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Examining Change in Metacognitive Knowledge and Metacognitive Control During Motor Learning: What Can be Learned by Combining Methodological Approaches?

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Abstract

Growing recognition of the importance of understanding metacognitive behaviour as it occurs in everyday learning situations has prompted an expansion of the methodological approaches used to examine metacognition. This becomes especially pertinent when examining the process of metacognitive change, where 'on-line' observational approaches able to capture metacognitive performance as it occurs during socially-mediated learning are being increasingly applied. This study applied a mixed methods approach to examine children's metacognitive performance as it was exhibited during participation in an intervention program aimed at addressing motor performance difficulties. Participants in the study were ten 7-9 year old children with developmental coordination disorder (DCD), a condition characterized by poor motor coordination and difficulty acquiring motor-based tasks. All participants engaged in a 10-session program in which children were taught to use a problem-solving strategy for addressing motor performance difficulties. To examine children's metacognitive performance, sessions were video-taped and subsequently analysed using a quantitative observational coding method and an in-depth qualitative review of therapist-child interactions. This allowed for a fine-grained analysis of children's demonstration of metacognitive knowledge and control and how such performance evolved over the course of the program. Of particular interest was the finding that while children were often able to express task-specific knowledge, they failed to apply this knowledge during practice. Conversely, children were often able to demonstrate performance-based evidence for metacognitive control but were not able to make conscious reports of such skill following practice. This finding is consistent with models of metacognitive development which suggest that the emergence of performance-based metacognitive skills precede the ability for the conscious expression of metacognitive awareness and knowledge. Furthermore, it supports the use of multiple methods for examining metacognitive performance and change in the context of a meaningful learning situation.

Keywords: metacognition, motor learning, multiple methods, developmental coordination disorder

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Introduction

Growing recognition of the importance of understanding metacognitive behaviour as it occurs in everyday learning situations has prompted an expansion of the methodological approaches used to examine metacognition. This becomes especially pertinent when examining the process of metacognitive change, where 'on-line' observational approaches able to capture metacognitive performance as it occurs during socially-mediated learning are being increasingly applied. For such research to be ecologically valid and practically relevant, it needs to attend to the role of context in shaping metacognitive development, to be conducted in naturalistic settings and to reflect individuals acting within social contexts (Perry, 2002). Arguably, the application of multiple methods allows for the exploration of metacognitive performance as a process that unfolds over time and across tasks and in the context of various social influences. A mixed methods approach has also been advocated as a tool for better examining metacognition in both its conscious, stateable and implicit, performance-based forms, where prospective or retrospective self-reports are examined alongside concurrent observation of metacognitive performance in a learning situation (Veenman, 2005; Winne & Perry, 2000). The present research applied a mixed methods approach to examine children's metacognitive performance as it was exhibited during participation in an intervention program for children with developmental coordination disorder (DCD). As a relatively under-researched area in the field of metacognition, this small-scale investigation took an exploratory approach with the aim of gaining early insight into the role of metacognition in motor learning and in the difficulties of children with DCD.

Exploring Metacognition Amongst Children with Developmental Coordination Disorder: Why is this Important?

Developmental coordination disorder (DCD) is a chronic condition characterized by a marked impairment in motor coordination. Prevalence rates have been most recently reported at approximately 2 percent of the school population, with a higher incidence amongst boys than girls (Lingham, Hunt, Golding, Jongmans, & Emond, 2009; Sugden, Kirby, & Dunford, 2008). Children with DCD experience difficulty performing everyday motor tasks (Chambers, Sugden, & Sinani, 2005) and, while many 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 (Missiuna, 1999; Sugden et al., 2008). If left unaddressed, DCD has been demonstrated to have many negative long-term behavioural and socio-emotional consequences such as poor self-confidence, limited social skills, and decreased motivation for physical activity (Chambers et al., 2005; Cousins & Smyth, 2003; Polatajko, 1999; Sugden & Wright, 1998).

The most recent approaches to intervention for working with children with DCD aim to assist children in mastering the functional activities that they need to perform in everyday contexts (Sugden, 2007; Wilson, 2005). Within this framework, several approaches have emerged which, through a blending of cognitive-learning and motor control theories, involve working on problem-solving strategies with children during skill acquisition and assisting children in becoming more aware of the cognitive processes and strategies used to guide motor performance (Missiuna, Malloy-Miller, & Mandich, 1997). One such approach, the Cognitive Orientation to daily Occupational Performance (CO-OP) (Polatajko & Mandich, 2004) 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 the metacognitive skills of goal setting, planning, self-monitoring, and evaluation by encouraging 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 strategies on his or her own.

This new generation of intervention approaches has framed DCD as a specific learning difficulty and has prompted the hypothesis that children with DCD poorly self-regulate their own motor performance. Bouffard (1990) has argued that the difficulties experienced by children with DCD might, in part, be due to a deficiency in metacognitive processes such as monitoring and evaluating performance and applying appropriate strategies. Similarly, Missiuna et al. (1997) have suggested that children with DCD possess a smaller repertoire of cognitive and metacognitive strategies 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. It has been further argued, therefore, that children with DCD need support in developing problem-solving and self-regulatory skills for addressing their motor performance difficulties (Mandich, Polatajko, Missiuna, & Miller, 2001). This became a central principle guiding the development of the intervention approaches discussed above.

Despite the promising potential offered by this new generation of intervention approaches (Polatajko & Mandich, 2004), many of these underlying assumptions have yet to be fully examined. In their support for the application of theoretical frameworks from the self-regulation (SR) and metacognition literature to the study of DCD, Lloyd, Reid, and Bouffard (2006) stress that further research is first necessary to gain a clearer picture of self-regulation and metacognition in this population before embarking too quickly on the development of further intervention strategies aimed at supporting self-regulated motor performance.

Understanding Metacognition in the Motor Domain

To date, there exists limited empirical investigation aimed at exploring the role of metacognition in the context of actual motor performance and explaining the processes through which metacognitive competence is acquired and used by children with and without motor difficulties (Martini, Wall, & Shore, 2004). Thus far, the majority of metacognition research conducted in the motor domain has applied self-regulated learning (SRL) models to examine the differences between expert and novice performers in constructed motor practice situations. On the whole, this research has demonstrated clear differences in self-regulatory (SR) competence between motor performers of varying levels of expertise and has provided substantial evidence for the interacting relationship between motor performance level and SR competence (Cleary & Zimmerman, 2001; Kitsantas & Zimmerman, 2002). For example, higher levels of skill performance were demonstrated to be correlated with more effective forms of goal-setting and self-monitoring and higher levels of intrinsic interest (Kolovelonis, Goudas, & Dermitzaki, 2010; Zimmerman & Kitsantas, 1997).

Research examining the role of metacognition in the motor difficulties of children with DCD has similarly begun to shed light on the metacognitive and self-regulatory competence of this population. In general, children with motor difficulties have been demonstrated to possess less detailed and interconnected knowledge about motor tasks than children without DCD, to focus on irrelevant information when identifying and addressing performance problems, to often select inappropriate performance strategies, and to be less likely to spontaneously plan, monitor and evaluate their performance (Martini & Shore, 2008). In an investigation of metacognitive processes underlying motor performance in children with and without DCD, Martini et al. (2004) found that, while both groups of children exhibited similar amounts of cognitive and metacognitive verbalizations during practice of a novel motor task, the *quality* of these verbalizations was different. Amongst children with DCD, there were significantly more frequent verbalizations of inappropriate, inaccurate or irrelevant statements related to planning and evaluation activities. This difference in SR quality was similarly demonstrated by Lloyd et al. (2006), where verbalized planning and evaluative statements amongst children with DCD were less specific and more frequently representative of inaccurate task knowledge.

Together, this emerging body of research provides growing evidence for a relationship between SR and metacognitive competence and success in motor performance. While this early work has offered interesting insight into how different types of motor performers (experts, novices, children with motor difficulties) use and apply self-regulatory or metacognitive skill, studies thus far have predominantly applied a quantitative approach to examine metacognition in a controlled performance situation, where participants are given a simple motor task devised by the researcher and metacognitive behaviour is counted and compared across groups. The metacognitive performance of children engaged in motor learning activity has not yet been fully examined in the context of meaningful, socially-mediated motor practice. Similarly, there is nearly no research examining the manner in which a cognitively-oriented intervention strategy might facilitate metacognitive performance amongst children with DCD nor how this might be related to motor skill acquisition. In a recent study examining the effect of the CO-OP approach on the self-regulatory performance of children with DCD, Sangster Jokić, Polatajko, and Whitebread (2013) demonstrated that SR performance improved amongst children who similarly demonstrated improved motor performance, prompting the suggestion that self-regulation is an important mediator in motor skill acquisition for this group of children. However, many questions remain regarding the process through which the development of SR and metacognitive competence evolves in meaningful motor learning situations and the precise role of metacognition in the difficulties of children with DCD. In order to address such questions, it is first necessary to establish a clear definition of metacognition and the manner through which it might be measured.

Understanding Metacognition: Knowledge, Performance and the Implicit-Conscious Debate

Early theoretical models have depicted metacognition as a multifaceted construct consisting of metacognitive experience (monitoring of mental processes and reflection on such processes), metacognitive control (regulation of mental processes), and metacognitive knowledge (knowledge about one's own cognitive processes) (Brown, 1987; Flavell, 1979). The division of metacognition into these components continues to be a fundamental idea in the empirical and theoretical literature and highlights an issue currently receiving significant attention: the distinction between the learner's repertoire of relevant metacognitive knowledge that is explicitly and declaratively available to the learner and implicit metacognitive skill that can more readily be observed through 'on-line' self-regulatory or metacognitive control.

Indeed, current understanding of metacognitive processes recognizes that both implicit, performance-based metacognitive skill and conscious metacognitive knowledge are equally critical to overall metacognitive competence (Whitebread & Pino Pasternak, 2010). This more inclusive definition of metacognition is supported by research suggesting that metacognitive knowledge and performance-based metacognitive skill exhibit differing developmental trajectories. Namely, research examining metacognition in young children has suggested that performance-based evidence for metacognitive skill (such as monitoring and control functions) emerge earlier than what can be observed in the conscious, explicit articulation of metacognitive knowledge and understanding, with even very young children exhibiting sophisticated, but implicit, metacognitive processing (DeLoache & Brown, 1987; Whitebread, Bingham, Grau, Pino Pasternak, & Sangster, 2007). It has been further argued that, in early childhood, the relationship between explicit knowledge and metacognitive performance is not necessarily a very strong one (Schneider & Bjorklund, 1998; Whitebread & Pino Pasternak, 2010).

Clearly, current evidence and theoretical thought supports the view that implicit metacognitive ability is critical to overall metacognitive competence. However, the role of conscious processes and explicit knowledge are not discounted entirely in this modern conceptualisation of metacognition. In conjunction with the recognition that, in early childhood, on-line monitoring and control are more directly related to performance than general metacognitive knowledge, it has been further argued that the inter-connections between knowledge, strategic behaviour and task performance strengthen with age and experience (Schneider, 1985). This emerging relationship between knowledge and performance is reflected in the principle of *reciprocal mediation* developed by Pressley, Borkowski, and O'Sullivan (1985), which purports that early strategic behaviour prompts an emerging recognition of strategy usefulness which in turn leads to further use of the strategy which, finally, contributes to the development of knowledge about the strategy's utility in a process through which strategy use and knowledge become increasingly intertwined. This gradually emerging link between knowledge and performance has similarly been demonstrated in research demonstrating that one's knowledge repertoire influences both performance of a task and the level of self-regulation demonstrated in performance (Brown, Bransford, Ferrara, & Campione, 1983).

Based on this growing body of work, it seems reasonable to argue that any examination of metacognition should consider both explicit, articulated forms of metacognitive knowledge and implicit, performance-based evidence of metacognitive control. This was an underlying aim of the present examination of metacognitive competence amongst children with DCD. While recent research has begun to shed early insight into the role played by metacognition in the difficulties of children with DCD and the manner in which a cognitively-oriented intervention program might facilitate metacognitive performance, many questions remain unanswered. Arguably, an exploration of the process through which explicit and implicit forms of metacognition are exhibited and evolve during meaningful, everyday motor skill acquisition and in the context of a socially-mediated intervention program requires a dynamic, holistic approach applying a number of different research methods.

Using such an approach, the research from which this paper is derived aimed to examine the self-regulatory and metacognitive performance of children with DCD and to determine whether, and in what way, participation in a cognitively-oriented intervention program (CO-OP) influenced metacognitive performance. In this paper, findings arising from qualitative and quantitative observational analyses will be explored in order to answer two of the research questions developed as part of this larger research project:

- How are implicit and conscious forms of metacognition exhibited by children with DCD?
- In what way do these forms of metacognition evolve over the course of a cognitively-oriented intervention program?

Method

Prior to embarking on the data collection phase of the research, the project received 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.

Participants

Research participants were recruited from primary schools and occupational therapy practices in a large city 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 was established through formal motor assessment using the Movement-ABC test (Henderson & Sugden, 1992)[1], 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 and the consequent disruption to academic achievement or activities of daily living was obtained through verbal reports from key individuals in the child's life (teacher, parents, coach, etc.). Due to the study's high reliance on verbal reports, children for whom a learning, 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

[1] The MABC test is a standardized motor skill assessment designed to measure a child's motor skill level, as compared to other children of the same age. It includes items such as tracing around a flower pattern, flipping coins over as fast as possible, balancing on one foot, and bouncing and catching a tennis ball.

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.

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 children attended public school in mainstream classrooms. 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 all participating children.

Table 1. *Summary of Demographic and Assessment Measures*

Variable	Participants
N	10
Boy:Girl Ratio	9:1
Age	*M*=8.1 *SD*=0.7
MABC Test Score[a]	*M*=19.1 *SD*=6.7
Tasks selected	Bike riding, Frisbee catch Handwriting, Skipping rope Football catch, Badminton serve Baseball catch, Volleyball serve Basketball shot, Floor hockey

Note. [a]Higher raw scores indicate greater difficulties. For children aged 6-12 years, scores of 13.5 or above are equivalent to performance norms below the 5th percentile.

In the analysis phase, quantitative behavioural observation was conducted with all 10 participants. This was followed by a qualitative analysis phase carried out with four individual cases, one of which is reported in the present paper. This phase of the study is described further in the Analysis section.

Procedure

Each child participated in a series of 10 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. These sessions were generally structured according to the CO-OP approach (Polatajko & Mandich, 2004) described earlier. Sessions were carried out by the primary researcher, an occupational therapist with extensive training and experience in implementing the CO-OP program.

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, 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 mediated 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 GPDC or task-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 GPDC strategy or providing instructions for a reflection task), verbal protocols were developed to ensure that these instructions were consistent across children.

Analysis

Once all children had completed the program, an in-depth observational analysis of video-recorded sessions was carried out. All sessions were video-recorded in their entirety, which allowed for direct observation of metacognitive behaviour during task performance, mediated practice and self-reflection tasks.

Quantitative Observational Analysis was carried out using the Observer software and an observational coding scheme for reviewing, recording and classifying the verbal and non-verbal behaviour of children.

The structure of the coding scheme was developed using socio-cognitive models of self-regulation (Schunk, 2001; Zimmerman, 2000) and early theoretical models of metacognition (Brown, 1987; Flavell, 1979). Further detail in developing and refining code definitions was derived from coding schemes developed in previous research examining metacognition (Pino Pasternak, 2008; Whitebread et al., 2007) and previous research examining cognitive and metacognitive strategy use during motor skill acquisition (Mandich, 1997; Sangster, 2005; Sangster, Beninger, Polatajko, & Mandich, 2005). Using this existing theoretical and empirical work as a conceptual basis, the analytical framework used for observing metacognitive performance in the present study distinguished between the explicit expression of task and metacognitive knowledge and 'on-line' metacognitive performance or self-regulatory skill. Based on the work of Flavell (1987), the former concept was defined as task-specific and general knowledge of factors or variables likely to influence learning. The observation of on-line metacognitive control applied a definition from the SRL literature, which defines self-regulatory (or metacognitive) skill as any specific activity indicative of an attempt to direct, control or regulate cognitive activity or motor performance. It includes behaviours such as goal setting, planning, self-monitoring, using a performance strategy and self-evaluation (Zimmerman, 2000). In addition, codes were built up through a review of the videos from the current research and the application of the emerging coding scheme to the data itself. This grounded, theory-driven process, in which the general structure of the coding scheme was constructed using existing theory and the development and refinement of codes and code definitions was carried out through a continuous review and re-application of the coding scheme to the data itself, assured overall validity.

Two overarching codes were developed in order to observe the manner in which children demonstrated metacognitive competence over the course of the program: expressed task/metacognitive knowledge (EK) and metacognitive skill (MC). The operational definitions developed for these codes, as well as sample excerpts from the data, are presented in Table 2.

Table 2. *Operational Definitions and Behavioural Examples for Quantitative Observational Codes*

Code	Operational Definition	Behavioural Example
Expressed Knowledge (EK)	Utterances indicative of knowledge of self as a learner, task or environment variables influencing performance, a strategy for performing a specific task, or a metacognitive process and how it contributes to one’s own learning or skill acquisition.	One thing that helps me is learning the same thing over and over, or when you tell me what I already know. I know a good way for printing the letter 'R' (*then explains sequence*)
Metacognitive Skill (MC)	Child verbalizes or demonstrates a goal for task practice; describes an action necessary to meet a goal; assesses performance, effort, or strategy use; applies a strategy during task performance; evaluates the quality of performance, goal attainment, or the level of follow through on a proposed strategy or plan.	I’m trying to hit the volleyball up and straight…like in an arc. I need to put my hands out to get ready to catch. It was tricky for me to keep hold of the ball...it went through my fingers.

An assessment of inter-coder agreement was carried out in which the primary researcher and a second coder independently coded a pre-selected sample of videos totalling an amount equal to approximately 20 percent of the total video time to be analysed. In light of the often-cited challenge in precisely defining what constitutes a codeable unit of behaviour when working with socially-based categories (Bakeman & Gottman, 1997), inter-coder agreement was assessed by calculating absolute agreement, or the extent to which the observers agreed that the behaviour 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 0.85 using Cohen's Kappa.

Due to the large amount of video data accumulated over the course of the program and the time-intensive process of observational coding, coding was carried out using four program sessions (2, 4, 8 and 10) for each participant. In order to compare metacognitive performance over the course of the program, coded data was grouped together into early (sessions 2 and 4) and late (sessions 8 and 10) observations.

Once coding was completed, code frequencies for each session and all children were transferred into a database in preparation for descriptive and statistical analysis. The size of the sample and the nature of this phase of the analysis dictated the use of non-parametric statistics. As such, for the purposes of comparing behaviour across sessions, a Wilcoxon test was employed. While the methodological design allowed for the use of this statistical technique, it should be noted that the number of cases with which it is being applied places a limitation on the extent to which statistical results can be interpreted and generalised.

Qualitative Observational Analysis - while use of the observational coding scheme and subsequent numerical analysis offered a quantitative depiction of the nature of children's metacognitive behaviour across sessions, it did not fully allow for subtle variations in observed metacognition across children to be captured nor fully take into consideration the contextual nature of metacognitive behaviour and the process through which metacognitive performance and knowledge changed over time. As such, the inclusion of a qualitative analysis phase was deemed critical for fully exploring patterns and sequences of behaviour as they occurred in the context of the therapist-child interaction during task practice.

This phase of analysis was preceded by the development of a thematic framework for describing the behaviour of children in the context of socially-mediated task practice. Here, thematic categories were derived in a gradual, grounded fashion using themes emerging from the results of quantitative analysis, along with issues and ideas arising from previous research. Specifically, qualitative observations made during the process of data collection, a review of video-recorded sessions and notes recorded during observational coding, and the results of quantitative analysis were used collectively in order to create a list of themes and sub-themes for qualitative exploration. This list was organized into a structured framework of thematic categories, which is presented in Table 3.

Table 3. *Qualitative Thematic Coding Framework*

Thematic Category	Behavioural Observation	Behavioural Description
Metacognitive Control (MC)	Type of metacognitive control (MC-t)	Observation of a specific type of metacognitive control (goal setting, monitoring, etc.)
	Level of metacognitive control (MC-l)	Observation of a specific level of metacognitive control (independent, cued, etc.)
	Change in metacognitive skill (MC-c)	Indication of changing or emerging metacognitive skill (improved type or quality)
Expression of Knowledge (KNOW)	Level of knowledge expressed (KNOW-l)	Observation of high/low quality of expressed knowledge (accuracy, depth, relevance, etc.)
	Type of knowledge expressed (KNOW-t)	Observation of specific type of knowledge (goal, strategy, plan, person/task/environment variable, etc.)
	Ineffective knowledge representation (KNOW-x)	Expression of knowledge that is inaccurate, inappropriate or ineffective for task practice
	Knowledge-performance dissociation (KNOW-d)	Child expresses knowledge in reflection but fails to apply this knowledge during on-task practice or exhibits metacognitive skill on task but does not demonstrate an ability to consciously report it
	Change in knowledge (KNOW-c)	Indication of new knowledge or ability to report on metacognitive or self-regulatory behaviour (metacognitive reflection)
Interaction Between Variables	Influence of knowledge representation on child performance (KNOW-PERF)	Instances in which especially rich or poor knowledge representation has an influence on child's metacognitive and/or task performance

This framework was applied to an in-depth review of data derived from all 10 program sessions for four individual cases. This data included video-recorded sessions, reflection logs, and the extensive field notes taken by the researcher during data collection. Individual cases were selected using a theoretical sampling strategy (Patton, 2002) after the bulk of quantitative analysis had been completed. Here, the results of this first analytical phase, along with the research questions and theoretical framework under which this research was being conducted, were taken into consideration in selecting four individual cases that would most effectively explore findings revealed through quantitative analysis. For comparative purposes, the individual cases were selected so any relevant variables, including age and motor assessment scores, remained somewhat similar across groups.

During analysis, events illustrative of the various thematic categories in the analytical framework were first flagged and organized according to each category. Second, descriptive reports for each case were developed in which findings relevant to each category were summarized and interpreted. These reports were structured according to the research program itself, examining analytical themes in introductory sessions, during early and late practice, and in the final session. For the purposes of the present paper, findings derived from a single case study will be presented and discussed in relation to the quantitative findings.

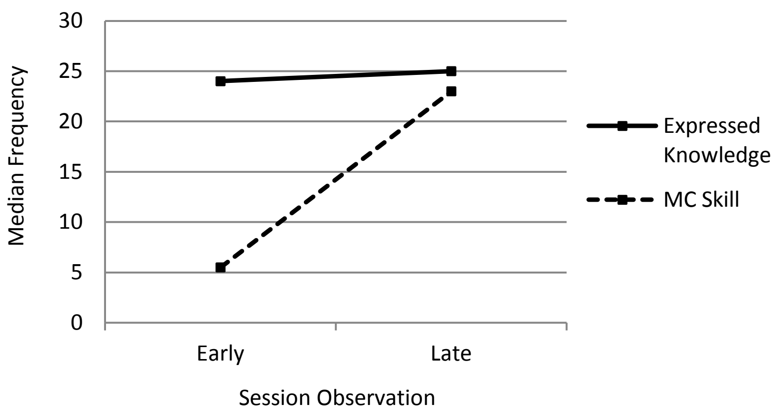
Results

The examination of the metacognitive performance of all children will be presented as it unfolded during analysis itself: first, through a quantitative comparison of metacognitive behaviour observed across sessions and, second, through a consideration of qualitative data using an individual case study.

Quantitative Comparison of Metacognitive Performance

Figure 1 presents the median frequencies of observed instances of expressed knowledge (EK) and metacognitive skill (MC) for the whole group. As described previously, these frequencies were measured across four sessions and subsequently grouped into early (sessions 2 and 4) and late (sessions 8 and 10) observations.

Figure 1. *Observed Frequency of Expressed Knowledge and Metacognitive Skill (Whole Group)*



Immediately evident from this figure is the observation that, in early sessions, children are exhibiting EK and MC skill at very different frequencies. Arguably, this difference is suggestive of an often cited observation concerning the motor learning difficulties experienced by children with DCD, where children are able to express a reasonably well-developed repertoire of knowledge relevant to learning and performing their selected task but fail to effectively apply this knowledge to actual task practice (Martini & Shore, 2008).

The second finding of note in this figure is the striking difference in the manner in which these differing components of metacognitive performance change across sessions. In the case of expressed knowledge, very little change is observed. In fact, while there appears to be some fluctuation in the frequency of EK, these changes are not significant. As such, it might be argued that children's expression of knowledge remained relatively unchanged over the course of the program. The picture is quite different in the case of MC skill, where there is a clear and significant (z=-2.207, p<.05) increase in observed frequency.

This finding is of interest in light of the arguments put forward in the introductory section, where it was suggested that conscious and implicit forms of metacognition are equally important contributors to overall metacognitive performance but may serve different functions at various times during the learning process. Arguably, the findings presented here offer supporting evidence to suggest that these two elements are operating differently during motor learning and are perhaps following differing trajectories during the development of metacognitive competence. This apparent distinction between the development of performance-based metacognitive skill and the explicit expression of task or metacognitive knowledge, and the manner in which they were exhibited over time and in the context of a socially-mediated learning situation, was explored further using a second, complementary method. This in-depth qualitative analysis will be presented in the following section.

Understanding the Process: Observing Metacognition Through Qualitative Case Study

In this section, the evolution of metacognitive performance during participation in the CO-OP program will be explored through the qualitative analysis stemming from an individual case study.

Brendan, an 8-year old boy with DCD, was originally referred to occupational therapy due to the difficulties he experienced learning and performing motor based tasks such as using scissors, printing neatly, and participating in sports. A formal motor assessment revealed moderate to severe motor difficulties. Brendan's parents reported that he had difficulty managing simple tasks such as tying shoelaces and experienced significant frustration when he was unable to keep up with peers in sport and play situations. In his first CO-OP session, Brendan selected throwing and catching a football as the task he wished to work on over the course of the program. Initial observation revealed motor performance to be clumsy and effortful with frequent errors (e.g., missed catches, poor control of the ball). However, over the course of the program, Brendan's task performance improved and he demonstrated growing confidence and skill during toss and catch practice.

Qualitative observation of metacognitive performance using the thematic framework revealed that, in early sessions, Brendan was able to articulate some basic knowledge concerning the task and his own performance. Specifically, he was able to identify areas of difficulty and several variables that influenced performance success:

Therapist (T): What's tricky for you in football?

Brendan (B): Mostly, it's my speed and my catching...it's usually not a complete pass. I just drop the ball.

T: I see. And why do you think catching is difficult?

B: I'm better at catching with a normal ball than a football. It's easier to hold onto. (Session 1)

Similarly, task knowledge was exhibited through the identification of strategies previously applied to learning:

B: I gotta remember where to go so I will be open. I see where my friend is, and if he's open, I just pass it. (Session 1)

B: I have to remember to think about putting my hands like this (gestures ready position). (Session 1)

However, while pre-existing task knowledge did appear to exist, Brendan was often observed to experience difficulty transferring this articulated knowledge to actual performance. In other words, while Brendan was able to verbalize a reasonable repertoire of relevant information about his chosen task, he seemed to lack the metacognitive or self-regulatory skill to use this task knowledge in order to engage in effective task practice. This was evident in learning sessions characterized by little evidence for any effective metacognitive control of learning. For example, Brendan often struggled to effectively monitor his performance or identify performance errors, often repeating practice trials using the same ineffective strategies with little awareness of the reasons for failed performance:

Brendan (in response to repeated missed football tosses towards a target): I just don't know why it keeps missing! (Session 2)

Similarly, Brendan exhibited ineffective forms of self-monitoring and self-evaluation behaviour, often providing very general observations not tied to specific aspects of performance:

T: How do you think you did in catching today?

B: I did pretty good.

T: OK. And what kinds of things have you tried to practice before to get better at catching?

B: Not sure. Usually my skill just improves. (Session 2)

This failure to exhibit effective monitoring or evaluation skill subsequently influenced the efficacy with which Brendan applied strategies to performance, where a failure to identify specific strategies contributing to performance outcomes resulted in a limited ability to identify and apply such strategies to addressing performance difficulties:

When attempting to throw the football to a target, Brendan frequently fails to look at the target when throwing or to adjust the force of his throw on subsequent trials. With repeated trials, this error is repeated and Brendan exhibits no awareness of why it is difficult for him to successfully catch the ball:

T: Why is it tricky to hit the target?

B: Not sure. Maybe I'm just not throwing it straight. (Session 2)

Similarly, Brendan demonstrated little active thought about how developed strategies were used to reach his goal and offered limited responses to questions probing his perspectives on the sessions' practice:

T: So, how do you think you did today?

B: Good.

T: Could you have done better?

B: Kind of.

T: What would be different?

B: Not sure. (Brendan, Session 4)

This analysis suggests that, while Brendan was able to express some task-based knowledge in early sessions, he struggled to apply this knowledge to effectively monitor or regulate his own learning, a finding consistent with the quantitative results described previously. However, as sessions progressed, Brendan was observed to more effectively direct and monitor his own learning. By late sessions, he makes increasingly more independent and effective use of metacognitive skills and applies this new skill to more complex learning and practice situations. This is illustrated in the following excerpt in which growing self-monitoring skill contributes to the selection of appropriate strategies for addressing identified difficulties:

Brendan runs for a football toss and touches the ball with his fingers but does not manage to catch it.

T: Oh, close! What happened there?

B: I knew where it was going to come, so I got my body ready to move in that direction. But I didn't quite get to it.

T: That's right...you predicted where the football was going, and got yourself in a good position to catch it and almost got the ball! And then?

B: It slipped from my fingers even once I had it.

T: That's right.

B: Next time I need to hold it, to bring it in and squeeze it. (Session 8)

By late sessions, Brendan also demonstrated the ability to adjust his movement strategy in response to task changes and experienced difficulty:

T: What will you have to do differently now that the net (target) is farther away?

B: I'll have to throw it harder, so the ball gets all the way to the net. And lob it a bit, like this.

Brendan attempts this toss and, with several failed attempts, decides to move closer to the target:

B: Oops, that was a bit too far for me. I'll slow down a bit and come closer. And, with success on this new task:

B: I'm doing better now because I'm back at a closer spot. This is a good spot for me to throw from. (Session 9)

In these excerpts, Brendan uses newly developed metacognitive skill to apply independently derived performance strategies to conditional features of performance. In addition, he is responsive to increasingly specific events during learning and newly discovered knowledge about his own skill and, as a result, identifies performance errors and develops strategies with growing accuracy and specificity. Brendan also begins to tie strategic performance to previous discussion and practice, as illustrated in the following quote:

Brendan catches a low toss by using bent knees to lunge low.

B: See, that's what I meant about going low. (Session 8)

Improved metacognitive skill is also evident in the performance of planning and self-evaluation tasks. Prior to performance, Brendan verbalizes new goals spontaneously and indicates the need to change his strategy:

B: I am trying to catch the ball when it is thrown high, so I'll need to jump on these ones. (Session 6)

He also makes predictions about performance and develops strategies based on these predictions:

B: Probably I'll go slow, because I've never practiced it before. (Session 6)

B: I'll need to pay attention to the ball's arc, have my legs ready to move, and keep my fingers flat in my fist. (Session 8)

Together, these excerpts are a clear illustration of the improved metacognitive skill exhibited by Brendan over the course of the program. It might be further argued that it is suggestive of a growing understanding of variables influencing the task, specific performance strategies and the conditions in which they are applicable. In other words, as increasingly effective metacognitive skill emerged, so did Brendan's ability to link existing knowledge to the planning, monitoring and evaluation activities of metacognitive control.

This positive response to participation in the program also enabled Brendan to become increasingly able to verbally articulate his understanding of the variables affecting motor performance and the process through which such variables can be addressed through self-directed practice. This is illustrated in the following excerpt describing the transfer of discovered knowledge to other situations and the conditional nature of performance strategies:

B: Here, I had to slow down as I threw to make it to the target, but I would run fast if I were running with the ball to the endzone. (Session 8)

Arguably, Brendan's growing metacognitive skill contributed to a growth in declarative task knowledge as well as the emergence of a metacognitive awareness of how such knowledge can be used to direct practice and improve motor performance. This is similarly evident in the following excerpt from the final session, during which Brendan was asked to reflect back on his learning over the course of the program and talk about what helped him get better at football. Here, he articulates a clear understanding of the metacognitive processes of goal-setting, planning and monitoring and the role they play in motor skill learning:

B: I need to remember to keep my plans in my head and check back that I used them...that way I can reach my goal. (Session 10)

Consistent with the findings presented from the quantitative analysis, this qualitative phase similarly illustrated the differing trajectories in which conscious and implicit forms of metacognitive competence are exhibited and evolve over the course of the program. This analysis additionally provided further insight into the manner in which these elements were interacting as Brendan's metacognitive ability emerged, where early ineffective metacognitive performance was related to a failure to apply pre-existing task knowledge and growing independence in demonstrating effective on-task metacognitive skill gradually contributed to a greater metacognitive understanding of the role of such skills in motor skill acquisition. These ideas will be explored further in the following section.

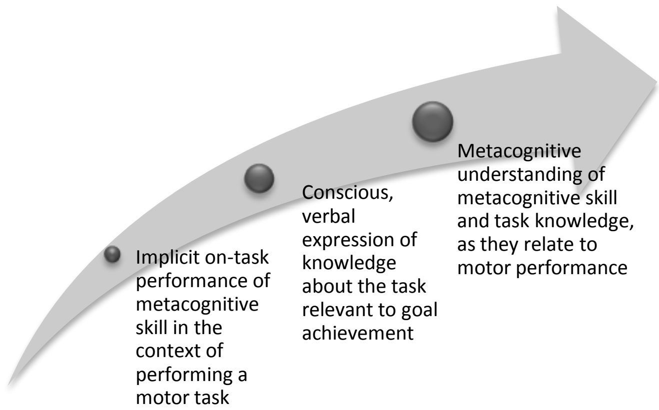
Discussion

The quantitative findings provided evidence for improved metacognitive performance in the form of an increased frequency of effective metacognitive skill. Arguably, this increased ability to effective engage in goal setting, planning, monitoring, and evaluation tasks during motor learning is a positive response to participation in the CO-OP program. The quantitative group data additionally demonstrated the differing nature in which conscious and implicit components of metacognition were demonstrated over the course of the program. The complementary use of qualitative observational analysis allowed for further insight into how this was actually happening in the context of task practice with the therapist. Here, thematic analysis of descriptive excerpts from an individual case study demonstrated how pre-existing task knowledge did not initially transfer to the effective monitoring and evaluation of learning during task practice. However, with the emergence of independent and effective metacognitive skills over the course of the program, task knowledge was increasingly applied to the successful self-regulation of learning. In addition, a more articulate understanding of the role of knowledge and metacognitive skill on acquisition of the chosen task was evident.

These observations seem consistent with the models presented in the introductory section, which propose that growing metacognitive skill contributes to a widening of one's knowledge repertoire and typically precedes a child's ability to articulate metacognitive knowledge about motor performance and learning (Brown et al., 1983; Pressley et al., 1985). As such, these findings might be used to support previous theoretical and empirical work that has advocated a more inclusive conceptualisation of metacognition in which both implicit and conscious forms of metacognition processes should be acknowledged (Whitebread et al., 2007). Consistent with previous research, the findings presented here support the argument that performance based monitoring and control functions (or in the present research, MC skill) emerge earlier than the ability to explicitly articulate metacognitive knowledge, particularly in young children, and that the development of metacognitive competence might be best characterized as a process in which metacognitive skill and knowledge become gradually intertwined (Pressley et al., 1985).

In light of these arguments, this analysis might be viewed as a micro-representation of the process through which metacognitive competence emerges, where improved metacognitive skill occurring as a response to participation in an intervention program contributed to the more successful application of task knowledge to learning. In turn, children became increasingly aware of the manner in which the application of effective metacognitive skills such as planning, monitoring and self-evaluation contribute to successful learning and, eventually, develop the ability to articulate this understanding as metacognitive knowledge. This hypothesized process of metacognitive development is illustrated schematically in Figure 2. Here, implicit performance of metacognitive skill, influenced itself by existing task knowledge, is depicted as an earlier developing ability than the conscious articulation of such knowledge and, even later, than the development of a metacognitive understanding of the role these processes play in motor skill acquisition.

Figure 2. *Developmental Continuum of Metacognitive Competence*



Of course, these arguments are still merely hypotheses, and more research is needed to further examine these ideas and more deeply understand the manner in which metacognition in the motor domain develops and the role of the therapist or other mediating influence on metacognitive performance. Future research might also address several methodological limitations arising in this study. Perhaps the foremost limitation in the present research is its small scale. As an individual research endeavour examining a topic that has yet to receive significant research attention, this project applied an exploratory approach to examine a number of issues related to the role of metacognition in the difficulties of children with DCD and the effects of a cognitively-oriented intervention program on metacognitive performance. However, in light of the very small sample, any generalizations about the nature of metacognitive competence amongst children with DCD and the manner in which it changes over the course of intervention must be made very tentatively. Variance across cases and groups (for example, motivational factors, differing motor tasks) might have influenced the observation of metacognition and should be taken into consideration during future research dedicated to examining these emerging insights using a larger sample.

Conclusion

Despite its limitations, the present study does offer several important and unique contributions to the body of empirical literature dedicated to metacognition and motor learning difficulties. The unique use of quantitative and qualitative analytical approaches and the observation of metacognition in a situated, socially-mediated learning situation have provided new insight into the role of metacognition in the difficulties of children with DCD and the potential of a cognitively-oriented intervention approach for facilitating metacognitive skilfulness during motor skill acquisition. As such, the findings of the present study provide support for the ongoing use of cognitive learning approaches to understanding and addressing the needs of children with DCD.

The present study additionally provides supporting evidence for the important contribution of both implicit and conscious forms of metacognition in learning. As such, it contributes to the growing body of research supporting a comprehensive definition of metacognition that includes both conscious, articulated forms of metacognitive understanding and knowledge as well as implicit, on-line metacognitive performance. It additionally provides support for the use of a mixed methods approach conducted in naturalistic and contextually meaningful settings for most accurately understanding the dynamic and interacting nature of metacognitive knowledge and control. Using such a framework, it is believed that this and future research will arrive at a more complete and nuanced understanding of the manner in which metacognition contributes to learning in social settings and the role of intervention programs in facilitating metacognitive development.

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