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Editorial

New and emerging approaches to understanding developmental coordination disorder

The study of movement clumsiness in children (or *Developmental Coordination Disorder*—APA, 1994) has evolved considerably over the past 20 years. The field has mirrored parallel developments in the areas of motor control and learning, but also has influenced thinking in the mainstream developmental literature. A significant development has been cross-disciplinary approaches to understanding DCD; developmental disorders like DCD are of interest to psychologists, physical therapists, occupational therapists, movement scientists, physical educators, paediatricians, child neurologists, nutritionists, and so on. Work has begun to integrate different methodologies, including genetic research using twin studies (e.g., Martin, Piek, & Hay, 2006), neurophysiology (e.g., Lust, Geuze, Wijers, & Wilson, 2006), and dynamical systems approaches (e.g., Whitall et al., 2006). This special issue of human movement science reflects this evolution. Furthermore, it shows how the work of international experts has influenced our very conception of atypical motor development, its broader impact on child and adolescent adjustment, and how movement skill can best be facilitated in children.

Papers here are drawn from the *7th International Conference on DCD*, held in Melbourne, Australia in February 2007. The event attracted over 130 delegates representing a total of 20 nations, and covering all continents. There were 36 oral papers and nearly 100 poster presentations. Conference papers covered different aspects of theoretical, empirical, and applied research including: diagnosis, assessment, and measurement; postural control, balance, and coordination; perception-action research; clinical issues (comorbidity, adjustment, and consequences), and intervention. The selected papers here provide a representation of current thinking, and show how far the field has progressed since the first DCD consensus conference in London, Ontario in 1994. The DCD conferences have helped put the spotlight on issues of motor development among researchers of childhood and scientist-practitioners in health and education. Current work reflects how we have come to understand the nuances of the disorder, its varied expression, and its significance in the fabric of child development.

An important development supporting both research and clinical practice has been the development of new assessment tools, particularly the use of non-standard screening devices that make use of teacher and parent observation. The work of Faught and colleagues

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shows how a simple 10-item checklist can be developed for parents, yielding valid data on movement competency in primary-school aged children. Screening nearly 500 Canadian children, the TEAF showed good sensitivity in detecting DCD, suggesting that it deserves consideration as an initial screener, perhaps followed by a more formal skill assessment. The ability to trim or avoid formal assessment when it is unnecessary has obvious benefits for researchers and educators alike. In a similar study, Schoemaker and colleagues report data on the Motor Observation Questionnaire for Teacher's (MOQ-T), an 18-item questionnaire assessing fine and gross-motor ability. Sensitivity and specificity for this tool were also encouraging when evaluated against the MABC (Henderson & Sugden, 1992), which is among the best available screening tools for DCD. Of interest in the future is how well these new screeners perform in cross-cultural studies, and against other validated measures. In another study, Rosenblum shows how parent reports might be used to inform assessment of writing difficulties in children, also commonly seen in children with DCD. This study shows how standardized measures of writing product and process might be combined with parent report to yield a comprehensive picture of handwriting ability. The use of parents as informants is also shown in an innovative and much needed qualitative analysis by Summers and colleagues in Australia. One of the defining criteria of DCD is the presence of movement problems that interfere significantly with performance of everyday activities. However, this is probably the first study of its type to examine how their coordination difficulties impact the activities of daily living in the home. This study paints a vivid picture of how children with DCD tackle, avoid, and adapt movement in the home, notably the performance of self-care activities. Striking are similarities between Australian and Canadian children and the level of support provided by parents, providing task and environmental constraints to effect a workable level of function.

The mixed methodologies that are brought to bear on the issue of DCD have never been as apparent. In de Castelnau et al.'s work we see the use of neurophysiological recording using EEG. Interestingly, the use of these techniques is not widespread in the DCD literature; a recent study by Lust and colleagues (2006) is but one recent example. De Castelnau's and colleagues enlist spectral coherence analysis to examine coupling between brain regions on a simple (paced) motor rhythm. Intra-hemispheric coherence between frontal and central regions increased with task difficulty for the DCD group only, suggesting greater reliance on the frontal cortex for motor programming, even for simple movements (in this case, flexion-extension movement of the index finger). With regard to graphic performance, Di Brina and colleagues report on a new technique for assessing graphic production deficiencies in children with DCD and dysgraphia—dynamic time warping (DTW). This technique compares trajectory information based on spatial and temporal information; letter trajectories are compared on a point-to-point basis, permitting a fine-grained analysis of movement form and variability. Indeed, DTW revealed high variability in the letter forms of poor writers, independent of kinematic results. The technique should be a valuable measurement tool in both experimental and intervention work. From a dynamical systems perspective, Mackenzie and colleagues examine how sensory information (visual and auditory) is used to control multi-limb coordination. Not surprisingly, children with DCD were, in general, more variable in coupling foot-strike with hand clapping while marching. More surprising, manipulation of the informational constraints was not shown to alter the motor rhythm for either DCD or typically developing children. Interestingly, the authors draw on computational concepts (e.g., internal modeling) to explain this somewhat unexpected set of findings.

Approaches that could be considered more purely (neuro)computational have also reported on work that implicates *internal modeling*, either as an explanation for null findings or as a causal hypothesis in its own right. Building on earlier work, Williams and colleagues compared children with mild and severe DCD on two mental rotation tasks (hand and whole-body rotation), and also examined the effect of instruction. Importantly, children with severe DCD showed generalized imagery deficits and did not benefit from instruction. Children with mild DCD showed deficits for the more complex whole-body task only, and benefited from instruction. These data provide provisional support for their *internal modeling deficit* hypothesis, but suggest caution in generalizing this account to mild DCD. The effect of advance information on response planning was investigated by Petitt and colleagues using a simple manual pointing task with precuing. Unlike adults and typically developing children, children with DCD responded faster as the quality of precue information increased. This was said to support a "*constrained action selection hypothesis*". Even for a highly constrained movement (with few possible solutions), young children with DCD appear to have a number of possible movement patterns associated with it. Pettit et al. argue that these children have failed to assemble accurate internal models of even the most basic of actions, suggesting an underlying motor learning issue. Computational models (like Wolpert, 1997, and Flanagan, Vetter, Johansson, & Wolpert, 2003) map particular mechanisms for both control and learning, unlike earlier serial models. There is also an emerging base of neuroscience research suggesting possible neural bases for both feed forward and inverse modeling processes with the cerebellar-parietal axis and dorsal stream network implicated, respectively.

A more sophisticated developmental design using multiple (age) control groups was employed by Smits-Engelsman and colleagues. Using a (manual) isometric force production task they examined a maturational lag account of force control variability in DCD. The study compared the performance of 7-, 9-, and 11-year-old children, both typically developing and DCD. Children with DCD were found to be more variable than typically developing children, while producing similar levels of force output. Notably, however, the children with DCD tended to catch up to their typically developing peers when they were compared over successive age groups. The development of noise reduction strategies (e.g., co-contraction) was suggested to support this change. For tightly constrained movements that do not involve trajectory planning, this account holds some merit. But it is unlikely to hold for more complex movements where coordinate transformations are involved.

We have seen in recent years growing recognition of the overlap between DCD and comorbid problems of childhood. In this edition, two papers address this broad issue. There is much conjecture about whether motor overflow (or associated movements—AMs) hold diagnostic or other significance in many developmental disorders including DCD and ADHD; or, indeed, whether AMs reflect particular forms of pathology. Licari and Larkin present a very tight analysis of associated movements in children with DCD, ADHD, and comorbid DCD-ADHD. They show that the severity of AMs is associated with a diagnosis of DCD (either pure or comorbid), and not ADHD alone. In another paper, we see how DCD has broader psychosocial implications for children. Using path analysis, Poulsen and colleagues provide support for their hypothesis that higher levels of motor ability predict higher life satisfaction and lower levels of loneliness in children aged 11–13 years. As well, high motor ability predicted higher scores on a measure of *perceived freedom in leisure* (PFL), which mediated the said effects. Hence, children with DCD are more prone to experience lower life satisfaction and loneliness. One important implication of this work is that high PFL appears to be an important ingredient to ensure children stay engaged in and motivated by team sport and other physical activities. At the physiological level, Cantell and colleagues show clearly how fitness- and health-related variables are compromised in children, adolescents, and adults with "low motor competence": strength, flexibility, aerobic capacity, cholesterol level, bone density, and BMI were among those variables that revealed this broad effect. This information should shape some of the more radical interventions for movement difficulties; the informed practitioner needs to be alerted to these individual constraints when designing motor programs.

Knowledge generated by experimental work on DCD has helped question some of the old assumptions of clinical theory and transformed intervention practices. Here, we have a nice example of how this legacy has informed a cognitive approach to intervention and an evaluation study of high quality. Green and colleagues examined the CO-OP approach (or cognitive orientation to daily occupational performance—see Polatajko, Mandich, Miller, & Macnab (2001)—but ask the intriguing question of whether therapeutic effects are contingent on DCD subtype, formed on the basis of perceptual-motor variables. No significant effects of subtype were found. However, it was noted that children with more severe presentation at the initial assessment continued to experience difficulties, post-intervention. The study provides a number of pointers for subtype research into the future—for example, enhancing the scale properties of cluster variables and integration of other types of variable including measures of resilience, environmental milieu, and developmental markers.

The corpus of work on DCD and related conditions is growing to a point where both mainstream developmental researchers and health practitioners alike cannot ignore it. The simple message from this work is that DCD matters. It is not a trivial condition that warrants consideration only after all the "hard work" is done diagnosing and treating behavioral and medical conditions. It represents a significant risk factor in the longer-term development of children and adolescents. This reinforces the need to develop good measurement devices and principled ways of treating the disorder, as seen in this edition. As well, some of what we now know about the causal antecedents to DCD informs our knowledge of rate-limiting factors in normal development. For example, the development of internal modeling generally (and online adaptive control more specifically) marks a crucial transition in how children acquire more adaptive behavior. What will enlighten us further in this regard and others are studies that examine change over multiple levels of function and timeframes. These studies are difficult, expensive and time-consuming, but necessary.

Postscript

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