Self-Regulation as a Mediator in Motor Learning: The Effect of the Cognitive Orientation to Occupational Performance Approach on Children With DCD

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Children with developmental coordination disorder (DCD) experience difficulty performing everyday motor tasks. It is has been suggested that children with DCD have fewer self-regulatory (SR) skills with which to acquire motor skills. This article presents the results of an exploratory study examining the development of SR competence among ten 7–9-year-old children with DCD participating in the Cognitive Orientation to daily Occupational Performance (CO-OP) program (Polatajko & Mandich, 2004). Using a quantitative observational coding method, children’s SR behavior was examined and compared across intervention sessions. Results indicate that children demonstrating improved motor performance similarly demonstrated more independent and effective SR behaviors. In contrast, children whose motor performance remained relatively stable failed to demonstrate such a change. These findings suggest that CO-OP enables SR performance among children with motor performance difficulties and, as a result, facilitates improved task performance.

Keywords: developmental coordination disorder, self-regulated learning, CO-OP, motor learning, cognitive intervention

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Developmental coordination disorder (DCD) is a condition of impaired motor coordination that results in problems performing everyday motor tasks and is often associated with secondary social, emotional, and academic difficulties. The emerging evidence suggests that these difficulties are, at least in part, due to problems in effectively using cognitive and metacognitive, or self-regulatory, skills to guide motor performance (Martini, Wall, & Shore, 2004). Intervention approaches focused on the application of cognitive paradigms, grounded in theories of motor learning, are now available to address the needs of children with DCD (Polatajko & Mandich, 2004; Sugden, 2007) and have the potential to effect self-regulation. The nature of self-regulatory performance during motor learning among children with DCD, however, is poorly understood as is the ability of cognitively-oriented, learning-based intervention programs to facilitate self-regulated motor performance.

Empirical and Theoretical Foundations

Understanding and Addressing DCD From a Self-Regulatory Perspective

Developmental coordination disorder (DCD) is a chronic condition characterized by a marked impairment in motor coordination. Its defining characteristic is a core motor deficit, but there is a well-established heterogeneity in the motor performance of children with DCD (Sugden, 2006) as well as frequent overlap with other developmental disorders (Kaplan, Wilson, Dewey, & Crawford, 1998). While many children with DCD eventually learn the basic motor skills required to perform daily tasks, these learned motor skills are often delayed, are noticeably clumsy in nature, or require an abundance of effort to learn (Sugden, Kirby, & Dunford, 2008). If left unaddressed, DCD has been demonstrated to have many negative long-term behavioral and socioemotional consequences, such as poor self-confidence, limited social skills, and decreased motivation for physical activity (Chambers, Sugden, & Sinani, 2005; Cousins & Smyth, 2003).

Traditionally, it has been assumed that the performance difficulties of children with DCD reflected underlying sensorimotor dysfunction and that remedial approaches aimed at addressing such dysfunction are effective for addressing performance difficulties (Mandich, Polatajko, Missiuna, & Miller, 2001). These assumptions have not been supported empirically, however, nor are they consistent with current theories of motor learning advocating a focus on direct skill training using functional activities in everyday contexts (Missiuna et al., 1997; Sugden, 2007; Wilson, 2005). A diverse range of research efforts, grounded in behavioral, cognitive, neurological, and motor developmental perspectives, has more recently emerged to provide potential explanations for the movement difficulties experienced by children with DCD (Barnett, 2008; Wilson, 2005). Similarly, a new generation of intervention approaches has emerged which, through a blending of cognitive and motor learning theories, involve working on problem-solving strategies with children during skill acquisition and performance and assisting children in becoming more aware of the cognitive processes and strategies used to guide motor performance (Missiuna et al., 1997).

The application of this new generation of intervention strategies has prompted the hypothesis that children with DCD poorly self-regulate their own motor performance. More specifically, they are said to have a smaller repertoire of cognitive
and metacognitive skills from which to draw during motor performance and have
difficulty learning the many strategies that most children discover, learn, and apply
implicitly through everyday movement experiences (Missiuna et al., 1997). It has
been further suggested, therefore, that children with DCD need support in develop-
ing problem-solving and self-regulatory skills for addressing motor performance
difficulties (Mandich et al., 2001).

The Cognitive Orientation to daily Occupational Performance (CO-OP; Polata-
jko & Mandich, 2004) is one such intervention approach. It focuses on teaching
children to use a four-step self-instructional problem-solving strategy for working
through performance difficulties and achieving skill competence. This strategy,
summarized by the mnemonic GOAL-PLAN-DO-CHECK (GPDC), targets self-
regulatory skills in goal setting, planning, self-monitoring, and evaluation by encour-
aging the child to consciously reflect on performance and select, enact, evaluate, and
adapt performance strategies. Using questioning, guiding, and coaching techniques
in a process called guided discovery, the child is instructed in the use of the GPDC
framework and guided to discover domain-specific strategies (DSS) for solving
motor performance problems. Initially, the adult adopts a leading role in guiding
the use of the GPDC strategy and the discovery of DSS. Through questioning and
cueing, it is intended that the child gradually becomes more familiar with strategy
use and eventually begins to use them on his or her own.

A number of promising outcomes have been demonstrated through the applica-
tion of this new generation of interventions, including improved performance on
meaningful motor-based occupations (Miller et al., 2001; Sangster et al., 2005).
However, many of the underlying assumptions about the manner in which processes
of guided discovery serve to facilitate the development of self-regulatory ability
among children with DCD have yet to be fully examined. In their support for the
application of theoretical frameworks from the self-regulation and metacognition
literature to the study of DCD, Lloyd, Reid, and Bouffard (2006) stress that further
research is first necessary to gain a clear picture of self-regulation in this popula-
tion. What remains to be understood is the precise role played by self-regulation in
motor skill acquisition among children with DCD, how this differs from the self-
regulated motor performance of typically developing children, and whether, and in
what way, a cognitively-oriented intervention program supports the development

Applying Models of Self-Regulation to the Study of DCD

Self-regulation (SR) is a multidimensional phenomenon in which an individual exhib-
its appropriate and effective use of cognitive and metacognitive strategies for meeting
the demands of specific tasks and includes goal setting and planning, monitoring,
and adapting performance and effective evaluation (Pintrich, 2000). Self-regulation is
also characterized by an intrinsic motivational orientation, where the individual seeks
challenge, persists despite difficulties, and interprets difficulties as opportunities for
further learning (Boekaerts, 1999; Pintrich, 2000; Zimmerman, 2002).

One of the more prevalent SR models is that proposed by Zimmerman (2000),
whose conception of self-regulation is cyclical. Here, learning moves from a fore-
thought phase, which entails setting goals and strategic planning through a perfor-
mance phase in which social comparison, feedback, and the self-verbalization of
strategies is used to guide action and assess progress, and finally a self-reflection phase, where performance is assessed via evaluative judgments. These self-reflections, in turn, influence subsequent forethought processes (Zimmerman, 2000). In each phase, self-regulatory processes are linked to key motivational beliefs that serve to perpetuate the SR cycle. Motivational patterns can be ego-oriented, where the individual is guided by factors extrinsic to the real purpose of the task, or task-oriented, where learning is based on intrinsic interest and a focus on the meaning of the task (Dweck, 1991).

Zimmerman’s (2000) model also recognizes the social nature of learning, where the acquisition of new skills proceeds through four sequential phases of learning: observation, emulation, self-control, and self-regulation (Kitsantas, Zimmerman, & Cleary, 2000). This view of SR argues that, in the first two phases, children’s skill acquisition is supported by the modeling, instruction, monitoring, and guidance activities of teachers, parents, or peers. These experiences provide the learner with a clear idea of how a skill should be performed. In the latter two phases, self-directed practice enables the learner to adapt his or her own performance to changes in internal and external conditions (Zimmerman, 2006). In other words, the development of self-regulated performance is viewed as a progression from mediated practice toward the independent self-regulation of performance and learning (Kitsantas et al., 2000).

Support for this model has been provided through a number of studies testing hypotheses derived from the model. For example, in studies examining performance on a dart-throwing task among children of varying ages, higher levels of skill performance were demonstrated to be correlated with more effective forms of goal-setting, self-monitoring, and higher levels of intrinsic interest (Kolovelonis, Goudas, & Dermitzaki, 2010; Zimmerman & Kitsantas, 1997).

**Self-Regulatory Performance Among Children With DCD: What Do We Know?**

Despite the widespread recognition that cognitive and metacognitive skills influence complex motor behavior and motor learning (Ferrari, 1996; Newell & Barclay, 1982; Wall et al., 1985), there exists limited empirical investigation aimed at exploring self-regulated motor learning in the context of actual motor performance. Recent research examining the effects of specific self-regulatory processes on motor performance among elementary school students has demonstrated the positive influence of self-monitoring on skill performance (Kolovelonis et al., 2010) and examined the effects of different goals (process, outcome, and multiple goals) and self-recording on SR performance during a dart-throwing task (Kolovelonis, Goudas, & Dermitzaki, 2011).

Research focused on explaining the processes through which SR skills are acquired and used by children with and without motor difficulties in the context of an intervention is even more limited (Martini et al., 2004). This work stems in part from an early knowledge-based model of motor development proposed by Wall and colleagues (Wall et al., 1985). Using this framework, recent research has demonstrated that children with motor difficulties possess less detailed knowledge about motor tasks, focus on irrelevant information when identifying and addressing performance problems, often select inappropriate performance strategies, and are less likely to spontaneously plan, monitor, and evaluate their performance (Martini & Shore, 2008).
In two studies investigating the metacognitive processes underlying motor performance in children with and without DCD, Martini et al. (2004) and Lloyd et al. (2006) found that while both groups of children exhibited similar amounts of cognitive and metacognitive verbalizations during practice of a novel motor task, there were significantly more frequent verbalizations of inappropriate, inaccurate, or irrelevant statements related to planning and evaluation activities among children with DCD. These findings are supported by a more recent study comparing the SR performance of children with and without DCD in the context of a meaningful motor learning situation in which children with DCD less frequently exhibited independent self-regulatory skill and were more likely to exhibit ineffective forms of self-regulatory skills and rely on the external assistance of a therapist to effectively self-regulate performance (Sangster, 2009).

On the whole, previous research seems to suggest a relationship between SR competence and success in motor performance. While this early work has additionally offered interesting insight into the performance difficulties of children with DCD, the self-regulatory performance of children engaged in motor learning activity has not yet been examined in the context of intervention. The present study aimed to examine the manner in which a cognitively-oriented intervention program facilitates change in SR performance among children with DCD and to investigate the impact that any change in SR performance has on motor performance. To address these aims, the study was carried out in the socially-mediated context of the CO-OP intervention program. As a result, the observation of self-regulatory behavior took on a dynamic approach, where SR performance was observed both in the context of what the child is able to do independently as well as under therapist support. Consistent with Zimmerman’s (2000) view of the sequential manner in which self-regulatory competence develops, this approach allowed for an examination of the manner in which self-regulatory performance evolved over the course of the program. This approach is similarly consistent with the work of Vygotsky and the concept of dynamic assessment, which purports that development occurs along a continuum in which performance is initially scaffolded by external support, which is gradually faded as the child becomes increasingly independent (Kozulin, 2003).

The aims outlined above were addressed with the following two research questions:

1. In what way does the self-regulatory performance of children with DCD change during participation in the CO-OP program?
2. To what extent does any observed change in children’s self-regulatory performance relate to change in task performance?

Method

Participants

Identifying candidates for participation. Research participants were recruited from primary schools and occupational therapy practices in a large urban center in Canada. Using the diagnostic criteria for DCD provided in the DSM-IV-TR (APA, 2000), inclusion criteria for identifying potential participants were developed. First, a deficit in motor performance and the consequent disruption to academic achievement or activities of daily living was established through formal
motor assessment using the Movement-ABC test (Henderson & Sugden, 1992), where a deficit in motor performance was defined as a test score at or below the 5th percentile. Additional information about children’s difficulties in motor performance was obtained using the M-ABC Checklist (Henderson & Sugden, 1992) and verbal reports from key individuals in the child’s life (teacher, parents, coach, etc.), obtained through discussion during participant recruitment and intake. Due to the high prevalence of comorbidities among children with DCD (Sugden, 2006), children whose motor performance difficulties co-occurred with difficulties in learning and/or attention were included. As a result, children were grouped according to whether they exhibited motor performance difficulties alone (DCD) or whether motor difficulties co-occurred with other difficulties (DCD+). However, due to the study’s high reliance on verbal reports, children for whom a language or intellectual impairment had the potential to significantly interfere with their ability to participate in the research activities were excluded. As such, all children participating in the study were required to exhibit normal intelligence levels and have no documented evidence of a specific language impairment. In addition, children whose motor performance deficit was due to a general medical condition or pervasive developmental disorder were similarly excluded. Information regarding children’s intelligence and any co-occurring or potentially contributing conditions was gathered through parent and teacher interview and any previous formal assessment the child may have undergone. Participants selected were between the ages of seven and nine years of age.

Recruiting participants. Once permission for conducting the research had been obtained from the local educational authority and individual schools, 26 potential candidates were identified using the above criteria. Of these 26 children, 10 were found to meet the study criteria based on observation and standardized assessment and were thus invited to participate in the full study. The sample consisted of 9 boys and 1 girl; the mean age was 8.1 years at the time of participation and all attended public school in mainstream grade 1, 2, or 3 classrooms. Five children met criteria for inclusion in the DCD group while the remaining five children were included in the DCD+ group (Table 1). Informed consent for participation in the project was provided by the parents or guardians of children participating in the research and additional verbal assent was provided by the children themselves. Table 1 summarizes demographic variables and assessment results for the children in the two groups.

Ethics

Before embarking on the data collection phase of the research, the project received empirical and ethical approval from an advisory committee made up of faculty members from the university department at which the first author was conducting her doctoral studies.

Procedures

Intervention sessions. Each child participated in a series of 10 CO-OP intervention sessions on a twice-weekly basis, which were conducted in quiet therapy or study rooms in schools and video-taped to allow for retrospective analysis.
Sessions were carried out by the first author, an occupational therapist with extensive training and experience in implementing CO-OP. While CO-OP sessions typically last 45–50 min, the sessions in this study were limited to 30 min to accommodate younger children and the attention difficulties of some participants, a modification consistent with recommendations from the developers of CO-OP (Polatajko & Mandich, 2004).

Sessions were generally structured according to the CO-OP approach (Polatajko & Mandich, 2004). The first and second sessions served as an opportunity to introduce the approach to the child and establish a starting point for further sessions through observation of task performance and interview exercises. Here, using the Pediatric Activity Card Sort (PACS; Mandich et al., 2004), children were given an opportunity to select one task for all further skill learning. The PACS tool involves a card-sorting task in which children are asked to sort cards depicting various childhood motor activities (such as handwriting, bike riding, or tying a shoelace) according to their own perceived skill and participation level. Using this tool,
participants were asked to identify and select a task on which they wished to focus during the course of the intervention. This task self-selection ensured that all children were learning a task for which they were motivated to improve and in which they experienced some performance difficulty. All subsequent sessions followed a standard format, beginning with a brief review of the previous sessions’ activities followed by active engagement in motor learning using the CO-OP strategies for improving task performance. All sessions finished with a reflection log activity in which children were encouraged to reflect upon and discuss the session’s events and any learning or progress that may have occurred. These activities included recording the global or domain-specific strategies, identifying specific challenges, and discussing potential goals and new plans. Where specific task instructions or explanations were required (for example, when introducing children to the global strategy or providing instructions for a reflection task), verbal protocols were developed to ensure that these instructions were consistent across children.

Once all children had completed the program, an in-depth observational analysis was carried out to address the two research questions. For this purpose, video-taped sessions became the primary source of data.

Measures

Two measures were used during observational analysis: an observational scale for evaluating children’s performance on a motor-based task and an observational coding scheme to record and compare self-regulatory behavior. Each of these tools will be described here in turn.

Performance Quality Rating Scale. To examine change in children’s motor task performance over the course of the program, performance ratings were made by the first author in the initial and final sessions using the Performance Quality Rating Scale (PQRS; Miller et al., 2001). This is a 10-point observational scale used to evaluate performance on everyday motor-based tasks. Using these ratings, two performance profiles were created: Improved (an upward progression in researcher-rated task performance, operationally defined as a growth in the PQRS score of 3 or more points) and a Stable condition (little or no change in researcher-rated task performance over the intervention sessions, defined as a change in the PQRS score of less than 3 points). Using these criteria, 6 of the 10 participating children were included in the improved group while the remaining four children made up the stable group.

Observational coding scheme. To examine children’s self-regulatory behavior, an observational coding scheme was developed. Because this study represented a first attempt to observe and code SR behavior in the dynamic context of mediated intervention sessions, the coding scheme applied a number of existing models of self-regulation (Zimmerman, 2000), metacognition (Flavell, 1987), and motor learning (Newell & Barclay, 1982; Thomas, Gallagher & Thomas, 2001), as well as coding schemes developed in previous research examining SRL (Pino-Pasternak & Whitebread, 2010; Whitebread et al., 2007) and cognitive and metacognitive strategy use during motor skill acquisition (Mandich, 1997; Sangster, 2005; Sangster et al., 2005). In addition, codes were built up through a review of the videos from the current research, where individual codes and code definitions
were constructed and modified so that all codes could accurately and validly describe the self-regulatory performance of children in the present research. This process generated the coding scheme illustrated in Figure 1, where white boxes are the codes themselves and black boxes delineate the structural organization of the codes.

Consistent with the social-cognitive models of SRL described earlier, the structure of the coding scheme reflected the triadic interaction among task and metacognitive knowledge, self-regulatory skill, and motivational regulation; however, to address the research questions posed in the present paper, only findings relating to children’s performance of SR skills will be reported here. While children’s knowledge and motivational behavior certainly influence the development of overall self-regulatory competence, the development of specific SR skills in the context of the CO-OP program, and the manner in which these skills mediate motor performance, were of primary interest in addressing the research questions of this study.

The self-regulatory skill category represented the SR behaviors in which a child engaged during motor learning, which included individual codes for goal setting, planning, self-monitoring, strategy use, and self-evaluation. Behaviors coded under this category could be verbal or nonverbal and typically occurred while on task or in discussion immediately preceding or following task performance. Table 2 provides the operational definitions developed for each self-regulatory code and behavioral examples from the data. Based on the results of previous research demonstrating the qualitative differences in the SR behavior of children with DCD (e.g., Martini et al., 2004), behaviors coded in this category were further...
Table 2  Behavioral Codes Measuring Self-Regulatory Skill

<table>
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<tr>
<th>Operational Definition</th>
<th>Behavioral Example</th>
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| **Goal Setting (GS).** Child verbalizes or demonstrates a goal for task practice of performance. | Independent, cued, or mediated  
- Sets a specific, achievable goal or recalls a previously stated goal: *I’m going to try to dribble through the pylons and shoot the ball.*  
- Ineffective:  
  - Sets unclear, unachievable, or unrealistic goal: *I want to be better than everybody else.* |
| **Planning (PL).** Child describes action or sequence of actions necessary to meet a goal or otherwise engages in relevant cognitive activity prior to performing task and in preparation for task performance. Behaviors and utterances here are typically aimed at describing an intention for future action. | Independent, cued, or mediated  
- Identifies a potential strategy for use in performance and explains why it might be useful or appropriate or recalls a strategy from previous learning: *I’ll need to go slow so I don’t cut the picture. I’ll start here because it’s close to the edge.*  
- Asks a question or otherwise seeks clarification of task demands before engaging in performance: *Why don’t you tell me when you’re going to throw the ball?*  
- Makes a decision regarding task parameters: *This time it will be harder because this ball is heavier and so it will bounce less.*  
- Ineffective  
  - Describes irrelevant, unclear, or unrealistic plan: *I’m going to stand WAY back here!* (child decides to position self an unrealistic distance for catching ball)  
  - Demonstrates inaccurate recall of plans or strategies from previous sessions: *I just had to make sure I was ready.* |

(continued)
Table 2 (continued)

<table>
<thead>
<tr>
<th>Operational Definition</th>
<th>Behavioral Example</th>
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<tr>
<td>Monitors performance (MP).</td>
<td>Independent, cued, or mediated</td>
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</table>
| Child indicates ongoing assessment of performance, effort, or strategy use during task practice. Behavior remains in the context of active task practice. | • Self-corrects action or performance on task: *Child checks work just printed, and self-corrects a letter error.*  
• Monitors own skill or performance, and progress on task: *Well, I guess I shouldn’t use one hand! (after failed catch attempt)*  
• Explains or compares strategies used in performance: *It’s easier to catch when I throw underhand because it goes higher.*  
Ineffective  
• Inaccurate assessment of performance, strategy use, or effort: *That time the ball went too far (when ball failed to reach the target).*  
• Attributes performance outcome to nature of equipment, inappropriate strategy, or irrelevant variable: *I do better when I can lean my head on my hand (during printing).* |
| Uses a strategy (US). | Independent, cued, or mediated |
| Applies a strategy during task performance to reach a goal. The monitoring of performance and application of a strategy often occur in a cyclical feedback pattern. | • Applies appropriate strategy: *Child lines up his bicycle and handlebars with his body as per a strategy developed in previous session.*  
• Changes strategy when previous one is deemed not to be effective: *Child switches to underhand toss after observing that the ball was bouncing back from the wall too quickly using overhand toss.*  
• Transfers strategies to a new situation appropriately: *This is the same for when I’m catching a football (child bends down in ‘ready’ position in preparation for catching a volleyball)*  
Ineffective  
• Applies inappropriate or ineffective strategy: *Child decides to stand far away from the therapist to catch ball, despite repeated misses.*  
• Continues to apply a strategy after it has ceased being useful or when it is not contributing to goal achievement: *Child repeats an ineffective throwing pattern and repeatedly suggests the same throwing strategy despite repeated failed trials.*  
(continued)
Table 2 (continued)

<table>
<thead>
<tr>
<th>Operational Definition</th>
<th>Behavioral Example</th>
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</thead>
<tbody>
<tr>
<td>Evaluates performance (EP).</td>
<td>Independent, cued, or mediated</td>
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</table>
| Following performance, child evaluates the quality of performance, goal attainment, level of difficulty, or the level of follow through on a proposed strategy or plan. Behaviors here are distinguishable from monitoring behaviors in that they occur once the child has separated him or herself from task practice. | • Offers self-evaluation using specific criteria: *That was the first time I touched the ground!*  
• Describes strategy used for task success or goal attainment: *I threw that one harder, so it made it all the way to you.*  
• Accurately assesses any difficulty experienced: *The birdie was too far over. I didn’t get to it fast enough.*  
• Evaluates the appropriateness or usefulness of a plan or strategy: *The new target was lower, so it was easier to hit.* |
| Ineffective | • Offers nonspecific, general evaluation of performance: *It was pretty good.*  
• Attributes performance success or failure to inappropriate, irrelevant, or invented variables: *The ball wanted to get away!*  
• Offers general or unclear plans to explain task success or failure: *I just got better!* |
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...distinguished through the use of modifiers describing behavioral quality. These modifiers reflect whether SR behavior was generated spontaneously by the child (independent regulation), was in response to a prompt (cued regulation) or active mediation (mediated regulation) from the therapist, or was ineffective or inappropriate to the task (ineffective regulation).

An assessment of intercoder agreement was carried out in which the first author and a second coder independently coded a preselected sample of videos totaling an amount equal to approximately 20% of the total video time to be analyzed. In light of the often-cited challenge in precisely defining what constitutes a codeable unit of behavior when working with socially-based categories that attribute meaning to the verbal and nonverbal behaviors of children (Bakeman & Gottman, 1997), intercoder agreement was assessed by calculating absolute agreement or the extent to which the observers agreed that the behavior observed constituted a unit of coding and assigned the same code to these agreed-upon units of coding. Using this method, agreement reached a respectable 0.850 using Cohen’s Kappa. Disagreements between coders were reviewed and discussed by both coders and, in most cases, agreement was reached. This discussion also contributed to the refinement of the coding scheme so that code definitions became more clear and precise.

Analysis

Analytical approach. The focus of data analysis was on the observation of SR behavior exhibited during video-recorded task learning and interview and self-reflection tasks. Observational analysis was carried out using the Observer software (Noldus, 2006) and an observational coding scheme for classifying the verbal and nonverbal behavior of children. This observational analysis was carried out using 4 of the 10 intervention sessions, representing initial and final assessment sessions (2&10) and early and late intervention sessions (4&8). For the purposes of comparing groups and change over time, data were grouped into an early (2&4) and late (8&10) observation.

Statistical analysis of coded behavior. Once coding was completed, code frequencies for each session and all children were transferred into a database in preparation for descriptive and statistical analysis. For the purposes of comparing behavior between groups, nonparametric statistical tests (Kruskal-Wallis and Mann-Whitney) were employed.

Using the coded data, the comparison of SR performance across and within groups was in part achieved through the calculation of a composite SR score. This score was calculated in two steps: First, a total score for each measured SR skill (goal setting, planning, etc.) was calculated by summing independent and cued regulation totals and subtracting mediated and ineffective totals. For example, to calculate a total frequency score for goal setting, the observed frequencies of independent and cued goal setting behavior were summed. From this, frequencies of mediated and ineffective goal setting behavior were subtracted. Following this, the composite scores for each SR skill (goal setting, planning, etc.) were summed together to arrive at a total composite regulation score for each child, which provided a single measure for a general overview of self-regulatory performance across groups. This calculation method meant that scores could be either positive or negative, depending on the child’s relative SR skill. It should be remembered,
however, that the composite nature of these scores merely indicates the relative level at which these behaviors were exhibited.\(^2\)

While the decision to designate independent regulation as “positive” and ineffective regulation as “negative” is based on the obvious qualitative distinction between these forms of regulation, the designation of cued and mediated regulation as positive and negative regulation, respectively, was based on observed differences in the manner in which these forms of regulation were exhibited by the children participating in the study. Namely, the response to cues with effective SR behavior (cued SR) was deemed a positive indicator of SR competence, where researcher cues in the form of questions such as *What are you going to do next?* did not significantly support any specific skill but rather prompted the demonstration of the child’s own SR skill. In contrast, mediated SR skill followed significantly higher levels of support and thus required less independence on the part of the child to generate a response. For example, the therapist might use a two-choice question or physical demonstration to scaffold the child’s SR behavior. In the case of supporting the child in the discovery of strategies for readying oneself for catching a ball, the therapist might ask, *Do you think it will be easier to catch with one or two hands?* or ask the child to compare his own body position with that demonstrated by the therapist. With this distinction in mind, the quantification of these forms of regulation on either side of the continuum of skill quality was deemed a valid technique in the development of a formula for calculating the composite regulation score.

**Results**

**Defining Groups According to Motor Performance Change**

Apart from the presence of co-occurring difficulties, children in the DCD and DCD+ groups did not differ significantly on variables of age (\(U = 10.500, Z = −0.849, p > .05\)), motor checklist score (\(U = 13.500, Z = −0.274, p > .05\)) or motor assessment score (\(U = 9.500, Z = −0.629, p > .05\)). As such, these groups were merged for subsequent consideration of the manner in which change in self-regulatory performance was related to any observed change in performance of selected motor tasks. Children were first grouped according to profiles describing the general nature of task performance change occurring over the sessions. As previously described, these profiles (Improved and Stable) were developed using task performance ratings on the PQRS Scale from the initial and final sessions.\(^3\)

To establish whether there were indicators at the beginning of the intervention to suggest that children might have been more or less likely to demonstrate improved task performance, demographic and assessment data for children across groups, illustrated in Table 3, were examined. The results indicate that the age and motor ability of children in the improved and stable groups were not significantly different from each other at the outset of the intervention. The types of tasks selected by children in each group were also similar, representing approximately equal distribution of fine and gross motor skills.
### Table 3  Comparison of Group Participants: Preparticipation Assessment Measures, Initial Self-Regulatory Behavior, and Selected Tasks

<table>
<thead>
<tr>
<th>Assessment Measure</th>
<th>Improved Group</th>
<th>Stable Group</th>
<th>U-, Z-, and p-values</th>
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<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
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<tr>
<td>Median (Range)</td>
<td>8.5 (1.75)</td>
<td>7.8 (1.58)</td>
<td>U = 8.000, Z = –0.874, p &gt; 0.05</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>8.25 (0.7)</td>
<td>7.88 (0.8)</td>
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</tr>
<tr>
<td><strong>MABC Checklist</strong>*</td>
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<tr>
<td>Median (Range)</td>
<td>58.5 (75.0)</td>
<td>45.5 (36.0)</td>
<td>U = 6.000, Z = –1.279, p &gt; 0.05</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>64.3 (26.1)</td>
<td>42.8 (15.9)</td>
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<tr>
<td><strong>MABC Test</strong></td>
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<td></td>
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<tr>
<td>Median (Range)</td>
<td>17.5 (14.5)</td>
<td>23.75 (15.5)</td>
<td>U = 9.000, Z = –0.642, p &gt; 0.05</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>18.2 (8.4)</td>
<td>22.5 (7.0)</td>
<td></td>
</tr>
<tr>
<td><strong>PQRS Score (Pre-test)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (Range)</td>
<td>2.0 (4.0)</td>
<td>3.5 (2.0)</td>
<td>U = 6.500, Z = –1.218, p &gt; 0.05</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>3.0 (1.7)</td>
<td>3.7 (1.0)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Initial SR</strong>* Behavior</th>
<th>Improved Group</th>
<th>Stable Group</th>
<th>U-, Z-, and p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent SR</td>
<td>3</td>
<td>3</td>
<td>U = 11.000, Z = –0.217, p &gt; 0.05</td>
</tr>
<tr>
<td>Cued SR</td>
<td>6.5</td>
<td>5</td>
<td>U = 11.000, Z = –0.215, p &gt; 0.05</td>
</tr>
<tr>
<td>Mediated SR</td>
<td>1.5</td>
<td>2.5</td>
<td>U = 11.000, Z = –0.215, p &gt; 0.05</td>
</tr>
<tr>
<td>Ineffective SR</td>
<td>6</td>
<td>5</td>
<td>U = 9.500, Z = –0.541, p &gt; 0.05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Selected Tasks</strong></th>
<th>Improved Group</th>
<th>Stable Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tasks</td>
<td>Bike riding, football catch/toss, skipping rope, Frisbee catch, basketball dribble, handwriting</td>
<td>Football catch, returning badminton serve, printing, baseball catch</td>
</tr>
</tbody>
</table>

*Note. *MABC = Movement Assessment Battery for Children (Henderson & Sugden, 1992)

**PQRS = Performance Quality Rating Scale (Miller et. al, 2001)

***SR = Self-regulatory, Self-regulation; Numbers represent median values in each category.*
The results of observational coding from Session 2, presented using median values for each code in Table 3, suggest that some preintervention group differences existed in the SR performance of children in the two groups; however, these differences were not significant.

On the whole, it seems that children in the improved and stable groups were exhibiting equal levels of SR and motor skill when they started the intervention. In contrast, the groups are readily distinguished by a clear and significant difference in task performance in the final session, where median post intervention PQRS scores were 4.0 (range: 2.0) and 6.0 (range: 4.0) for the improved and stable groups, respectively (U = 3.000, Z = −1.973, p < .05). The role of self-regulatory performance in mediating such a change, and the influence of intervention on this performance, will be explored through a presentation of the findings in the following sections.

Self-Regulatory Performance Over Time: A Comparison of Performance Groups

To address the research questions exploring the manner in which self-regulatory performance changed and the relation of this change to task performance, the self-regulatory performance of children in the improved and stable groups was examined. In Figure 2, median values of the composite self-regulation scores are presented for early and late sessions.

Immediately evident in this graph is the sharp contrast between the significant change observed in composite SR scores in the improved group (Z = −2.207, p < .05, r: −0.698) and the overall stability of SR skill in the stable group. As a result of these differing trajectories of change, the initial similarity in SR skill between groups is sharply contrasted by a clear and statistically significant group difference in later intervention sessions (U= 1.500, Z = −2.245, p < .05, r: −0.710).

![Figure 2](image)

**Figure 2** — Median values for composite self-regulation scores across learning sessions.
Examining Change in Performance Quality:
A Comparison Across Groups

A more in-depth consideration of SR performance change across groups was achieved by examining the level at which SR skill was performed. The graphs in Figure 3 illustrate median values for all exhibited levels of SR skill, as they were demonstrated in early and late sessions in the improved and stable groups.

In the improved group, there is an early dominance of cued forms of self-regulation (CSR) with comparatively low levels of mediated self-regulation (MSR); however, the second most frequent level of skill to emerge in early sessions was ineffective self-regulation (XSR). More promisingly, a decline in XSR over the course of the program, along with a statistically significant growth in independent self-regulation (ISR; \( Z = -2.023, p < .05, r: -0.640 \), point to the positive effect of the intervention. By late sessions, ISR is the dominant form of SR skill, followed by CSR. Ineffective forms of SR skill are considerably less frequent and SR under higher levels of therapist mediation (MSR) similarly declines in late sessions, a decline that reaches statistical significance (\( Z = -2.214, p < .05, r: -0.700 \)).

**Figure 3** — Comparison of median values of self-regulation levels across groups.
In contrast to the changes observed in the improved group, the observation of SR behavior in the stable group suggests a less promising result. While previously presented data indicated an overall stability in the SR skill of children in the stable group, examination of the data in Figure 3 further suggests that some subtle changes did occur. In early sessions, SR skill is predominantly observed in response to therapist support or is ineffective to the learning situation. By late sessions, ISR remains at this low level while all other forms of SR decline. None of the observed changes reach statistical significance in this group, however, confirming the lack of performance change observed in the composite SR score for this group.

**Discussion**

In general, this examination of self-regulatory performance revealed clear and significant differences in the manner in which children in improved and stable groups performed and developed SR skill over the course of intervention and, as such, begins to provide insight into the research questions posed earlier. In the first instance, the findings demonstrated a clear and significant improvement in overall SR performance among children in the improved group, as demonstrated through the composite SR score. This observed change in SR, in conjunction with improved task performance, might be said to reflect a positive response to the intervention. In contrast, the stability of SR performance among children in the stable group seems suggestive of an overall failure to acquire any self-regulatory ability over the course of the intervention.

The examination of children’s performance at each specific SR level allowed a more detailed look at the manner in which SR performance evolved over the course of the program. In the improved group, the combination of relatively high levels of cued SR and comparatively low levels of mediated SR might be argued to represent an early reliance on therapist prompting to engage in SR skill without the need for higher levels of therapist support. In other words, children in this group were generally able to respond to low levels of therapist prompting. On the other hand, relatively high levels of ineffective SR suggest that while children were able to demonstrate some evidence for effective SR skill, observed behavior was almost or equally as likely to be ineffective. This balance between effective and ineffective SR skill might be argued to be a significant factor contributing to the performance difficulties of children in this early stage of the intervention and is consistent with previous findings demonstrating the generally ineffective SR performance of children with motor difficulties (Lloyd et al., 2006; Martini et al., 2004). More promisingly, the decline in XSR and an increased ISR observed in late sessions suggests that through mediated learning using the GPDC strategy, children in this group were able to demonstrate increasingly independent and effective SR skill and reject skills or strategies identified as ineffective or inappropriate. The corresponding decline in CSR and MSR in late sessions might similarly be argued to reflect an improvement in SR competence in which fewer instances of high levels of therapist support were needed as children increasingly engaged in independent SR skill. Together, these results are consistent with Zimmerman’s (2000) four-stage model of SR development, where initially higher levels of supported self-regulation (during observation and emulation stages) are gradually replaced by increasingly
independent forms of self-control and self-regulation. In contrast to the overall change in SR performance in the improved group, the examination of each SR level in the stable group revealed little change. More specifically, children in the stable group appeared less likely to exhibit the decline in XSR and growth in ISR so clearly observed in the improver group. In addition, the more frequent and more stable use of various forms of mediator support in this group (as demonstrated through cued and mediated forms of self-regulatory behavior) also suggests that any evidence for effective self-regulation generally occurred under the “scaffolded” support of a therapist. In contrast, children in the improved group were less likely to rely on external support to demonstrate effective self-regulatory behavior and, when they did so, the support provided was predominantly in the form of simple cues or prompts.

On the whole, the results seem to demonstrate that as motor task performance among children in the improved group improved, so did performance of SR skill. In contrast, the relatively unchanging task performance of children in the stable group was mirrored by similarly stable SR performance. These findings are a promising indication of the positive effect of the CO-OP approach on self-regulated motor performance, where improvement in task performance appears to be related to parallel development of self-regulatory skill. This link between improved performance and self-regulatory competence is consistent with literature examining intervention directed toward developing SR skill for improving performance in academic domains (Dignath, Buettner, & Langfeldt, 2008; Hattie, Biggs, & Purdie, 1996) and among children of varying learning abilities (Fuchs et al., 2003). Because this was not the case for all children participating in the intervention program, however, some interesting questions are raised concerning individual differences in the manner in which children responded to the intervention. It might be argued that, since improved SR and task performance was observed to co-occur among children in the improved group and the failure to exhibit significant improvement in self-regulatory competence co-occurred with a failure to exhibit significant change in task performance among children in the stable group, SR may be an important mediating factor in improved motor performance. This result must be interpreted with some caution, however, in light of the likely influence of other individual differences, such as difficulties with motivational regulation, limited repertoire of domain knowledge, or co-occurring difficulties in learning and/or attention, on motor and SR performance change (Martini & Shore, 2008). Furthermore, the nature of the specific skills selected by each child might have additionally influenced the manner in which SR skills were exhibited and evolved during the program. Arguably, different types of motor-based tasks (for example, discrete vs. continuous, gross vs. fine motor, simple vs. complex) elicit the need for differing degrees and forms of SR skill and, as such, were potentially a factor influencing the manner in which SR was exhibited by the children participating in the current study. While the findings provide promising and positive evidence in support of cognitively-oriented approaches to intervention with children with DCD, they alone cannot be used to suggest that improved SR skill is responsible for observed change in task performance and additionally raise questions concerning the manner in which such approaches might support such development and the various factors mediating children’s motor and SR performance during skill acquisition.
Conclusion

The aim of this study was to examine the manner in which a cognitively-oriented intervention program for children with motor performance difficulties serves to promote self-regulatory and metacognitive skill for effective motor skill acquisition among children with DCD. Arguably, the development of such skill has the potential to enable children to more effectively direct, monitor, and evaluate their own learning of specific motor tasks. In the current study, the in-depth observation of children participating in CO-OP suggested a link between improved task performance and improved self-regulatory performance. While it was argued that individually-specific variables such as motivational control, knowledge repertoire, or co-occurring difficulties in learning and/or attention have additionally influenced the degree to which children demonstrated task and SR performance change, it seems reasonable to suggest that self-regulatory competence is an important mediating factor in improving task performance and that cognitively-oriented intervention approaches such as CO-OP serve to facilitate the development of such self-regulatory skill through verbally-mediated task learning using a problem-solving strategy.

While the implications of these findings are diverse, the current study contains a number of limitations that must be taken into consideration when discussing such implications. Arguably, these limitations stem primarily from the degree to which this study can be generalized, where such generalization was limited by the purposive sampling strategy and small sample size used in conducting group comparisons. As such, generalizations based on group differences revealed in this study should be made tentatively.

Together, the findings and limitations of the current study suggest several implications for clinical practice and future research. It seems clear that cognitively-oriented programs such as CO-OP, which aim to provide children with the cognitive and metacognitive skills necessary to successfully acquire and perform motor-based tasks, are supported by the findings. By promoting SR development and enabling the application of SR ability to motor skill acquisition, such approaches assist children in overcoming performance difficulties on tasks relevant and important to their everyday life and provide them with the necessary cognitive and metacognitive tools with which to successfully find solutions to performance problems. Beyond an intervention context, this study additionally provides support for the application of principles of SR theory in other motor learning settings, such as physical education and sports programs. Indeed, it would seem likely that implementing strategies for promoting children’s SR competence, such as providing opportunities for goal-setting, self-monitoring, and strategy development, will assist children of all abilities to benefit from the development of effective SR ability for learning and mastering new motor skills.

The present research has only begun to explore the role of cognitively-oriented intervention programs in supporting the development of self-regulatory competence and the manner in which this development addresses motor performance difficulties. Future research might be most beneficially directed toward a more specific examination of the topics arising from the findings, including the differences in SR performance among children with DCD who present with and without co-occurring difficulties in learning or attention or whether improvement in SR performance during intervention is generalized to improved motor and task performance outside
the intervention setting. Future research should additionally be conducted using a range of quantitative and qualitative methodologies and larger samples. More specifically, in addition to the use of behavioral observation and numeric coding techniques presented here, future studies might also employ strategies to assess self-regulation using a more qualitative approach by employing thematic observation to examine the manner in which SR behavior is observed in the dynamic context of real-world and real-time learning situations. In addition, there is a need for future research to explore individual differences and examine more systematically other potential factors (for example, motivation, knowledge level, task selected) that may have made the intervention program more effective with some children than with others. Ongoing multimethod research might additionally serve to strengthen the explanatory power of some of the hypotheses arising from the findings in the present research.

While this study has provided new insight into the manner in which cognitively-oriented intervention programs address the difficulties of children with DCD through the development of self-regulatory competence, our understanding of the manner in which this process occurs, and indeed how the motor and self-regulatory performance of children with DCD is related, is only at the beginning of such lines of inquiry. It is hoped that the findings borne from this study will prompt further examination into the complex and dynamic nature of self-regulated motor performance and the manner in which SR competence develops among children with DCD. It is the belief of the authors that, in doing so, we can further our understanding of the difficulties experienced by children with DCD and most effectively meet the needs of children and families.

**End Notes**

1 The use of this cut-off to distinguish improved and stable profiles was based on an overall examination of score patterns across all participants and a clustering of cases based on degree of change. It should also be noted that in the stable group, any change that did occur was observed in the positive direction only.

2 So, for example, a score of −2 indicates that the child exhibited slightly more mediated or ineffective SR skill, while a score of 2 suggests that independent and cued forms of regulation were more common. In addition, while a score of zero might suggest that no evidence of the behavior occurred at all, it is in fact more likely that the child exhibited equal levels of both “positive” and “negative” forms of regulation.

3 Using this criteria, the distribution of DCD and DCD+ children in the improved and stable groups was equal, with three children from each group in the improved group and two children from each group in the stable group. While a comparison of SR performance between children with and without co-occurring difficulties would certainly be of interest to understanding the nature of SR competence among children with DCD, this was deemed beyond the scope of the current study due to the small number of participants.

**References**


