup>2</sup>Logitech, 6505 Kaiser Drive, Fremont, California 94555.

**Table 1. Age and Movement Competence Scores**

Developmental Coordination Disorder			Control		
Age (Months)	Movement ABC		Age (Months)	Movement ABC	
	Score	Percentile		Score	Percentile
142	15	3	143	15	23
134	10.5	13	140	7.5	65
129	12	8	129	5.5	40
120	18	1	120	2	79
107	23	2	107	1.5	93
106	20.5	3	100	0.5	49
101	13	6	95	0.5	93
81	33	1	75	3	45
81	23	1	80	5	84
77	17	3	80	4.5	89
72	14	9	74	6	36

*Note.*  $N = 22$ . Movement ABC = Movement Assessment Battery for Children. Higher scores on the Movement ABC denote larger movement deficits. Scores of 10 or above fall in the lower 15th percentile.

gram collected two measures of performance: feedback score and error score.

The feedback score was displayed on the computer monitor to each player. This score was measured in pixels (the points of light that together constitute the monitor screen image). A point system was used where 3 points were awarded for a catch at the center of the paddle, 2 points for catches 5 pixels from center of the paddle, and 1 point for catches more than 10 pixels from center of the paddle. Single-trial point scores were displayed after every trial. A total point score was given at the end of each session of practice. Error scores were recorded off screen and consisted of the number of pixels between the center of the paddle and the ball at the end of each trial.

Two features within this task were presented to the players. The first was a glitch that consisted of a color change of the ball image to white against the yellow background for 200 msec. The glitch was easily discernible to the viewer and occurred 1600 msec into the ball's descent. The second feature was a fade. The fade occurred 2000 msec into the ball's descent and during the 500 msec before the ball reached the bottom of the screen. The fade consisted of a shift in the ball's pathway sharply to the right.

The glitch and fade features were presented in controlled distributions. Each child completed five sessions of 100 trials each. Sessions 1, 2, and 4 were learning sessions. During the learning sessions on 50/100 trials, the glitch and fade were absent; this was the no-cue condition. On 50/100 trials, the glitch and fade were present; this was the cue condition. Sessions 3 and 5 were probe sessions. During the probe sessions, the no-cue condition was presented on 30/100 trials; the cue condition was presented for 35/100 trials. On the remaining 35 trials, the glitch was not followed by a fade; this was the false-cue condition.

### *Procedure*

Data collection was conducted singly and lasted approximately 70 min per child. Motor performance testing for final group assignment (developmental coordination disorder or control) was conducted during the same session as the computer task. Thirty children completed the session. Eight did not meet inclusion criteria as defined by the Movement ABC, and their computer task performance data were not used in the study.

Data collection was conducted in a private room at the child's school or home as arranged with his or her parents. The child was seated in front of the computer monitor and joystick. Before initiating the computer program, the game was described. The children were told that the game was simple, without the detailed pictures seen in most computer games. They were cautioned that although the game was

simple, it was not always easy to catch the ball but not to worry because they would get better. The children were encouraged to place or hold the joystick in any manner they found comfortable. They were told that they would play the computer game five times and that in between each session they would play a few of the researcher's games in a box.

Each child completed 5, 4.5-min, 100-trial sessions on the computer. A 5 to 10 min break was given between sessions. Testing for group membership confirmation was conducted simultaneously with data collection. During breaks between computer sessions, the children completed test items from the Movement ABC. During the first and second breaks, the examiner administered the manual dexterity portion of the Movement ABC. The ball skills portion of the Movement ABC was administered during the third break, and the balance skills portion was administered during the fourth break.

On completion of the five sessions, the children were asked four questions to determine whether they were consciously aware of any strategy:

1. How did you know how to catch the ball?
2. What would you tell another child to do to make a high score?
3. Did you have a secret way of knowing where the ball would land?
4. What was your secret?

### *Data Analysis*

Sessions 1, 2, and 4 were learning sessions and contained only cue and no-cue trials. Sessions 3 and 5 were probe sessions, included false-cue trials, and contained a larger number of no-fade ball pathways. For this reason, data analysis was conducted separately for the learning and probe sessions. The performances of the children with and without developmental coordination disorder were analyzed with mixed factorial analysis of variance with repeated measures for trials (Maxwell & Delaney, 1990). Feedback scores reflected overall performance on the task. Error scores allowed comparison of performance among cue, no-cue, and false-cue trials. Because the fade made the ball harder to catch, the highest error was expected for cue trials. If the children were responding to the cue and anticipating the fade, then greater error would be expected on the false-cue trials than on the no-cue trials, neither of which contained a fade.

## **Results**

### *Interview Data*

During the exit interview, 6 children made statements indicating that they were consciously aware of the glitch cue within the game. These children were the oldest 5 from the

control group and the oldest 1 from the developmental coordination disorder group. The remaining 16 children did not indicate any awareness of the relationship between the glitch cue and the direction of the ball's path. Chi-square analysis (group by awareness level) was not significant, ( $X^2 = 3.667$ ,  $df = 1$ ,  $p = .056$ ).

### *Feedback and Error Scores*

*Learning sessions.* There was no significant difference between the performances of the children with and without developmental coordination disorder as measured by feedback scores,  $F(1, 20) = 3.02$ ,  $p = .097$ , or error scores,  $F(1, 20) = 1.54$ ,  $p = .228$ . There was evidence that all the children performed better with practice and were learning the computer game. A main effect for feedback scores for session,  $F(2, 40) = 7.08$ ,  $p = .002$ , showed that the children's scores improved across sessions. Error score analysis also revealed improved performance as the children practiced the task, with a significant main effect for trials,  $F(3.43, 68.60) = 2.66$ ,  $p = .048$ . A main effect for type of trial for error scores,  $F(1, 20) = 12.87$ ,  $p = .002$ , revealed that the cue trials were indeed harder to catch. Error on cue trials ( $M = 76.29$  errors) was significantly higher than error on no-cue trials ( $M = 52.64$  errors).

*Probe sessions.* As in the learning sessions, no significant differences between the performances of the children with and without developmental coordination disorder were found for the probe sessions in feedback scores,  $F(1, 20) = .057$ ,  $p = .813$ , or error scores,  $F(1, 20) = .321$ ,  $p = .577$ . A main effect for type of trials was significant,  $F(1.12, 22.49) = 27.27$ ,  $p = .000$ . Simple contrasts revealed a significant difference among the three types of trials. The cue trials that included a fade produced the most error ( $M = 75.08$  errors); no-cue trials that contained neither cue nor fade produced the least amount of error ( $M = 38.13$  errors); and the false-cue trials produced greater error than the no-cue trials ( $M = 44.54$  errors).

### *Implicit Learning Analysis*

In the exit interviews, 6 of the 22 children indicated they had conscious awareness of the relationship between the glitch and fade. To determine whether the performances of these children accounted for the greater error on the false-cue trials, a second analysis was conducted on the probe session error data. The error scores of the 6 children who demonstrated conscious awareness of the cue were dropped from the analysis. Because no group differences had been identified, group was removed as a factor. In this second analysis, again a main effect for type of trial was significant,  $F(1.1, 16.65) = 13.01$ ,  $p = .002$ . Simple contrasts revealed significant differences among all types of trials, with cue trials showing the

most error ( $M = 69.53$  errors), no-cue trials showing the least error ( $M = 41.94$  errors), and false-cue trials again showing greater error than the no-cue trials ( $M = 46.57$  errors).

## Discussion

The children with developmental coordination disorder in this study were able to recognize and use a perceptual cue to enhance their performance. This recognition occurred without conscious awareness in that although the children's scores indicated they had learned that the glitch cue predicted a fade, the majority of the children themselves were unable to inform the examiner about the glitch-fade relationship. The ability to learn implicitly, therefore, is relevant to the occupational performances of children with developmental coordination disorder.

Although children with developmental coordination disorder frequently perform more poorly than their age-matched peers, this was not the case in this study. No group differences were identified in the analyses of feedback or error scores. One reason for this lack of group differences may have been the simplicity of the task. Motor differences between children with and without developmental coordination disorder may require a higher demand of task precision to be discernible. Further, this experiment used an artificial, two-dimensional task. How implicit learning proceeds for children with developmental coordination disorder in more complex and natural contexts requires further study. The task in this study, however, was not easy. Although the analysis of learning sessions indicated that the children made steady progress in the number and accuracy of their catches, the extent of their error on missed-catch trials remained large.

Several children indicated through the exit interviews that they had gained a conscious awareness of the relationship between the glitch cue and the path of the ball. Five of these children were from the control group and 1 from the developmental coordination disorder group. This distribution between groups was near significance when analyzed as nominal data. Age was also a factor in awareness of the relationship. Four of the 5 children from the control group older than the mean age of 8 years, 8 months, were consciously aware of the cue. Maturation may be influential in the ability to consciously identify or verbalize cues used in motor performance. Only the child near 12 years of age in the developmental coordination disorder group was able to verbalize knowledge of the cue. The children in the developmental coordination group appeared to be at a disadvantage for this ability.

Purposefully directing learners to consciously think about their motor strategies is a technique currently being

brought forward in occupational therapy treatment for children with developmental coordination disorder (Mandich, Polatajko, Missiuna, & Miller, 2001). It is important to note that the approach, called the cognitive orientation to daily occupational performance (CO-OP), does not recommend providing specific instruction and direction to the learner. Rather, the learner embarks on self-discovery of the parameters of the task through his or her own consciously mediated deliberation and self-talk.

This process of self-discovery is consistent with the methods suggested by Magill (1998, 2001). Magill stated that to enhance implicit routes of learning, detailed description of the perceptual cues inherent in the task should be avoided. Specifying cues is not necessary and, indeed, may impede learning. Children with developmental coordination disorder have difficulty learning nonhabitual motor tasks. Attempting to assist their learning with specific information about cues may have a detrimental effect. Instead, Magill has suggested that the learner's attention only should be drawn to the general area where the cues lie by using short verbal phrases, such as "look at the buttonholes" or "where are your legs?" Practice also should be structured, according to Magill, with cues relevant to the task in mind. Changing the context of an activity without changing the cue will assist in the recognition of the cue. For example, the angle of descent is a cue related to the likelihood that a falling object can be caught. Qualities of the descending object—size, color, speed—can be changed, leaving the relationship of the angle of descent to catch ability a constant to be discovered.

## Conclusion

Children with developmental coordination disorder experience a significant challenge in learning new motor skills. This challenge has an immediate and direct impact on the occupational performance of these children in tasks basic to work, self-care, and play. The results of this study indicate that children with developmental coordination disorder can implicitly recognize and respond to environmental cues important to task performance. What this means to the occupational therapist providing intervention is that it may not be necessary and, further, may even be detrimental to provide specific and direct information about the environmental cues important to occupational outcome. Further study is needed to examine implicit learning capabilities in more complex and natural contexts. ▲

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