School of Psychology and Speech Pathology

Motor Skills and Internalising Problems: Investigating the Elaborated Environmental Stress Hypothesis

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics, Approval Number # HR216/2014

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Abstract

The ability to execute coordinated motor functions has an important influence on the trajectory of psychosocial development. Individuals with motor difficulties are at greater risk for negative psychosocial experiences, and report higher levels of internalising problems (anxiety and depression) relative to their typically developing peers. While first identified in samples of children diagnosed with developmental coordination disorder (DCD), a number of more recent studies have shown this link between motor competence and psychosocial outcomes is not restricted to clinical samples, and can persist into later life. Despite accumulating evidence of a link between motor skills and internalising problems, there have been only few efforts to investigate why this relationships exists. The Elaborated Environmental Stress Hypothesis (Cairney, Rigoli, & Piek, 2013) provides a potential explanation for this relationship, claiming that this association is mostly indirect; having poor motor skills results in exposure to a cascade of negative secondary consequences that subsequently lead to internalising problems. While promising, limited research has tested the conceptual pathways posited by this framework. Each of the papers presented in this thesis share the common aim of evaluating the pathways between motor skills and internalising problems posited by the Elaborated Environmental Stress Hypothesis. In combination, the empirical studies provide a unique evaluation of the framework, testing components of this framework in samples ranging from early childhood to adulthood.

The first paper included in this thesis is a literature review of research relating to the Elaborated Environmental Stress Hypothesis. The aim of this literature review was to develop a better understanding of the current state of empirical support for the framework. The findings from this literature review support an association between motor skills and internalising problems across the full continuum of motor ability, and provide several examples of support for the framework in both older and community populations. However, many of the key pathways contained within this framework were yet to be tested empirically. The findings inform the additional papers included in this thesis.

The second paper in this thesis empirically evaluated an indirect association between motor skills and internalising problems via peer problems and two domains of perceived self-competence (physical and cognitive) in a community sample of young children aged 4 to 6 years (n = 197). Despite an increasing number of studies on the topic, few studies have investigated the stability of relationships contained within the Elaborated Environmental Stress Hypothesis in the same cohort over time. Consequently, this study evaluated these relationships at two time-points. The first period of data collection occurred at pre-primary

age (M = 5.40 years), and then again at 18-month follow-up. After controlling for age and gender, results identified only peer problems mediating the relationship between motor skills and internalising problems at pre-primary age. However, at 18-month follow-up, this relationship was mediated by peer problems and perceived physical competence. These findings may reflect important psychosocial changes which occur over this developmental period. The results of this study support the notion that the relationships contained within the Elaborated Environmental Stress Hypothesis may differ across different stages of development, highlighting the importance of age-appropriate intervention.

Extending upon the previous paper, the third paper tested an indirect association between motor skills and internalising problems via peer problems and perceived self-competence in a community sample of children aged 7 to 12 years (n = 164). In addition to the older sample, this study differed from the previous by measuring six domains of self-competence and tested whether the hypothesised mediation would be moderated by gender. Results showed an indirect association between motor skills and internalising problems via peer problems and perceived scholastic competence that was not moderated by gender.

The relationships between motor skills, psychosocial functioning and internalising problems are most commonly evaluated in child populations. However, a growing number of studies have identified these relationships in older populations. Furthermore, preliminary evidence suggests that the relationships contained within this framework may differ across different developmental periods, including older populations. This was investigated in the fourth and fifth papers in this thesis.

The fourth paper in this thesis tested an indirect association between motor skills and internalising problems via three domains of perceived social support in a community adolescent sample aged 12 to 16 years (n = 93). This study also investigated whether this indirect association differed between the anxious and depressive dimensions of internalising problems. After controlling for age, gender, verbal IQ, and ADHD symptoms, results showed that only perceived family support mediated the association between motor skills and depressive symptoms. Motor skills was associated with anxious symptoms, but this relationship was not mediated by perceived social support. These results indicated that different psychosocial factors contained within the Elaborated Environmental Stress Hypothesis may impact the association between motor skills and the anxious and depressive domains differently.

The fifth paper in this thesis tested an indirect association of motor skills and internalising problems via perceived social support and perceived physical self-worth in a

community adult sample aged 18 to 30 years (n = 95). After controlling for age, gender, and body mass index (BMI), results revealed an indirect association via perceived social support, but not perceived self-worth. These results provided support for the framework in an adult population, while further highlighting the importance of interpersonal factors previously found to mediate this association in younger populations.

The central aim of this thesis, presented over five published papers, was to provide an evaluation of a promising theoretical framework that seeks to explain the association between motor skills, psychosocial functioning, and internalising problems. The results across these five studies generally yield support for the Elaborated Environmental Stress Hypothesis in community populations of children, adolescents and adults. Consistent with previous tests of this framework, each of the current studies evaluated a smaller set of pathways embedded in the broader framework. There was an indirect association between motor skills and internalising problems via interpersonal factors (e.g. peer problems, perceived social support) in each of the empirical studies included in this thesis, highlighting the interpersonal domain as a critical pathway through which motor skills is associated with internalising problems. The current findings also highlight the comparatively weaker, but still important, role of intrapersonal factors such as perceived self-competence. Furthermore, there was preliminary evidence that this intrapersonal domain may be of greater importance during the later stages of childhood and into the later stages of development. The psychosocial factors found to mediate the association between motor skills and internalising problems in this series of cross-sectional, correlational research designs have helped to identify important targets for intervention that can 'interrupt' the trajectory from poor motor skills to internalising problems. The five studies included in this thesis extend the support for the Elaborated Environmental Stress Hypothesis, which can be further strengthened through ongoing evaluation of additional pathways using a range of range of research methodologies.

Publications Included as Part of the Thesis

Mancini, V. O., Rigoli, D., Cairney, J., Roberts, L. D., & Piek, J. P. (2016). The elaborated environmental stress hypothesis as a framework for understanding the association between motor skills and internalizing problems: A mini-review. *Frontiers in Psychology, 7.* doi:10.3389/fpsyg.2016.00239

Mancini, V. O., Rigoli, D., Roberts, L. D., Heritage, B., & Piek, J. P. (In Press). The relationship between motor skills and psychosocial factors in young children: A test of the elaborated environmental stress hypothesis. *British Journal of Educational Psychology*. doi:10.1111/bjep.12187/full

Mancini, V. O., Rigoli, D., Roberts, L. D., Heritage, B., & Piek, J. P.(In Press). The relationship between motor skills, perceived self-competence, peer problems and internalizing problems in a community sample of children. *Infant and Child Development*. doi:10.1002/icd.2073

Mancini, V. O., Rigoli, D., Heritage, B., Roberts, L. D., & Piek, J. P. (2016). The relationship between motor skills, perceived social support, and internalizing problems in a community adolescent sample. *Frontiers in Psychology, 7*. doi:10.3389/fpsyg.2016.00543

Rigoli, D., Kane, R. T., **Mancini, V.,** Thornton, A., Licari, M., Hands, B., . . . Piek, J. (2017). The relationship between motor proficiency and mental health outcomes in young adults: A test of the Environmental Stress Hypothesis. *Human Movement Science*. doi:10.1016/j.humov.2016.09.004

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Statement of Author Contribution

The nature and extent of the intellectual input by the candidate and co-authors has been validated by all authors, and can be found in Appendix A.

Vincent O. Mancini
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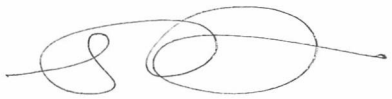

Lynne D. Roberts
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Introduction

'Motor skills' are the neurological activation of specific muscle groups required to make intentional, accurate, and controlled movements (Desrosiers, Rochette, & Corriveau, 2005). The ability to execute these movements influences an individual's ability to interact with their surrounding environment, which is considered essential to survival (Koziol, Budding, & Chidekel, 2012). Motor skill development follows a typical trajectory from infancy to adulthood influenced by the interaction of neurological and physical factors, as well as exposure to opportunity for development (Payne & Isaacs, 2017; Voelcker-Rehage, 2008). Childhood is a critical developmental period for many physical and psychosocial factors, including motor skill acquisition. Meeting developmentally appropriate movement milestones, such as walking, creates opportunities for additional developmental experiences, such as the ability to participate in play with peers. These experiences are not only essential to the development of increasingly skilful movements, but also influence the child's ability to learn about themselves and interact with their surrounding environment (Payne & Isaacs, 2017). Motor skills are considered a prerequisite for the acquisition and quality of cognitive, social and emotional developmental functions (Bushnell & Boudreau, 1993; Campos et al., 2000; Diamond, 2000; Murray et al., 2006; Piek, Dawson, Smith, & Gasson, 2008; Poole et al., 2015a).

The suggestion that motor skills influence other areas of development is not a recent proposition. For instance, Schilder (1939) provided one of the earliest accounts of a link between motor skills and psychological adjustment in both human and primate infants. In another early example, Piaget (1953) proposed that activity and sensorimotor experiences predispose the emergence of childhood cognitive ability. Subsequent studies have further established the pervasive influence of motor skills in an array of developmental areas including language, perception, cognition, social, behaviour and emotion (Bushnell & Boudreau, 1993; Diamond, 2000; Erlenmeyer-Kimling et al., 2000; Green, Baird, & Sugden, 2006; Iverson, 2010; Martin & Caro, 1985). In all cases, the relationship between motor development and these other areas of development is neither simple nor linear. Dynamic Systems Theory (DST) provides a basis for understanding these relationships. DST describes development in any specific area as the product of an interaction of multiple domains (also termed 'subsystems'), the task itself, and the surrounding environment (Smith & Thelen, 1993). Granott and Parziale (2002) also discussed the role of time as another critical component of DST; development in any area may be influenced by any events that preceded the current interaction between subsystems, and these interactions may vary due to the

influence of time. Piaget's stages of cognitive development, which describes the typical trajectory of cognitive development throughout childhood (Piaget, 1953), is an example of this concept. Consequently, even a slight change in one area can induce a shift in the whole process, impacting both current and future developmental outcomes. To exemplify this 'dynamic' process, we can consider the acquisition of a new motor skill as the result of an interaction between neurological, physical and environmental subsystems. If the individual were to have trouble in any one of these subsystems, their experience of attempting to acquire this new motor skill is likely to be impacted. The subsequent difficulties in the motor subsystem may then compromise development in other areas. In other words, motor development may influence other developmental areas, as much as these other developmental areas may influence motor development.

Historically, research into motor development has been investigated separately from cognitive, social and emotional development. However, growing recognition that human development involves the complex interaction of systems has led to a renewed interest in motor development and its relationship with other areas of development. Motor skills are best understood as a continuum of ability (Wassenberg et al., 2005). To date, most research in this area has focused on individuals who experience chronic difficulties with the attainment and implementation of coordinated motor skills, and whose motor skills are significantly lower than what is expected given their age and prior opportunity for skill acquisition. In research, this group of individuals is most commonly categorised as having a 'motor disorder' (American Psychiatric Association [APA], 2013). 'Motor disorders' is a broadband term that covers an array of neurodevelopmental conditions. Major, often visible, motor impairment characterises some motor disorders, such as cerebral palsy and muscular dystrophy. The negative impact of major motor disorders on other areas of development is well-documented (Lavigne & Faier-Routman, 1992). Other motor disorders are less discernible as they lack the observable physical indicators of a severe motor impairment. These 'invisible' motor disorders are, by definition, also characterised by the presence of chronic motor skill difficulties. However, the experiences of these individuals are shown to be different compared to those with 'visible' motor disorders (Goldberg, 1974; Joachim & Acorn, 2000; Miyahara & Piek, 2006). For example, in the absence of a visible explanation for motor difficulties, an individual with an 'invisible' motor disorder such as developmental coordination disorder (DCD; APA, 2013) may be expected to meet the same motor demands as their typically developing peers. The persistent inability to meet these demands can precipitate additional consequences, such as difficulties interacting with peers and developing

poor self-competence (Cairney, Hay, Faught, Wade, et al., 2005). These differing experiences based on the visibility of disability highlight the importance of disorder-specific strands of research. The current thesis is concerned with investigating the role of motor skills in other areas of development in samples free from visible major motor disorders.

Developmental Coordination Disorder (DCD)

DCD is an example of an 'invisible' motor disorder, describing a population who experience motor difficulties in the absence of intellectual disability or major movement disorder such as cerebral palsy (Cairney, Kwan, Hay, & Faught, 2012; Prince, 2017). DCD was first listed as a neurodevelopmental disorder in the Diagnostic and Statistical Manual of Mental Disorders (DSM)–Third Edition, Revised (APA, 1987), and officially adopted as the term that should be used in research and practice when referring to these individuals in 1994 and 2005 consensus meetings (Polatajko, Fox, & Missiuna, 1995; Sugden, Chambers, & Utley, 2006). Alternative terms such as 'dyspraxia', 'clumsy child syndrome', 'physically awkward', 'perceptuomotor dysfunction' and 'minimal brain dysfunction', and their fragmented areas of research, were therefore unified under the term of DCD (Gibbs, Appleton, & Appleton, 2007; Henderson & Barnett, 1998). A diagnosis of DCD (per the current DSM-5 criteria) may be given when: (a) the individual's motor skills are substantially below what would be expected given their age and opportunity for acquisition, (b) these movement difficulties interfere with daily functioning (including academic performance, leisure and play), (c) the onset of these symptoms occurs in the early developmental period, and (d) these symptoms cannot be better explained by other conditions (APA, 2013, p74).

DCD is one of the most common childhood disorders, with an estimated prevalence rate of approximately 5% to 6% (APA, 2013), although prevalence estimates have ranged from 1.4% to 19%, depending on case definition (Lingam, Hunt, Golding, Jongmans, & Emond, 2009; Wann, 2007; Wright & Sugden, 1996). Despite its prevalence, DCD is often unrecognised or misdiagnosed by healthcare and educational professionals (Missiuna, Moll, Law, King, & King, 2006). The disorder is thought to be more common in males, with a male to female ratio of between 1.7:1 and 7:1 (APA, 2013; Lingam et al., 2009). Other studies have identified comparable prevalence rates of DCD between sexes, and that issues such as referral bias may over inflate the male to female ratio of the disorder. For example, boys may participate in a greater number of activities where movement difficulties are easier to notice by parents and teachers (e.g., playing ball sports), leading to more referrals (Cermak & Larkin, 2002; Pearsall-Jones et al., 2008).

The formal recognition of DCD approximately three decades ago precipitated an expansion of interest concerning the aetiology, diagnosis, trajectory and treatment of this disorder. Accumulating research suggests that there may be no single cause of DCD (Zwicker, Missiuna, & Boyd, 2009). Environmental factors such as perinatal oxygen perfusion problems, perinatal alcohol exposure, and pre-term birth have been implicated as causes of DCD (Edwards et al., 2011; Landgren, Svensson, Strömland, & Grönlund, 2010; Pearsall-Jones, Piek, & Levy, 2010; Pearsall-Jones et al., 2008). Cerebellar processes can also cause motor skill disorders (Zwicker et al., 2009). Additional evidence supporting the aetiology of DCD has originated from research on disorders with high rates of comorbidity with DCD. Two commonly cited co-occurring disorders are attention deficit hyperactivity disorder (ADHD) and learning disability (LD), estimated to co-occur at a prevalence of 50% with DCD (Jongmans, Smits-Engelsman, & Schoemaker, 2003; Kaplan, Wilson, Dewey, & Crawford, 1998; Pitcher, Piek, & Hay, 2003; Silva, McGee, & Williams, 1982). These high rates may reflect shared aetiology, as similar environmental and neurological factors have been cited as causes of ADHD and LD (Martin, Piek, & Hay, 2006). Individuals with DCD and another comorbid disorder experience poorer outcomes compared to those with either disorder in isolation (Kadesjö & Gillberg, 2001; Pearsall-Jones, Piek, Rigoli, Martin, & Levy, 2011; Visser, 2003). However, the occurrence of DCD in the absence of these disorders (or vice versa) highlights the need to independently investigate the identification, trajectory and treatment of DCD. Some researchers specifically concerned with the impact of DCD on other areas of development have controlled for other disorders such as ADHD and LD in two key ways. Experimental studies may identify discrete groups based on the presence or absence of co-occuring disorders (e.g., a DCD group and a DCD + ADHD group) (Loh, Piek, & Barrett, 2011). Correlational studies in DCD literature may control for ADHD and LD symptomology (e.g., Rigoli et al., 2012). Demographic factors such as age and gender are also frequently included as control variables (Wilson et al., 2013).

Traditional views of DCD were that affected children would naturally ‘outgrow’ their poor motor skills (Dewey & Wilson, 2001). While this may be the case for some children with DCD, it is now recognised that DCD persists into adolescence and adulthood for the majority of affected children (Cantell, Smyth, & Ahonen, 2003; Hellgren, Gillberg, Gillberg, & Enerskog, 1993; Losse et al., 1991). Furthermore, the consequences of DCD may intensify over time, as affected individuals struggle to meet the demands of increasingly complex motor skills required in later development (Skinner & Piek, 2001). This has led to a growing

number of studies exploring DCD in adolescence and adulthood, including some promising intervention research (McIntyre, Chivers, Larkin, Rose, & Hands, 2015). However, childhood remains the most frequently researched developmental period in DCD literature due to the early onset of the disorder and critical period for intervention.

Difficulties with either fine and/or gross motor skills characterise the physical manifestation of DCD. Despite evidence supporting the early events that may cause the disorder (including perinatal factors such as low birthweight), it often remains unnoticed until approximately five years of age (Pearsall-Jones, Piek, Rigoli, Martin, and Levy., 2009; Missiuna & Campbell, 2014). This has been attributed to the heterogeneity of motor skills in earlier childhood versus the increased demand for coordinated movement that typically occurs at schooling age and consequently leads to poor motor skills being more easily noticed (Lingam et al., 2010; Stephenson & Chesson, 2008). Common movement difficulties experienced by those with DCD include struggling with handwriting or buttoning clothing and poor performance in sports (Piek et al., 2004). These physical symptoms are well-established in the occupational therapy and movement science literature (Geuze, Jongmans, Schoemaker, & Smits-Engelsman, 2001). These movement difficulties are often the primary target in traditional DCD treatment programs (Mandich, Polatajko, Macnab, & Miller, 2001).

Kaplan et al. (1998) suggested that while the primary issue for those with DCD were movement difficulties, it is rarely the only difficulty they experience as a consequence. This is consistent with the DST notion that a change in one subsystem (i.e., poor motor skills) can alter the development of other subsystems. Accumulating evidence has found those with DCD experience additional cognitive difficulties (Dewey, Kaplan, Crawford, & Wilson, 2002), academic underachievement (Rosenblum & Livneh-Zirinski, 2008), physical inactivity/obesity (Cairney, Hay, Faught, & Hawes, 2005), social problems (Campbell, Missiuna, & Vaillancourt, 2012), and emotional difficulties (Skinner & Piek, 2001). These ‘secondary’ consequences of DCD have become the subject of increasing clinical interest. Each of these consequences are problematic and can persist into later life (Harrowell, Hollén, Lingam, & Emond, 2017; Hill & Brown, 2013; Lingam et al., 2009).

Despite the long-standing suggestion that motor development plays an important role in cognitive, psychosocial and emotional development (Schilder, 1939), the body of research investigating this claim has only started to flourish over the past three decades. This may be partially attributed to the formal recognition of DCD and subsequent consensus of the use of the term that occurred around this time. The bulk of this research has focussed on the motor-cognitive link which has led to several important advances in our understanding of motor

skills, such as the role of executive functions in DCD (Graham, Li, King-Dowling, Rodriguez, & Cairney, 2016; Leonard, Bernardi, Hill, & Henry, 2015; Niederer et al., 2011; Piek et al., 2008). The importance of motor skills in relation to social and emotional development has been comparatively underexplored, but has gained momentum since the early 2000s. Skinner and Piek's (2001) pivotal study precipated growth in this area of research (Missiuna & Campbell, 2014). In their cross-sectional study, children and adolescents with DCD reported lower self-worth and higher anxiety, compared to age-matched samples without DCD. Furthermore, the adolescents reported additional social difficulties (such as lower social acceptance) and higher anxiety compared to their younger counterparts, providing a preliminary suggestion that the psychosocial consequences of DCD may become more pervasive in later development.

Research highlighting the numerous social and emotional difficulties experienced by individuals with DCD compared to their non-affected peers now populates this area of investigation. For example, individuals with DCD are more likely to be victimised by their peers (Campbell et al., 2012), be excluded or socially isolated (Gibbs et al., 2007) and underachieve at school (Alloway, 2007). They are also more likely to experience lower self-esteem (Harrowell et al., 2017), decreased self-competence/self-worth (Piek, Dworcan, Barrett, & Coleman, 2000; Sugden, 2014), and lower rates of physical activity (Cairney et al., 2005). Given these numerous social and emotional difficulties, it is not surprising that individuals with DCD also experience higher levels of internalising problems (commonly used to refer to symptoms, rather than a diagnosis, of depression and/or anxiety; Cairney, Rigoli, & Piek, 2013; Hill & Brown, 2013; Piek et al., 2007). The impact of motor skills on the development of internalising problems is an area of growing research interest (Cairney et al., 2013).

Children with DCD are more likely to miss valuable developmental opportunities such as forming friendships and social skills, or developing a sense of self-worth by participating in play (Kanioglou, Tsorbatzoudis, & Barkoukis, 2005). Preclusion from such experiences may have a lasting impact on the trajectory of their social and emotional development (Hill & Brown, 2013; Piek et al., 2008; Poole et al., 2016; Poole et al., 2015b; Poulsen, Ziviani, Johnson, & Cuskelly, 2008). This is supported by research demonstrating that DCD in childhood can predict social and emotional outcomes in later life, regardless of the individual's present degree of motor competence (Hill & Brown, 2013; Hill, Brown, & Sorgardt, 2011). A growing number of cross-sectional studies in adolescent and adult samples have provided additional support for the important role of motor competence in social and emotional outcomes in later life, with increasing attention placed on understanding

ththe association between motor skills and internalising problems (Rigoli, Piek, & Kane, 2012). This association is the central topic of investigation in this thesis.

DCD and Internalising Problems

Despite mounting evidence demonstrating that individuals with DCD experience greater internalising problems compared to their unaffected peers (e.g. Skinner & Piek, 2001), comparatively fewer studies have sought to understand why. The DST offers a generic approach to understanding development although the non-specific nature of this framework fails to adequately explain the unique interaction between motor skills and internalising problems, resulting in limited clinical utility. Shared biological factors that underpin both motor skills and internalising problems may explain these findings (Nicolson, Fawcett, & Dean, 2001). The cerebellum plays a critical role in motor control (Diamond, 2000; Doya, 2000; Paulin, 1993) and a range of higher cognitive and behavioural functions including emotion regulation (Dolan, 1998; Schutter & Van Honk, 2009; Strata, 2015; Turner et al., 2007). Consequently, an individual experiencing a deficit in cerebellar functioning is likely to experience difficulties in each of the areas in which the cerebellum plays a role (Erez, Gordon, Sever, Sadeh, & Mintz, 2004; Nicolson et al., 2001). While this is a plausible explanation, the notion of shared biological underpinnings is challenged in situations where individuals with DCD are free from internalising problems, or vice versa. For example, Erez et al. (2004) identified that approximately 50% of their sample diagnosed with anxiety disorders also experienced motor difficulties. A twin/sibling study by Waszczuk, Leonard, Hill, Rowe, and Gregory (2016) found that combined genetic/shared environmental factors accounted for approximately half of the variance in the association between motor skills and internalising problems. These findings suggested that biological factors may only partially account for the link between DCD and internalising problems.

The association between DCD and internalising problems may be explained by the role of environmental factors (Cairney et al., 2010). Because of their motor difficulties, individuals with DCD interact with their surrounding environment differently compared to unaffected peers. DCD is characterised by difficulties with numerous daily tasks that are completed with comparative ease by their unaffected peers (Cairney, Kwan, Hay, & Faught, 2012). For example, struggling with throwing and catching could lead to decreased self-competence and victimisation from peers, both of which are risk factors for internalising problems (Reijntjes, Kamphuis, Prinzie, & Telch, 2010). While distressing experiences such as peer victimisation are not restricted to individuals with DCD, this population is at greater risk for interpersonal difficulties (Campbell et al., 2012). Furthermore, the omnipresence of

their movement difficulties may also result in numerous and often unavoidable distressing experiences. These unique environmental interactions are posited to lead to greater internalising problems, as these experiences are often stressful and undesirable (Cairney et al., 2013; Pearlin, Menaghan, Morton, & Mullan, 1981). This notion is supported by monozygotic twin research by Pearsall-Jones et al. (2011), where monozygotic twins (understood to share 100% genes as well as shared environmental experiences) with DCD and/or ADHD reported higher depressive symptoms compared to the unaffected twin. In the previously mentioned study by Waszczuk et al. (2016), a moderate to large phenotypic association between motor skills and internalising problems was identified in a population of adult twins/siblings. After accounting for shared biological/environmental factors, unique environmental factors accounted for approximately one-third of this association. These studies provide some of the strongest support for the role of unique environmental factors in the association between DCD and internalising problems as they account for shared biological and environmental experiences.

While environmental factors may help to provide insight into the aetiology of the association between DCD and greater internalising problems, they may have an equally important role in the treatment and intervention for this disorder. The role of biological/neurological factors cannot be dismissed, however, they are seldom the target of treatment for DCD. Although, it should be noted that it is common for individuals to take medication if there are comorbid disorders such as ADHD (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012). In one study (Brossard-Racine, Shevell, Snider, Bélanger, & Majnemer,2012), medication for ADHD was shown to improve the motor skills of some children, though motor difficulties persisted in over half of the study sample. Currently, there is no evidence-based pharmacological treatment for DCD. Contemporary treatment and intervention for DCD seeks to optimise the individual's ability to interact with their environment, or to optimise the environment to best suit the needs of the individual. Physical therapy intervention involves the development and optimisation of motor skills that maximise the individual's opportunities to participate in quality interactions with the surrounding environment (Blank et al., 2012). Goals for physical therapy may be specific (e.g., riding a bicycle) or general (e.g., improvement in motor coordination); specific goals are often targeted with the aim to generalise these skills to other tasks. Occupational therapy intervention also offers methods to improve the quality of everyday activities, but places greater emphasis on adapting the material environment to best suit the individual's current motor difficulties (Blank et al., 2012). For example, if handwriting is the target for

intervention, an occupational therapist may test different writing instruments to identify which is most effective for the client.

Following the recognition that individuals with DCD experience greater social and emotional difficulties, mental health professionals are becoming increasingly involved in the treatment and intervention of DCD (Piek et al., 2010). Efforts to improve how children with DCD interact with their social environment (e.g., peers) is an important area of treatment (Piek et al., 2010). Social support is a protective factor against internalising problems and other emotional difficulties; individuals with DCD often report poorer social support (Lange, 2017). Individuals with DCD may develop poor self-competence due to their movement difficulties and may attempt to avoid potentially important activities such as completing school work or participating in play with peers. As poor self-competence is a risk factor for internalising problems, efforts to improve self-competence is an important target area for intervention (Mandich, Polatajko, & Rodger, 2003; Piek et al., 2010; Sowislo & Orth, 2013). Regardless of the goal of treatment, interventions for DCD are most effective when the individual is actively involved in the formulation of these goals (Sugden, 2007). The numerous consequences of DCD identifies numerous potential targets for intervention. Validated theoretical frameworks are critical, as they help to support the decision to target particular factors as part of these intervention programs.

Environmental Stress

Despite accumulating evidence that highlights the potential role of environmental factors in the development of internalising problems for individuals with DCD, few attempts have been made to develop a conceptual understanding of this association. One exception to this has been the work of Cairney, Veldhuizen, and Szatmari (2010) and Cairney et al. (2013). In a pivotal paper published in 2010, Cairney and colleagues acknowledged the importance of stress as a core component of the DCD experience. While stress may also refer to life events or trauma, DCD can be understood as a form of chronic stress. They suggested that persistent movement difficulties could be reasonably characterised as a "wellspring of stress" as they disrupt normal daily functioning across several domains (Cairney et al., 2010, p. 226). These movement difficulties can deplete protective factors, such as good social support and may instead precipitate exposure to further stressful events, such as ridicule from peers (Campbell et al., 2012). Cairney et al., (2010) recognised DCD as a primary source of stress, leading to the adaptation of a well-supported stress framework to the DCD literature.

Pearlin's Stress Process Model (Pearlin, 1989; Pearlin et al., 1981) provides a generic framework that describes the association between stress, protective factors and emotional

outcomes. It remains one of the leading sociological theories for understanding health and illness (Attell, Brown, & Treiber, 2017). This framework can be used for many different outcomes, but has most recently focused on internalising problems within the DCD literature. This model (Figure 1) highlights both the direct and indirect pathways through which exposure to stress can contribute to the development of internalising problems. Exposure to stress may itself lead to internalising problems. However, this stress can also 'erode' both social and personal protective factors that minimise the consequences of stress exposure, making an individual more vulnerable to internalising problems and other emotional difficulties. Social resources refer to interpersonal factors such as positive social support or healthy peer relationships. Personal resources refer to intrapersonal factors such as perceived self-worth and internal locus of control (Cairney et al., 2013; Pearlin 1989). These social and protective resources can both mediate and moderate the association between stress exposure and internalising problems.

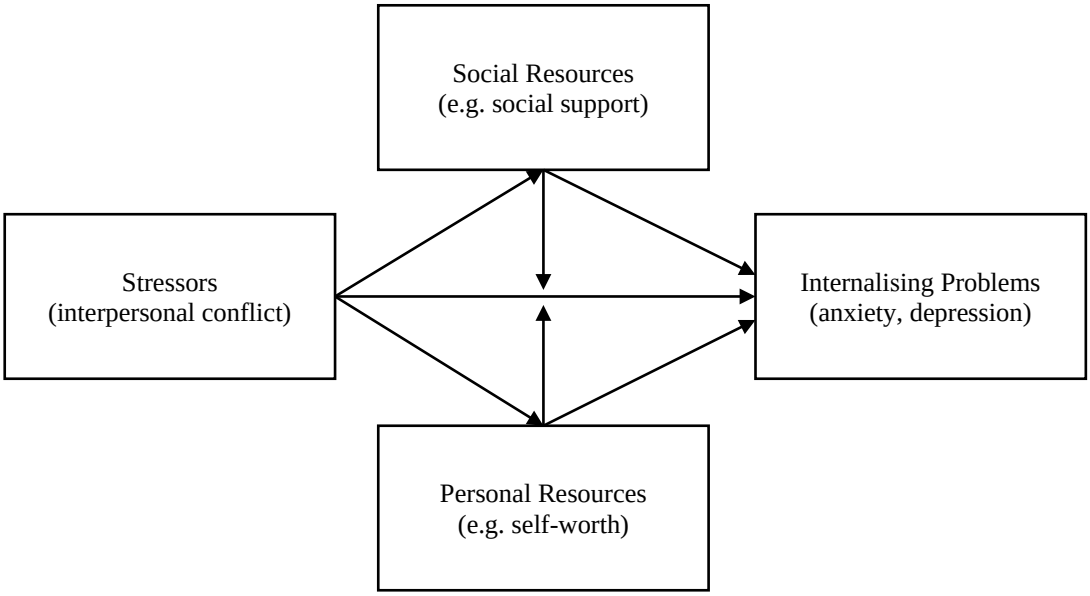

Figure 1. Pearlin's stress process model adapted from Cairney et al. (2013)

The ability for Pearlin's Stress model to be easily tailored to identify stressors and protective factors in a variety of situations has contributed to its widespread use in many different areas of research. Cairney et al. (2010) adopted this framework to capture the experience of children with DCD. Childhood is the developmental period which continues to receive the most attention in the DCD literature, thus providing the largest evidence base to

initially conceptualise a DCD-specific adaptation of Pearlin's Stress Process Model, referred to as the 'Environmental Stress Hypothesis'.

The Environmental Stress Hypothesis

While DCD and internalising problems may share some biological aetiology, Cairney et al. (2010) argued that DCD may also be a cause of internalising problems. DCD was introduced into the Stress Process Model as a 'primary stressor' as these movement difficulties influence many domains of functioning. This stress is chronic as the child with DCD will experience difficulties each time they are required to execute the motor skills that are affected by the disorder. These tasks may be in the presence of others (e.g., in the playground), or in isolation (e.g., difficulties with self-care such as dressing). The presence of this often-unavoidable stressor gives rise to a cascade of 'secondary stressors', which can have a direct and indirect impact on internalising problems (Figure 2). There are varying degrees of support for an association between DCD and each of the other components included in the framework. Cairney et al. (2013) provides a more elaborate summary of this literature, but presented below is a concise summary of studies supporting each of the relationships.

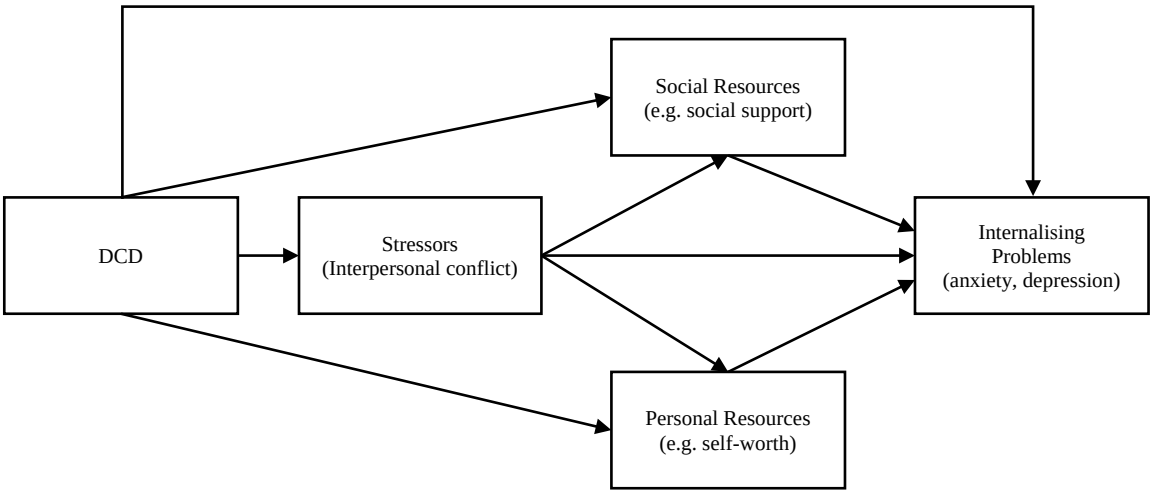

Figure 2. Pearlin's Stress Process Model as described in Cairney et al. (2010). DCD in childhood is a 'primary stressor' that gives rise to a cascade of secondary stressors that directly and indirectly lead to internalising problems.

Most of the studies indicating a link between DCD and internalising problems are quasi-experimental, demonstrating that children and adolescents with DCD are at greater risk for internalising problems relative to their unaffected peers (Francis & Piek, 2003; Sigurdsson, Van Os, & Fombonne, 2002; Skinner & Piek, 2001). Importantly, twin/sibling studies also established that this association could not be explained by shared genetic/environmental factors alone (Pearsall-Jones et al., 2008; Waszczuk et al., 2016).

Children and adolescents with DCD have been shown to experience greater interpersonal difficulties relative to their unaffected peers. They are more likely to be the victims of bullying, introverted and socially isolated (Campbell et al., 2012; Kadesjo & Gillberg, 1999; Schoemaker & Kalverboer, 1994). These interpersonal difficulties are a risk factor for a range of poor emotional outcomes, including internalising problems (Rivilis et al., 2011). In the context of the Stress Process Model, the exposure to stress concomitant with DCD erodes these social resources that help to protect against the development of internalising problems. Interpersonal functioning has become a part of some motor intervention programs that recognise these interpersonal difficulties typically experienced by this group. This may involve fostering positive peer interactions (e.g., Piek et al., 2010), or educating teachers and caregivers who may mislabel these children as lazy or defiant (Fox & Lent, 1996).

Intrapersonal difficulties have also been well-established in DCD populations. The most frequently investigated factors relate to the individual's perceived self-worth or competence. Children and adolescents with DCD have lower self-worth and see themselves as less competent compared to their unaffected peers (Francis & Piek, 2003; Piek, Barrett, Allen, Jones, & Louise, 2005; Piek, Baynam, & Barrett, 2006; Skinner & Piek, 2001). It may not be surprising that individuals with DCD see themselves as less competent athletically, considering the movement difficulties that characterise the disorder (Cantell, Smyth, & Ahonen, 1994). However, these individuals also report lower levels of self-worth and self-competence on a range of other domains that may not be directly related to motor skills, such as scholastic and social competence (Skinner & Piek, 2001). This may highlight a possible 'horns effect', where the negative self-competence in relation to motor skills can influence perceptions of self in other areas. Efforts to improve perceived self-competence are a key aim of many motor skill intervention programs as improved self-competence can lead to greater participation in activities (McIntyre et al., 2015; Peens, Pienaar, & Nienaber, 2008).

Furthermore, poor self-competence is a potential cause of internalising problems (Burt, Obradović, Long, & Masten, 2008).

Cairney et al. (2010) extended the Stress Process Model by including DCD as a 'primary' source of stress said to lead to several 'secondary' sources of stress. Compared to the other components of the framework, the link between DCD and stressors remains mostly conceptual; there is a lack of an appropriate measure of secondary stress for individuals with DCD. Though measures of stress are available, these are often generic and fail to capture the unique types of stress exposure experienced by this population. Consequently, most studies that have evaluated the framework have treated these two constructs (DCD and Stressors) as an undivided source of stress and in the absence of a suitable measure of secondary stress. This was also the process used in the papers included in the current thesis.

Elaboration of the Environmental Stress Hypothesis

The Environmental Stress Hypothesis was further extended by Cairney et al. (2013). 'Physical inactivity' and 'obesity' were added to the framework to improve the capacity for the framework to capture additional processes through which DCD may lead to greater internalising problems and based on a growing amount of evidence supporting this association. This elaborated version of the framework (Figure 3) provides the most up-to-date version of this framework.

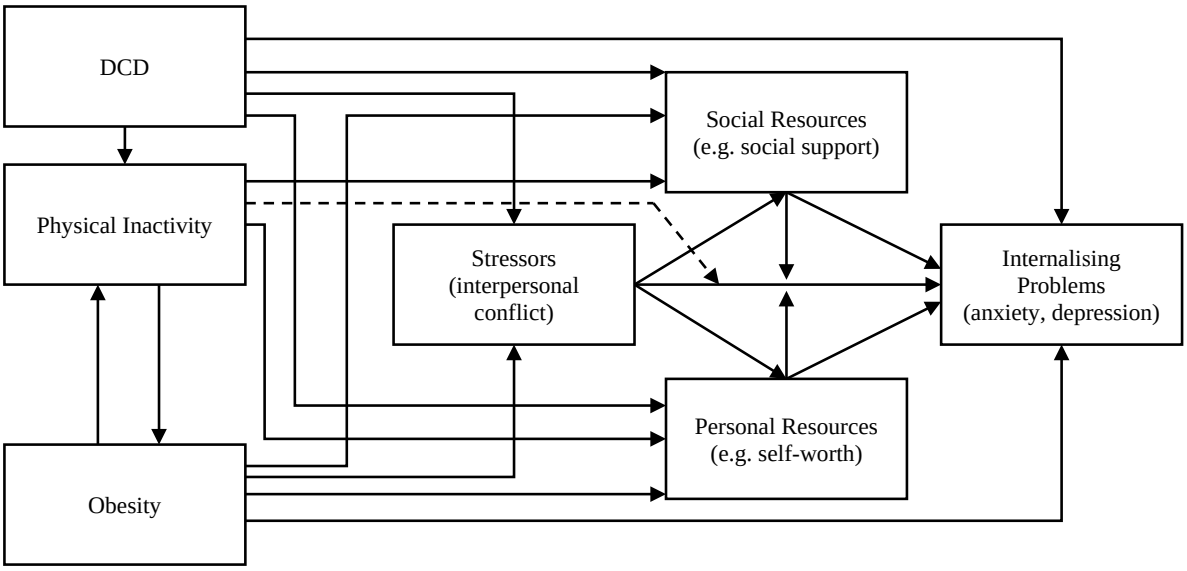

Figure 3. The Elaborated Environmental Stress Hypothesis as depicted in Cairney et al. (2013). This framework is an extension of the original Environmental Stress Hypothesis presented in Cairney et al. (2010).

Children and adolescents with DCD are often less physically active than their typically developing peers (Cairney, Hay, Faught, & Hawes, 2005; Cairney, Hay, Faught, Wade, et al., 2005). This association may manifest due to several issues. First, these individuals experience significant movement difficulties, which may make participation in physical activity an unenjoyable experience and impact their self-efficacy. Cairney, Hay, Faught, Wade, et al. (2005) found that generalised self-efficacy mediated the association between DCD and physical inactivity. Second, children with DCD are more likely to be excluded from opportunities to participate in peer-based physical activities such as structured and unstructured play, restricting their ability to be physically active even if they wanted to (Campbell et al., 2012). Greater sedentary behaviour is closely linked to obesity, meaning that children with DCD are at risk for weight issues (Cairney, Hay, Faught, & Hawes, 2005). Similar to DCD, both physical inactivity and obesity are risk factors for interpersonal and intrapersonal difficulties, and emotional difficulties such as internalising problems (Biddle & Asare, 2011; Sjöberg, Nilsson, & Leppert, 2005).

The direct pathway between DCD and internalising problems signifies variance in the association that cannot be accounted for by the numerous indirect pathways contained within the framework. This may represent the role of biological or other factors not explicitly included in the model. Furthermore, the causes of psychopathology are multi-factorial (Koplewicz & Klass, 1993), meaning that a specific framework such as the Elaborated Environmental Stress Hypothesis is unlikely to completely account for all of the interacting factors that contribute to constructs such as DCD or internalising problems. Nevertheless, the pathways contained within this framework may be able to explain a meaningful amount of variance in internalising problems and provide valuable targets for intervention and treatment initiatives.

Several direct and indirect associations between DCD and internalising problems populates the Elaborated Environmental Stress Hypothesis. While there is empirical support for many of the associations between pairs of included constructs, these studies cannot account for the important mediating and moderating pathways that are a critical component of this framework. The Elaborated Environmental Stress Hypothesis posits that the relationship between DCD and internalising problems is largely indirect; DCD gives rise to secondary psychosocial consequences, which lead to greater internalising problems (Cairney et al., 2013). Studies that test these indirect pathways are particularly important in determining the usefulness of this framework. Within the emerging literature that has tested

this framework (described in greater detail in Paper One presented in this thesis), several have enlisted the use of community populations rather than only individuals with DCD (e.g., Rigoli et al., 2012; Wilson et al., 2013). The studies that enlist community populations provide support for the framework; yet they also highlight an important issue within the DCD literature that has direct relevance to the current evaluation and application of the Elaborated Environmental Stress Hypothesis. Specifically, the issue relates to whether DCD is a discrete category or part of the broader continuum of motor functioning.

DCD and the Continuum of Normal Motor Functioning

The question of whether mental disorders exist as distinct categories or on a broader continuum of normal functioning remains an ongoing issue in the clinical literature (Widiger & Samuel, 2005). Motor skills are best described as a continuum of ability ranging from those with poor motor skills to those with excellent motor skills (Wassenberg et al., 2005). Norm-referenced motor assessments have identified that motor skills follow a normal distribution in the general population, which has normalised the use of qualitative descriptions such as 'below average motor skills', or the use of percentiles that rank an individual's motor skills relative to their peers (Henderson, Sugden, & Barnett, 2007). Pearsall-Jones et al. (2008) initially proposed that the neurological causes of DCD and cerebral palsy fall on a "continuum of motor disorder" (p. 387). However, this description still perpetuated the segregation of motor disorders from the rest of the normal motor continuum. This idea of a "continuum of motor disorder" has been extended to capture the full continuum of motor ability; motor disorders such as DCD may represent the lower end of the normal continuum of motor ability (Cairney et al., 2010).

The distinction of clinical motor difficulties from 'normal' motor skills has been fundamental to the motor disorder literature. Researchers in this area rely on a variety of instruments that seek to differentiate individuals with and without the disorder. The latter population is commonly used as a comparison group in quasi-experimental studies often demonstrating better outcomes across several domains (e.g., Skinner & Piek, 2001). These studies promote further research into the development and implementation of interventions for individuals diagnosed with a movement disorder such as DCD. Eligibility for DCD treatment and intervention is often determined by the diagnosis of a disorder (e.g., McIntyre et al., 2015). A diagnosis of DCD may have additional benefits. The diagnosis may provide a more 'legitimate' explanation for the individual's motor difficulties that can lead to greater understanding from peers and caregivers (i.e., parents and teachers) who may develop more realistic expectations of the individual's motor skills (Missiuna, Moll, et al., 2006). However,

the process of labelling an individual may result in undesirable consequence such as stigma from others and self-stigma. While these dangers are speculated on in the DCD literature, they are well-established in other mental disorder literature (Angermeyer & Matschinger, 2003; Corrigan & Watson, 2002; Missiuna, Moll, et al., 2006).

A categorical approach to motor disorders may oversimplify our understanding of the continuum of motor ability. Comparing those with DCD to those without may implicitly perpetuate the notion that these are two independent groups, and individuals within each group are homogenous. However, previous studies have shown that some individuals may transition between a diagnosis of DCD and not meeting diagnostic criteria for DCD over time (Cantell et al., 2003; Visser, Geuze, & Kalverboer, 1998). Furthermore, there are often poor levels of agreement between major diagnostic assessments for DCD; a child who meets diagnostic criteria for one assessment may not necessarily meet criteria on the other (Brantner, Piek, & Smith, 2009; Chen, Tseng, Hu, & Cermak, 2009; Tan, Parker, & Larkin, 2001). The way in which the individual's motor competence is assessed, rather than the actual presence of movement difficulties, may contribute to a DCD diagnosis. To best understand this issue, we first need to describe an important conceptual issue relating to the diagnosis of DCD.

The first, and arguably most important, diagnostic requirement for DCD is that the individual's motor skills are substantially below what is expected given their age and opportunity for skill acquisition (APA, 2013, p. 74; Cairney et al., 2013). Health professionals often enlist the use of standardised measures of motor competence to determine if this criterion has been satisfied. Based on the original prevalence estimate of approximately 5%, contemporary motor assessments (e.g., Bruininks & Bruininks, 2005) continue to use the 5^{th} percentile as a 'cut-off' to identify significant motor impairment (APA, 2013; Cairney et al., 2010). However, previous studies have shown that these prevalence estimates may vary based on the stringency of diagnostic criteria (Lingam et al., 2009; Wann, 2007; Wright & Sugden, 1996). Some studies only use the first criterion to operationalise a DCD sample. These samples are also sometimes referred to as 'probable-DCD', 'at-risk for DCD' or 'poor motor skills' (Cairney et al., 2013). This has led to the inconsistent use of terminology in the DCD literature, which is reminiscent of the earlier issues that led to the consensus meetings in 1994 and 2005 (Polatajko et al., 1995; Sugden et al., 2006). While some studies only use the first criterion and others use the full diagnostic criteria, they all describe a population of individuals who experience difficulties with movement relative to their peers. There is recognition that each threshold used to identify motor disorders will have unique costs and

benefits (Cairney et al., 2010). Contemporary standardised measures of motor assessment have since introduced an additional, more forgiving 'cut-off' score of the 15th or 16th percentile to identify individuals who are 'at-risk' for movement difficulties (e.g., Bruininks & Bruininks, 2005; Henderson et al., 2007).

Even when using the more lenient 'cut-off' scores, researchers are engaging in the process of categorizing those in the bottom 15-16% of motor competence into one group, and the rest of the general population in the other. However, this process oversimplifies our understanding of motor skills by stating that individuals can either be 'at-risk' or 'not at-risk' for a motor disorder. It is remiss to assume that individuals at the lower (but not 'at-risk') end of the motor skill continuum have comparable motor skills as someone with excellent motor skills. As an illustrative example, someone at the 17th percentile on the continuum of normal motor functioning may be only slightly more competent than an 'at-risk' individual at the 16th percentile, yet would instead be grouped with individuals with vastly different motor skills, such as those falling on the 99th percentile (Lingam et al., 2009). Despite the high levels of within-groups variance in this group, it remains common practice to treat them as a homogenous population that can be compared to 'at-risk' populations. This may lead to important processes that occur across the normal continuum of motor development to be overlooked. Despite this methodological issue, an accumulating body of studies has established important, consistent differences between groups with motor disorders compared to their unaffected peers in physical, cognitive, social and emotional domains.

The second diagnostic requirement for DCD is that the individual's movement difficulties lead to impairment in activities of daily living and other domains (APA, 2013, p. 74). As a continuum of functioning, poorer motor skills result in greater impairment (Cairney et al., 2010). This has led to the ongoing debate regarding how much impairment in daily living is enough to constitute the presence of a motor disorder, with consensus yet to be achieved (Cairney et al., 2010).

Correlational research designs that investigate motor skills from a dimensional perspective can circumvent the issues associated with artificially implementing 'cut-off' scores that categorize the continuum of motor skills. This growing body of research should be considered complementary to the quasi-experimental studies that currently populate the DCD literature. While experimental studies attempt to minimise within-groups variance to establish causality, the goal of correlational research designs is to explain this variance by identifying relationships between factors (Coolican, 2014). Correlational research designs have provided recent support for previously established differences between individuals with DCD and their

unaffected peers, with a particular focus on social and emotional functioning. For example, an experimental research design by Dewey et al. (2002) found that children with DCD or at-risk of DCD reported significantly higher social problems compared to a sample of unaffected peers. A correlational research design by Cummins, Piek, and Dyck (2005) found that motor skills could predict social problems in a sample of 234 children. In another example, previous experimental studies that have shown individuals with DCD to experience greater internalising problems compared to their unaffected peers (e.g., Skinner & Piek, 2001) have since been supported by correlational studies (Rigoli et al., 2012; Wilson, Piek, & Kane, 2013). Social and emotional difficulties are not confined to only individuals with DCD. Rather, motor skills are negatively associated with social and emotional difficulties across the full continuum of movement. Therefore, there is a need for studies that look beyond DCD populations; this was a critical finding in Paper 1 presented in this thesis (Mancini, Rigoli, Cairney, Roberts, & Piek, 2016).

Exploring the association of motor skills with social and emotional factors has important implications for treatment and intervention. Social and emotional factors are widely recognised as important targets in the intervention and treatment for motor disorders such as DCD (Blank et al., 2012; Watson & Knott, 2006). However, the accumulating correlational research findings have led to the suggestion that the benefits of interventions aiming to improve movement and social and emotional functioning may extend to individuals across the full continuum of motor ability (Piek et al., 2010). The current evidence provides mixed results. For example, universal motor intervention programs like the *Animal Fun* program have been shown to improve both motor performance and social and emotional outcomes in young children (Piek et al., 2015; Piek et al., 2013). However, Anna, Glykeria-Erato, Aspasia, and Fotini (2016) examined another motor intervention program for young children and found that while motor performance improved post-intervention, there was no improvement in perceived self-competence. The researchers suggested that the eight-week, twice weekly intervention was not long enough to improve self-perceptions. However, another plausible explanation may be that young children are yet to develop the cognitive skills to provide an accurate rating of their self-perceptions (Klaver, Palo, & DiLalla, 2014; Piaget, 1953). Combined movement and psychosocial intervention programs for older children and adolescents have been shown to improve self-perceptions (McIntyre et al., 2015; Peens et al., 2008). These findings highlight the potential need to identify age-appropriate approaches to intervention, and for the inclusion of purposeful efforts to target social and personal factors (Missiuna, Rivard, & Bartlett, 2006). Motor skills may be more strongly

associated with different social and emotional outcomes during different stages of development; targeting these stronger associations may improve the efficacy of the intervention. Correlational research designs that examine different age groups, such as the papers included in the current thesis, can provide an important first-step in identifying specific targets for intervention.

Aims and Rationale of this Thesis

The primary aim of this thesis was to identify whether the Elaborated Environmental Stress Hypothesis can be empirically supported as a framework to understand the association between motor skills and internalising problems. This framework comprises numerous direct and indirect pathways through which this association is posited to occur. Consequently, studies evaluating the Elaborated Environmental Stress Hypothesis commonly examine a smaller number of pathways embedded within the broader framework. Few of these pathways have been tested empirically, meaning further studies, such as those included in the current thesis, are required to better understand the relationships contained within this framework.

While the Elaborated Environmental Stress Hypothesis was originally developed for application to DCD populations, growing awareness that an association between motor skills and internalising problems is not confined to populations of children with DCD has highlighted the need to apply a theoretical framework to community populations spanning multiple stages of development. Theoretical frameworks developed using clinical populations may offer limited applicability for the general population. For example, individuals with chronic motor disorders such as DCD report significant difficulties with movement, leading to high levels of disruption in other domains. This may lead to an overestimation of the association between these domains in community populations (Rigoli et al., 2012). Correlational research designs offer one potential methodology to address this need. Preliminary studies have supported the extension of the Elaborated Environmental Stress Hypothesis to the full continuum of motor ability (Rigoli et al., 2012; Wagner, Bös, Jascenoka, Jekauc, & Petermann, 2012; Wilson et al., 2013) though additional studies are required to further evidence. Correlational research designs have shown that better motor skills are associated with positive social and emotional outcomes (e.g., Rigoli et al., 2012; Wilson et al., 2012; Wagner et al., 2016). Investigating motor skills as a continuum may help to develop a generalisable framework that can help to understand the role of motor skills in other areas of development at a population-based level, and allow for more effective universal intervention and prevention strategies.

Furthermore, studies have shown that the psychosocial correlates of motor skills can extend into adolescence and adulthood (Harrowell et al., 2017; Hill & Brown, 2013; Skinner & Piek, 2001), stressing the importance for theories that are equally applicable to these older populations. There is some suggestion that the dynamic trajectory of development may have implications for the Elaborated Environmental Stress Hypothesis; different pathways may be of greater (or lesser) importance depending on the age of the sample (Anna et al., 2016; Klaver et al., 2014; Piaget, 1953). Therefore, this thesis aims to test the Elaborated Environmental Stress Hypothesis framework across four different age-groups ranging from early childhood (4 to 6 years) to adulthood (18 to 30 years).

Despite well-supported associations between each pair of constructs included in the Elaborated Environmental Stress Hypothesis, limited research has investigated the relationships between more than two of these constructs. This research is particularly important, as a critical component of the framework is that the association between motor skills and internalising problems is mostly indirect; interpersonal and intrapersonal psychosocial factors may mediate and moderate this relationship. The studies included in this thesis tested several different mediating and moderating pathways posited by this framework with the intention of better understanding how motor skills are associated with internalising problems.

The rationale for testing specific indirect pathways included in the Elaborated Environmental Stress Hypothesis over a series of studies included in the current thesis is two-fold. First, these studies will add to the previous literature that attempts to understand why motor skills are associated with internalising problems. Second, by identifying the mechanisms through which this association occurs, we can identify potential targets for age-relevant interventions that can 'interrupt' the trajectory from poorer motor skills to greater internalising problems (Missiuna & Campbell, 2014). There is already evidence documenting a similar process. In a cross-sectional correlational research design, Wilson et al. (2013) found that social skills mediated the association between motor skills and internalising problems in a community sample of young children aged 4 to 6 years, highlighting that efforts to improve social skills may result in better emotional outcomes. This study supported the structure of the *Animal Fun* intervention program that aimed to improve the motor skills and psychosocial outcomes in young children, which included activities specifically designed to enhance positive peer interaction and social skill development. In 2015, Piek et al. found that the *Animal Fun* program was able to improve the emotional outcomes of children who received the intervention. However, social skills are only one of several pathways through

which motor skills are posited to be associated with internalising problems. The studies in the current thesis aim to identify additional interpersonal and intrapersonal factors that can be similarly targeted in interventions.

Outline of Papers Included in This Thesis

The first paper in this thesis (Mancini, Rigoli, Cairney, et al., 2016) presents a review of the literature pertaining to the Elaborated Environmental Stress Hypothesis. The aim of this review was to identify the current empirical support for the framework, with a specific focus on the emerging studies following its publication. The reviewed evidence supported the suggestion that the Elaborated Environmental Stress Hypothesis remains a useful conceptual framework to explore the association between motor skills and internalising problems, even when tested in community populations and different age groups. The framework has been most frequently evaluated in sections due to the numerous direct and indirect pathways between motor skills and internalising problems. The currently available evidence was limited, as several pathways embedded within the model remain empirically underexplored. The results of this review provided justification for the next four papers included in this thesis, which sought to provide an empirical investigation of pathways contained within the Elaborated Environmental Stress Hypothesis. The constructs of focus in these studies are visually presented in Figure 5.

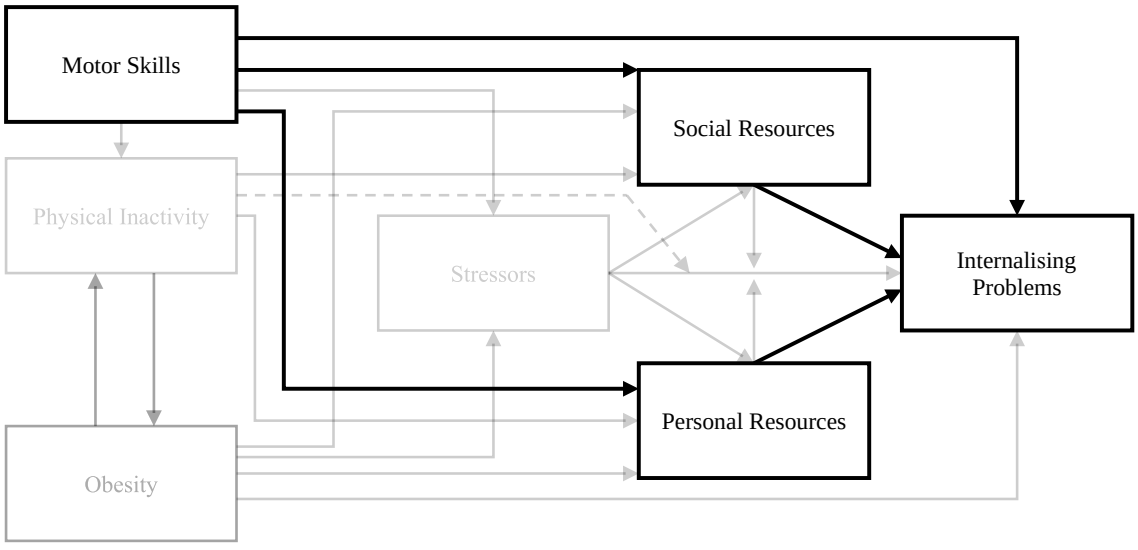

Figure 5. The Elaborated Environmental Stress Hypothesis pathways (depicted in bold) that were tested as part of the current thesis. Based on the results of the first study included in this thesis (Mancini, Rigoli, Cairney, et al., 2016), we investigated motor skills across the full

continuum of ability and tested these pathways in different age groups spanning from early childhood to adulthood.

The second paper in this thesis (Mancini, Rigoli, Roberts, Heritage, & Piek, 2017) investigated the relationship between motor skills, peer problems, perceived self-competence (physical and cognitive domains) and internalising problems, in a community sample of young children aged 4 to 6 years (Figure 6). In this study, participants were assessed at two time-points. The first assessment period occurred while children were in pre-primary and then again 18-months later. The results indicated that at Time 1, motor skills had an indirect association with internalising problems via peer problems, but not perceived physical or cognitive competence. However at Time 2, there was an indirect association via peer problems and also perceived physical competence. These results highlight the potentially dynamic nature of the pathways contained within the Elaborated Environmental Stress Hypothesis, where the association between motor skills and internalising problems may manifest through different pathways depending on the age of the individual. In this study, the findings highlight that during early childhood, individuals may not yet have developed the cognitive skills necessary to make an accurate appraisal of one's self-competence (Klaver et al., 2014; Piaget, 1953). However, the development of these skills may have occurred over the 18-month period between assessments, which could explain the additional indirect pathway via perceived physical competence at Time 2. These results highlight the potential importance for age-appropriate targets for intervention.

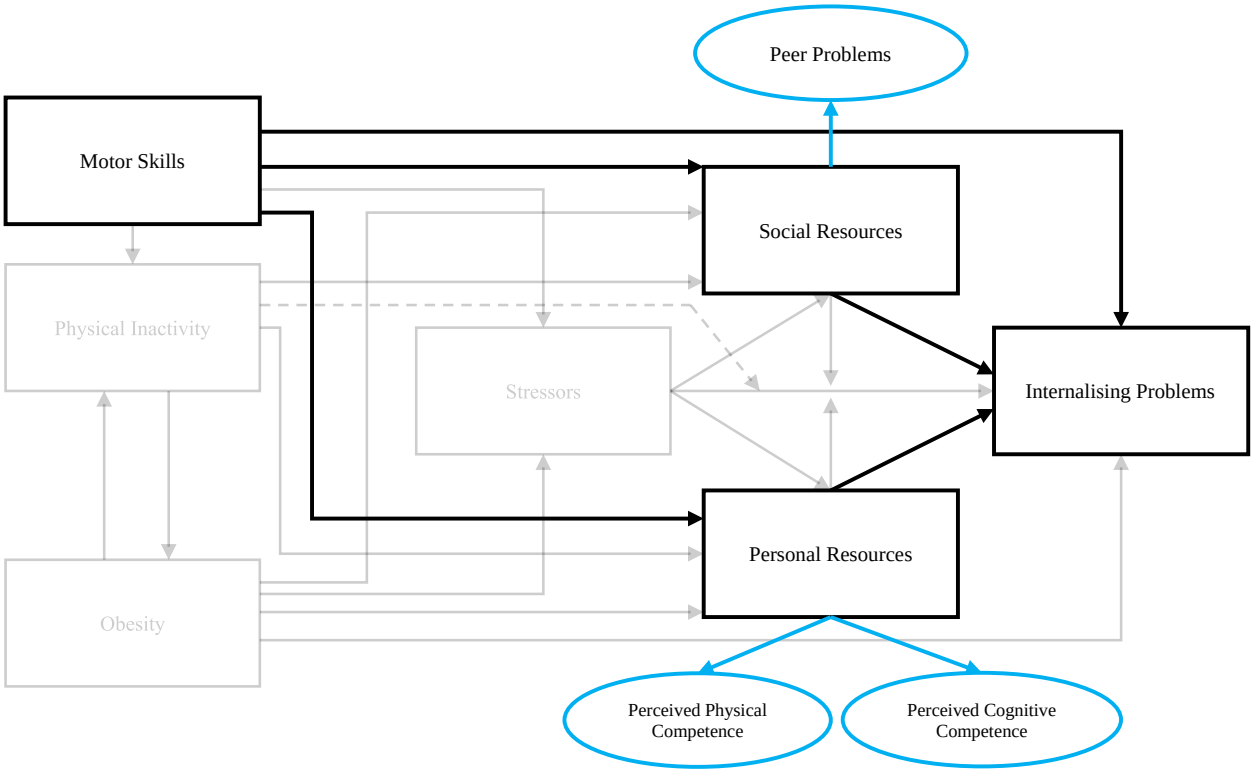

Figure 6. The Elaborated Environmental Stress Hypothesis pathways (depicted in bold) that were tested in Paper Two presented in this thesis. The specific social and personal resources included in this study are presented in blue. This study enlisted a community sample of young children aged 4 to 6 years, measured at two time-points spanning an 18-month period (time one N = 197; time two N = 107).

The third paper in thesis (Mancini, Rigoli, Roberts, Heritage, & Piek, Accepted) built on the previous study by investigating the relationship between motor skills, peer problems, perceived self-competence and internalising problems, in a community sample of children aged 7 to 12 years (Figure 7). In addition to recruiting an older child population, the current study also extended on the previous research by looking at several additional domains of perceived self-competence. Within the DCD literature, children with the disorder often experience poorer physical self-competence which manifests as a consequence of their movement difficulties. However, studies have also shown that these children also experience poorer perceptions of self-competence in a range of other domains (Cantell et al., 1994; Skinner & Piek, 2001). The results of this study found an indirect association between motor skills and internalising problems via peer problems and perceived scholastic competence. These findings are consistent with the second study where both interpersonal (i.e., peer

problems) and intrapersonal (i.e., perceived self-competence) were identified as indirect pathways between motor skills and internalising problems at Time 2 (Mancini et al., 2017). The results of this study highlight the persistence of interpersonal factors (i.e., peer problems) as an indirect pathway between motor skills and internalising problems and also identify perceived scholastic competence as a potentially important target area for intervention

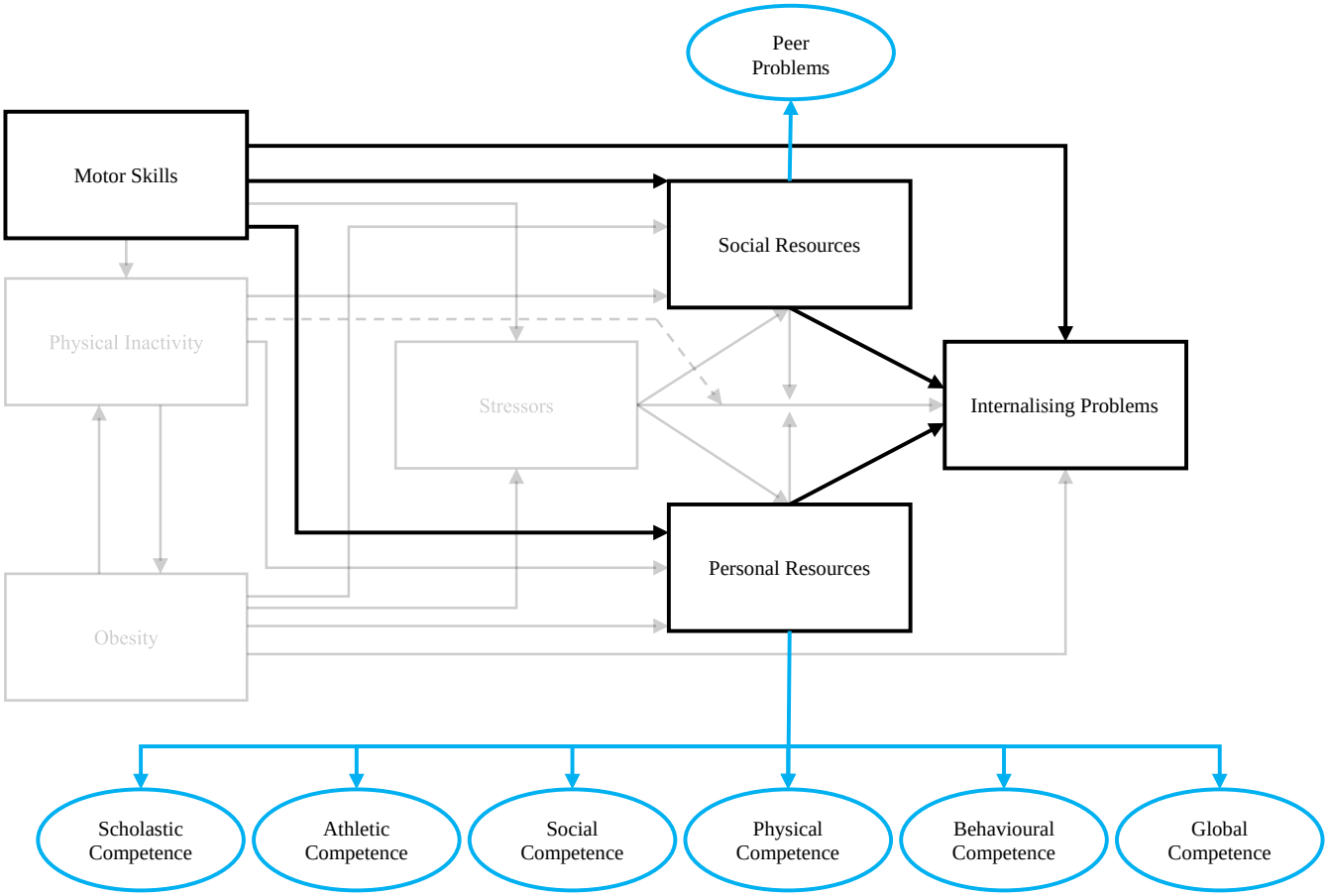

Figure 7. The Elaborated Environmental Stress Hypothesis pathways (depicted in bold) that were tested in Paper 3 presented in this thesis. The specific social and personal resources included in this study are presented in blue. This study enlisted a community sample of children aged 7 to 12 years (N = 164).

Paper Four (Mancini, Rigoli, Heritage, et al., 2016) tested an indirect association between motor skills, perceived social support (across three domains) and internalising problems in a community sample of 93 adolescents aged 12 to 16 years (Figure 8). The current study differed from the previous two studies by examining the anxious and depressive

components of internalising problems independently, in an adolescent population. The results indicated that motor skills were indirectly associated with depressive symptoms via perceived family support, but not perceived support from friends or a significant other. There was no indirect association between motor skills and anxious symptoms. These findings suggest that the role of perceived social support may interrupt the trajectory between poorer motor functioning and depressive symptoms, but not anxious symptoms. In addition, the current results found that support from family was the most important domain of perceived social support. This highlights the protective role of family support, even though adolescence is typically a period where individuals place increasingly important emphasis on their peer relationships (Pettit, Roberts, Lewinsohn, Seeley, & Yaroslavsky, 2011). Within the DCD literature, the potential for impaired relationships between affected individuals and family members has been noted; parents may become frustrated with their child's motor difficulties which can lead to conflict or being mislabelled as 'lazy' (Fox & Lent, 1996; Missiuna, Moll, et al., 2006).

The current findings suggest that efforts that seek to improve the quality of support from family members as part of combined movement and psychosocial intervention programs may be able to improve emotional outcomes in adolescents.

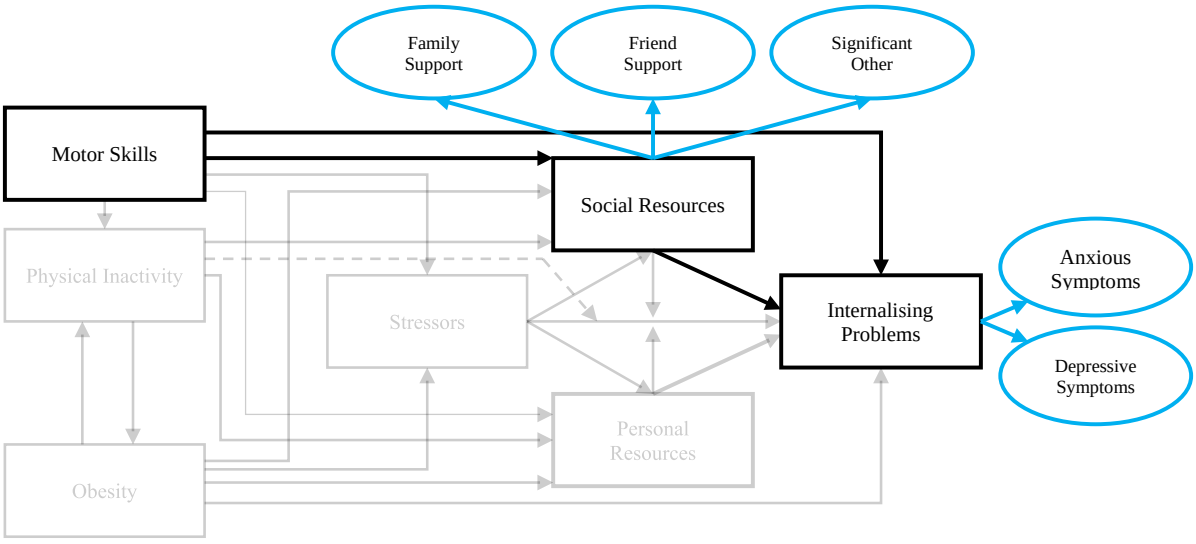

Figure 8. The Elaborated Environmental Stress Hypothesis pathways (depicted in bold) that were tested in Paper 4 presented in this thesis. The social resources and separate dimensions of internalising problems included in this study are presented in blue. This study enlisted a community sample of adolescents aged 12 to 16 years (N = 93).

Paper Five tested an indirect association between motor skills and internalising problems via perceived social support and perceived physical competence in a community sample of 95 adults aged 18 to 30 years (Figure 9). This study investigated whether the Elaborated Environmental Stress Hypothesis could be used to understand the relationship between motor skills and internalising problems in an adult population. The results revealed that there was an indirect association between motor skills and internalising problems via perceived social support, but not perceived physical competence. These findings further promote the importance of interpersonal factors in understanding the association between motor skills and internalising problems, which is a key finding that also emerged from each of the previous studies. There was a significant relationship between physical self-worth and internalising problems, which is consistent with previous studies (Burt et al., 2008; Mancini et al., Accepted). The results did not identify a relationship between motor skills and perceived physical-competence, despite evidence for this association being identified in adolescent populations (Schmidt, Blum, Valkanover, & Conzelmann, 2015). This provides further evidence for the importance of identifying age-appropriate targets to maximise the effectiveness of psychomotor intervention programs.

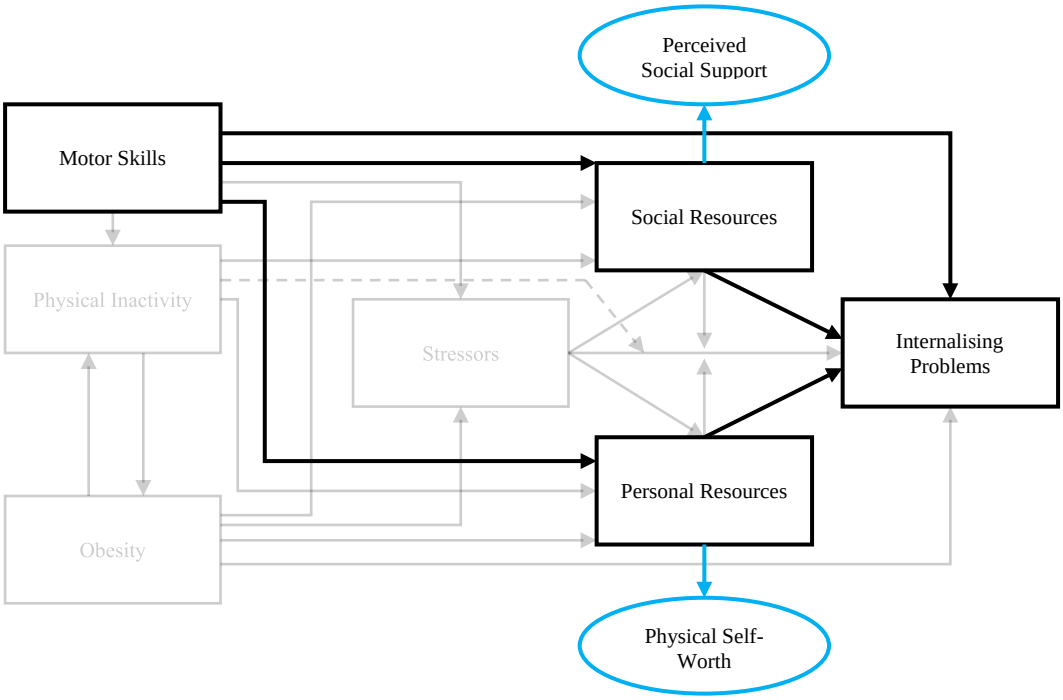

Figure 9. The Elaborated Environmental Stress Hypothesis pathways (depicted in bold) that were tested in Paper 5 presented in this thesis. The specific social and personal resources included in this study are presented in blue. This study enlisted a community sample of adults aged 18 to 30 years *(N* = 95).

The discussion section provides a summary of these five papers and discusses the findings of this PhD within the context of the broader literature. It concludes with a discussion on the limitations of the current evidence and recommendations for future research.

In summary, the papers included in this thesis provided much-needed empirical support for the Elaborated Environmental Stress Hypothesis. The first study provided an important review of the earlier literature, supporting the generalisation of this framework to the wider population. The four empirical studies identified an indirect association between motor skills and internalising problems in four different samples, spanning early childhood to adulthood. The discussion section integrates each of these previous papers (and other recent research developments) and discusses the strengths and limitations of the papers included in this thesis and the broader literature. By achieving a better understanding of how motor skills are indirectly associated with internalising problems via psychosocial factors, the current studies have identified several targets for combined motor skill and psychosocial intervention programs. Targeting these psychosocial factors as part of intervention studies can ‘interrupt’ the trajectory from poorer motor skills to greater internalising problems, while also allowing for the opportunity to establish true cause-and-effect associations (Missiuna & Campbell, 2014).

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MINI REVIEW
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The Elaborated Environmental Stress Hypothesis as a Framework for Understanding the Association Between Motor Skills and Internalizing Problems: A Mini-Review

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Poor motor skills have been shown to be associated with a range of psychosocial issues, including internalizing problems (anxiety and depression). While well-documented empirically, our understanding of why this relationship occurs remains theoretically underdeveloped. The Elaborated Environmental Stress Hypothesis by Cairney et al. (2013) provides a promising framework that seeks to explain the association between motor skills and internalizing problems, specifically in children with developmental coordination disorder (DCD). The framework posits that poor motor skills predispose the development of internalizing problems via interactions with intermediary environmental stressors. At the time the model was proposed, limited direct evidence was available to support or refute the framework. Several studies and developments related to the framework have since been published. This mini-review seeks to provide an up-to-date overview of recent developments related to the Elaborated Environmental Stress Hypothesis. We briefly discuss the past research that led to its development, before moving to studies that have investigated the framework since it was proposed. While originally developed within the context of DCD in childhood, recent developments have found support for the model in community samples. Through the reviewed literature, this article provides support for the Elaborated Environmental Stress Hypothesis as a promising theoretical framework that explains the psychosocial correlates across the broader spectrum of motor ability. However, given its recent conceptualization, ongoing evaluation of the Elaborated Environmental Stress Hypothesis is recommended.

Keywords: motor coordination, motor skills, motor proficiency, environmental stress, internalizing problems, anxiety, depression

There is growing recognition that motor skills have a significant role in psychosocial development. The ability to make accurate and coordinated age-appropriate movements enables opportunities for the optimal development of psychosocial wellbeing. Indeed, studies have shown that poor motor skills are associated with a range of negative psychosocial outcomes. More recently, studies have investigated the psychosocial implications of motor skills in both clinical and non-clinical populations; while early studies often focused on the physical deficits experienced by children diagnosed with developmental coordination disorder (DCD). DCD is a neurodevelopmental disorder characterized by poor motor skills that are unrelated to other physical and/or intellectual impairments (American Psychiatric Association, 2013). The prevalence of DCD is estimated to be between 1.8% and 6% of children, making it one of the most pervasive neurodevelopmental disorders (American Psychiatric Association, 2013).

Literature investigating the psychosocial consequences of poor motor skills has only recently experienced significant empirical development. Skinner and Piek (2001) indicated that children (8–10 years) and adolescents (12–14 years) with DCD reported lower self-worth and higher anxiety when compared to their non-DCD peers. In addition, adolescents with DCD reported higher anxiety than children with DCD, suggesting that these psychosocial consequences become more pronounced with age. In their sample of 47 children with DCD, Green et al. (2006) identified a significant proportion of participants were at risk of psychopathology. Children with both poor motor skills and emotional/behavioral difficulties (EBD) have also been identified as having more depressive symptoms and more problematic behaviors than EBD-only children (Heath et al., 2005). Such findings have stimulated further research in this area of investigation.

Within the literature, the etiology and implications of poor motor skills are often investigated from a diagnostic perspective. Analogous to Skinner and Piek (2001), studies often employ a diagnosis of DCD (or 'probable-DCD') to dichotomize their population into those with or without motor coordination problems, and examine differences between the groups. This approach is not without its limitations, but has proven useful within research seeking to investigate the psychosocial consequences of poor motor skills (when poor motor skills are operationalized within a clinical context). Results have indicated that DCD is associated with a range of psychosocial consequences, including less enjoyment in daily tasks (Bart et al., 2011), low self-esteem (Miyahara and Piek, 2006), less developed social support (Smyth and Anderson, 2000; Skinner and Piek, 2001), poor social skills (Kanioglou et al., 2005), social isolation (Smyth and Anderson, 2000), academic underachievement (Alloway, 2007), peer victimization/bullying (Campbell et al., 2012), decreased quality of life (Hill et al., 2011), and physical inactivity (Cairney et al., 2005). Each of these associated difficulties have important links with internalizing problems (anxiety and depression) in their own right. Furthermore, an individual with DCD could be exposed to any combination of these psychosocial consequences that may contribute to the onset and maintenance of internalizing difficulties, and also complicate intervention strategies.

There is consistent support for an association between DCD and internalizing problems from studies that vary in terms of both population and research design. Skinner and Piek (2001) employed a cross-sectional research design and found that children and adolescents with DCD had higher levels of anxiety than those without. The finding that the association between DCD and internalizing problems becomes more pronounced over time was limited by the cross-sectional design. This has since been supported longitudinally by Lingam et al. (2012). In their community sample of 6,902 children, the authors identified that a diagnosis of probable DCD at 7 years of age was associated with depressive symptoms and mental health difficulties at 10 years of age. Sigurdsson et al. (2002) also identified that poor motor skills in childhood were a risk factor for anxiety in adolescence. These findings provide preliminary suggestion that poor motor skills precede the development of internalizing problems. A monozygotic twin study by Piek et al. (2007) was able to account for genetic effects and shared environmental influences in their sample of 24 pairs of monozygotic twins discordant for probable DCD, whilst also controlling for the confounding influence of ADHD. It was found that twins with DCD demonstrated higher levels of depressive symptoms when compared to the unaffected co-twins. The authors suggested that the higher level of internalizing problems could be attributed to the unique environmental experiences of the twin with DCD, such as more negative peer interactions, academic underachievement, and negative self-perceptions (Piek et al., 2007). Such studies provide examples of the growing evidence to support an association between DCD and internalizing problems, although this area of investigation is currently lacking additional meta-analytic support.

Studies that employ the comparison of DCD (or probable DCD) groups to non-DCD groups have made important contributions to our understanding of the association between poor motor skills and internalizing problems. However, this approach does not take into account that motor skills are distributed dimensionally, rather than dichotomously, throughout the population. Subsequently, there has been an increase in studies that have enlisted community samples which reflect the broader spectrum of motor skills. Cross-sectional and longitudinal studies of community samples have indicated a negative association between motor skills and internalizing symptoms across the full spectrum of motor skills; better motor skills are associated with lower levels of internalizing symptomology (Piek et al., 2010; Rigoli et al., 2012; Wilson et al., 2013; Poole et al., 2015). These findings demonstrate that the psychosocial implications of motor skills are present across the full spectrum of ability, promoting further research in community samples. Therefore, this mini-review focuses on understanding the relationship between the full spectrum of motor skills (including DCD and non-DCD populations) and internalizing problems, and how these intermediary psychosocial issues may mediate this association.

Studies investigating the association between motor skills and internalizing problems have been largely empirical. While

the association between motor skills and internalizing problems is well documented, this area is currently limited by a lack of theoretical development underlying the causal nature of this association (Cairney et al., 2013). In this mini-review we discuss the recently proposed Elaborated Environmental Stress Hypothesis by Cairney et al. (2013) that attempts to address this current limitation. A brief overview of the model is provided, before discussing the recent empirical studies evaluating this theoretically driven framework.

THE ELABORATED ENVIRONMENTAL STRESS HYPOTHESIS

The Elaborated Environmental Stress Hypothesis (Cairney et al., 2013) provides a conceptual model (see **Figure 1**) that allows for the testing of causal pathways from motor skills to internalizing problems. This recent framework expanded on the earlier work of Cairney et al. (2010). The Elaborated Environmental Stress Hypothesis illustrates the complex relationship between motor skills and internalizing problems and posits DCD as a primary stressor that exposes the individual to a range of secondary psychosocial stressors (e.g., peer conflict, low social support, poor academic performance, peer victimization, low self-esteem, low self-competence, physical inactivity, and obesity). It is hypothesized that the consistent exposure to these secondary stressors may then give rise to the onset and maintenance of internalizing problems through these potential mediating and moderating variables, whilst also acknowledging that the relationship between motor skills and internalizing problems is likely to be an interaction of both genetic and environmental factors. A more complete description of the model can be found in Cairney et al. (2013).

The Elaborated Environmental Stress Hypothesis was originally developed within the context of children with DCD, and how their poor motor skills may give rise to internalizing problems. However, there is evidence to support the application of the framework across the broader spectrum of motor skills. A negative linear association between motor skills, internalizing problems and other psychosocial variables described in the Elaborated Environmental Stress Hypothesis has been found in community samples (e.g., Wilson et al., 2013; Poole et al., 2015), suggesting that the psychosocial implications of motor skills extend beyond the DCD population. This negative linear association demonstrates that better motor skills are associated with decreased psychosocial problems. This provides important information for prevention and intervention strategies. For example, universal intervention programs that aim to promote motor skills may have psychosocial benefits for the wider population, rather than being limited to only those with DCD (e.g., Piek et al., 2015).

RECENT DEVELOPMENTS

Cairney et al. (2013) provide a comprehensive description of the previous literature that contributed to the development of the Elaborated Environmental Stress Hypothesis. Therefore the present focus is on the recent developments that have occurred since the framework was published. However, where appropriate, some earlier literature is reflected upon in light of these more recent findings. At the time this mini-review was written, the Cairney et al. (2013) framework had been cited 22 times in peer-reviewed literature (*Google Scholar citations, 19 November 2015*). Some of this literature has reflected on the development of the model and its possible use in future studies (e.g., Missiuna and Campbell, 2014), while others have started to provide the empirical evaluation necessary to test this causal framework.

Illustrated in **Figure 1**, the Elaborated Environmental Stress Hypothesis highlights the complex causal network that describes how poor motor skills may lead to internalizing problems. Empirically evaluating this entire framework in a single study presents a range of methodological considerations that make such an approach difficult. These considerations include the response burden for participants, difficulties acquiring a large enough sample size to detect the likely small effects (Wilson et al., 2013), and the complexity of the analyses required to evaluate the full model. Consequently, the Elaborated Environmental Stress Hypothesis is more practically investigated through studies that evaluate a smaller combination of pathways embedded within the broader causal model. This has led to several studies that have since evaluated the various moderating/mediating variables specified by the framework (see **Table 1**).

These studies have used a combination of different samples and research designs, and often provided support for the framework. Wilson et al. (2013) found the relationship between motor skills and internalizing problems in a community sample of 475 young children (4–6 years) to be mediated by social skills. Rigoli et al. (2012) enlisted a community sample of 93 adolescents (12–16 years). Their findings provided further support for the framework; self-perceptions were found to mediate the association between motor skills and internalizing problems. Similar findings have been replicated in a more recent study by Viholainen et al. (2014) with a community sample of 327 female adolescents (12–16 years). Self-concept, specifically related to school-related physical education, was found to mediate the relationship between motor skills and psychosocial wellbeing in this cohort. These results provide further support for this key pathway embedded within the framework.

Recent support for the Elaborated Environmental Stress Hypothesis extends beyond cross-sectional studies. Recent findings by Piek et al. (2015) conducted the first intervention study to evaluate the Elaborated Environmental Stress Hypothesis. The authors use 6 and 18-month follow up data of a 4–6 years old community population who participated in the randomized control trial (RCT) of the *Animal Fun* program (Wilson et al., 2013). The *Animal Fun* program is a 10-week school-based universal intervention program aimed at promoting motor development in 4–6 years old children. Findings from the RCT indicated the intervention group demonstrated significant improvement in prosocial behavior at 6-month follow-up, which remained at 18-month follow up. These results provide support for the pathways in the framework which suggest that interventions to improve motor skills and

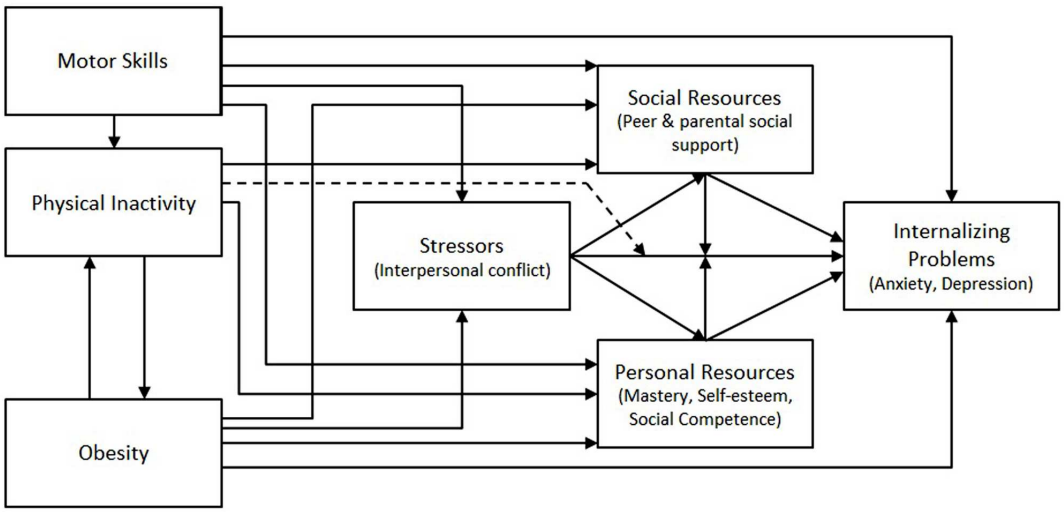

FIGURE 1 | An adapted Elaborated Environmental Stress Hypothesis. This adapted version examines motor skills across the full spectrum of ability; the original Elaborated Environmental Stress Hypothesis described by Cairney et al. (2013) specifically focused on children with developmental coordination disorder (DCD).

TABLE 1 | Summary of recent, peer-reviewed empirical support for the elaborated environmental stress hypothesis by Cairney et al. (2013).

Study	Research design	*N*	Sample type	Key supporting findings
Lingam et al., 2012	Longitudinal	6,902	Community; children (7–10 years)	Motor skills at 7 years of age predict mental health problems at 10 years of age. Poor social skills, peer victimization, self-esteem, and perceived scholastic competence mediate this relationship, in children with probable DCD.
Rigoli et al., 2012	Cross-sectional	93	Community; adolescents (12–16 years)	Self-perceptions mediate the association between motor skills and internalizing problems
Wilson et al., 2013	Cross-sectional	532	Community; children (4–6 years)	Social skills mediate the association between motor skills and internalizing problems
Viholainen et al., 2014	Cross-sectional	327	Community; adolescent females (12–16 years)	Self-concepts mediate the association between motor skills and internalizing problems
McIntyre et al., 2014	Intervention	35	Clinical; adolescents (13–17 years)	Intervention improving exercise in populations with low motor competence also improved their physical self-perceptions
Piek et al., 2015	Intervention	337*	Community; children (4–6 years)	Interventions improving motor skills and participation improve prosocial behavior
Poole et al., 2015	Longitudinal	189*	Community; lifespan (0–40 years)	Childhood motor difficulties predict internalizing problems in adulthood. Limited by retrospective report of childhood motor difficulties at age 29–35 years. Mental health problems measured at 8 years, 22–26 and 29–36 years only.

*N = Total number of participants. *Final sample at final follow-up periods.*

physical engagement will result in secondary improvements in psychosocial areas such as prosocial behavior. Similarly, Bart et al. (2009) found that intervention improving balance reduces anxiety and increased self-esteem in children with comorbid balance and anxiety disorders.

McIntyre et al. (2014) identified that participation in a 13-week physical activity intervention program for adolescents with poor motor skills resulted in an increase in physical self-perceptions, which is congruent with the pathways specified within the framework. A limitation of this study was that no measure of internalizing symptoms was included. However, previous studies have identified that increased physical self perceptions act as a protective factor against internalizing symptoms in similarly aged populations (Rigoli et al., 2012; Wilson et al., 2013; Viholainen et al., 2014).

Longitudinal evaluation of the Elaborated Environmental Stress Hypothesis is currently limited. However, recent longitudinal studies provide support for the causal relationship between motor skills and internalizing problems; this association underpins the entire framework. Lingam et al. (2012) used a

community sample of 6,902 children and identified that motor skills difficulties at 7 years of age were associated with mental health difficulties (including internalizing problems) at 10 years of age; however, mental health difficulties were not measured at 7 years of age which limited the ability to conclude a causal relationship. The authors did identify several mediating variables between motor skills and mental health difficulties which were relevant to the Elaborated Environmental Stress Hypothesis, namely poor social skills, peer victimization, self-esteem, and perceived scholastic competence. More recently, Poole et al. (2015) published the results of a longitudinal study which included measures of motor skills and mental health. Their study provided an indication that childhood coordination problems were associated with internalizing problems in adulthood. However, childhood motor difficulties were reported retrospectively at age 29–35 years, relying on a subjective recount of motor skills. Similarly, mental health problems were only measured at age 8 (parent and teacher report) and self-report at age 22–26 and 29–36 years. Consequently, there is a need for more rigorous longitudinal investigation of motor skills and mental health.

These studies provide some indication that poor motor skills do precede the development of internalizing problems. In addition, they also emphasize that motor difficulties in early childhood are associated with psychosocial issues in later life. However, it is important to note that a current lack of longitudinal studies that consider shared risk factors for internalizing problems and motor skills such as infant emotional regulation and maternal stress limits the ability to make conclusions about the causal relationship between motor skills and internalizing problems as specified by the Elaborated Environmental Stress Hypothesis. Research by Hill and Brown (2013) has contributed qualitative support for the psychosocial impacts of DCD in adulthood. Within the recent developments pertaining to the Elaborated Environmental Stress Hypothesis, it was noted that several of these studies used community samples, moving beyond investigating the DCD population only. Each of these studies were able to provide support for different components of the overall framework. These findings promote the efficacy of the Elaborated Environmental Stress Hypothesis as a theoretical framework that is meaningful across the full spectrum of motor skills (and across the lifespan), rather than limited to DCD in childhood only.

While the framework provides a comprehensive description highlighting poor motor skills as a risk factor for internalizing problems, it is important to recognize the other risk factors that may contribute to the onset of anxiety and depression in childhood. Shaw et al. (1997) identified several risk factors during infancy that were related to the development of internalizing problems at pre-school age. Similarly, low socio-economic status and low birth weight/gestational age have also been identified as both risks for DCD and internalizing problems (Lingam et al., 2009). Such evidence provides a suggestion that these predisposing risk factors for internalizing problems may have similar repercussions for motor development. While the measurement of infant emotional regulation is notoriously difficult, further longitudinal investigations that consider the risk factors for internalizing factors and poor motor skills (e.g., maternal stress and infant emotional regulation) is necessary in order to achieve a better understanding of the association between internalizing problems and motor skills, and to evaluate the Elaborated Environmental Stress Hypothesis.

CONCLUSION

This mini-review has provided an up-to-date appraisal of the Elaborated Environmental Stress Hypothesis by Cairney et al. (2013). The Elaborated Environmental Stress Hypothesis provides a framework to describe how poor motor skills may lead to the development of internalizing problems through a range of secondary psychosocial consequences. The ability to make accurate, coordinated, age-appropriate movements facilitates the ability to meet developmental milestones and foster opportunities for positive social engagement. Consequently, poor motor skills may increase psychosocial difficulties. It is important to recognize that the Elaborated Environmental Stress Hypothesis does not intend to provide a complete explanation of the etiology of internalizing problems, as psychopathology is multi-factorial. Rather, the purpose of this framework is to highlight motor skills as a potentially important factor to consider when understanding the onset of internalizing problems. There is a growing body of empirical support for the framework, using cross-sectional, intervention, and longitudinal research designs. The key finding from this mini-review is that the Elaborated Environmental Stress Hypothesis has utility beyond the DCD population. Studies enlisting community samples have provided evidence supporting the Elaborated Environmental Stress Hypothesis as a useful framework to understand the psychosocial implications of motor skills across the full spectrum of motor skills. This causal framework also provides a useful tool in the development of intervention strategies. Initiatives that aim to improve motor skills can be complemented by psychosocial components that focus on improving the secondary psychosocial stressors of poor motor skills. This has the capacity to buffer the impact of poor motor skills on internalizing problems. The negative linear association between motor skills and psychosocial issues provides support for universal motor skill interventions such as *Animal Fun*. Preliminary findings have shown that implementation of this movement program in children increased psychosocial wellbeing (Piek et al., 2015). Further empirical investigation of the Elaborated Environmental Stress Hypothesis is recommended, as not all of the causal pathways specified in the framework have been empirically tested, particularly using longitudinal designs. Similarly, there is an alternative argument to suggest that shared predisposing risk factors associated with internalizing problems may have similar implications for motor development (e.g., maternal stress, low socioeconomic status); longitudinal studies are required in order to address this argument. Future evaluations of the framework should identify how key pathways may differ across different contexts (e.g., age/gender), which could facilitate the development of more targeted psychosocial interventions. Future research should consider the model developmentally, in order to

identify if these pathways differ across different developmental periods.

AUTHOR CONTRIBUTIONS

VM was the primary author of this study, and wrote the mini-review and received feedback from each of the other supervisors. DR, JC, LR, and JP were all supervisors as part of this PhD research topic. Each of the supervisors provided insight, expertise, and feedback on the paper. They provided several edits and proofreads throughout the refinement of the article.

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Publication Two

Mancini, V. O., Rigoli, D., Roberts, L. D., Heritage, B., & Piek, J. P. (In Press). The relationship between motor skills and psychosocial factors in young children: A test of the elaborated environmental stress hypothesis. *British Journal of Educational Psychology*. doi:10.1111/bjep.12187

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Abstract

Background. The elaborated environmental stress hypothesis (EESH) provides a framework that describes how motor skills may indirectly cause internalizing problems through various mediating psychosocial factors. While there is evidence to support this framework, little is known about how the proposed relationships may vary across different stages of development.

Aims. This study aimed to investigate whether peer problems and perceived self-competence mediated the relationship between motor skills and internalizing problems in pre-primary children, and at 18-month follow up.

Sample. A community sample of 197 pre-primary school children (M = 5.40 years, SD = 0.30 years; 102 males, 95 females) participated at Time 1, with 107 completing the Time 2 follow-up.

Methods. Standardized instruments were used to measure motor skills and verbal IQ. Perceived self-competence was measured using a self-report measure. Participant peer problems and internalizing problems were measured using teacher report. Age, gender, and verbal IQ were included as covariates.

Results. Mediation analysis using PROCESS showed that the relationship between motor skills and internalizing problems was mediated by peer problems at Time 1. At Time 2, the relationship was mediated by peer problems and perceived physical competence.

Conclusions. The current results indicate the EESH may function differently across different periods of development. The transition from pre-primary to Grade 1 represents a time of important cognitive and psychosocial development, which has implications for how the relationship between motor skills and internalizing problems can be understood. These findings highlight potential age-appropriate targets for psychomotor interventions aiming to improve the emotional well-being of young children.

Introduction

There is an important link between motor skills and psychosocial outcomes in childhood. Children with developmental coordination disorder (DCD) are more likely to experience interpersonal difficulties, have decreased self-competence, higher levels of obesity/physical inactivity and internalising problems such as anxiety and depression (Cairney, Rigoli, & Piek, 2013). A diagnosis of DCD may be assigned when the person's motor skills are substantially below that expected given their age and opportunity for development, and that these movement difficulties interfere with activities of daily living, academic performance, leisure, and play. The onset of these symptoms occurs in the early developmental period, and must not be better explained by other conditions (American Psychiatric Association [APA], 2013, p74). Research has recently revealed that the negative association between motor skills and poor psychosocial outcomes is not confined to DCD populations and appears across the full continuum of motor ability (Mancini, Rigoli, Cairney, Roberts, et al., 2016).

As DCD is a risk factor for internalising problems, research has focussed on understanding the mechanisms underlying this association (Missiuna & Campbell, 2014). Furthermore, many of the psychosocial difficulties experienced by those with DCD are also well-established risk factors for internalising problems (Hawker & Boulton, 2000; Sowislo & Orth, 2013). Based on these findings, DCD may be an indirect cause of internalising problems; individuals with DCD experience greater psychosocial difficulties and the presence of such difficulties result in greater internalising problems (Cairney et al., 2013). This notion underpins the Elaborated Environmental Stress Hypothesis (EESH; Cairney et al., 2013). DCD is thought to be a primary cause of several secondary 'environmental stressors' that manifest in either interpersonal difficulties (e.g. peer problems) or intrapersonal difficulties (e.g. low perceived self-competence). The presence of these secondary stressors mediate

and/or moderate the relationship between motor skills and internalising problems (Cairney et al., 2013). Studies using community populations have also provided evidence supporting this indirect relationship (e.g. Mancini, Rigoli, Heritage, et al., 2016; Wagner et al., 2012).

Though originally conceptualised as a possible explanation of the presence of internalising problems in children with DCD, many of the relationships posited by the EESH have also been identified in community populations of children, and older samples of adolescents and adults (Mancini, Rigoli, Cairney, et al., 2016). These findings support the flexibility of the framework to identify the impact of environmental stressors under a variety of different circumstances and contexts (Cairney et al., 2013). Studies that enlist community samples are particularly important in this area, given the difficulty in clearly defining developmental disorders such as DCD (Chen, Tseng, Hu, & Cermak, 2009; Hattori et al., 2006). Furthermore, the generalization of findings from studies using clinical samples may lead to the overestimation of the strength of the association between variables in community populations who experience less severe, but still problematic, symptoms (Rigoli et al., 2012). Intervention studies have also shown that the benefits of psychomotor interventions are not limited to only those with clinical motor difficulties (Piek et al., 2015).

As the EESH is comprised of relationships between numerous psychosocial factors, it is most commonly evaluated through studies that examine select components of the framework (e.g. Rigoli et al., 2016). Previous research has indicated that both intrapersonal and interpersonal factors mediate the association between motor skills and internalising problems, but seldom in a single study (e.g. Rigoli et al., 2012; Wilson, Piek & Kane, 2013). Including both types of factors in a single research design allows researchers to identify if one psychosocial factor is a stronger (or weaker) mediator than the other. Perceived self-competence in both physical and cognitive domains have been previously identified to mediate the relationship between motor skills and internalising problems (Rigoli et al., 2012).

Though perceived self-competence may also comprise other areas, physical and cognitive competence are most relevant to the interference in activities of daily living and academic performance that are diagnostic requirements of DCD (APA, 2013, p74). Individuals with DCD perceive themselves as less competent physically when compared to their typically developing peers (McIntyre et al., 2014; Miyahara & Piek, 2006). In addition, they experience greater academic difficulties and perceive themselves as having lower cognitive competence (Alloway, 2007; Dewey, Kaplan, Crawford, & Wilson, 2002; Engel-Yeger & Hanna Kasis, 2010). Both dimensions of perceived self-competence are inversely associated with greater internalising difficulties (Sowislo & Orth, 2013; Vannatta, Gartstein, Zeller, & Noll, 2009). Therefore, these domains were included in the current study.

Peer problems have also been identified as a mediator in previous research (e.g. Wagner et al., 2012; Wilson et al., 2013). For example, the ability to perform well in sports and games is highly regarded by children (Livesey, Lum Mow, Toshack, & Zheng, 2011). It is not uncommon for children with DCD to have trouble in these areas, which can lead to peer victimization and rejection from their peers, which also predict internalising problems in children with DCD (Campbell, et al., 2012). Other studies have also identified similar relationships where peer problems mediate the relationship between motor skills and internalising problems in community samples of children (Wagner et al., 2012; Wilson et al., 2013). Improved perceived self-competence and peer relationships have also been identified as potential targets in psychomotor interventions that aim to improve motor skills and psychosocial outcomes in children (Piek et al., 2010). Consequently, these factors have been included in the current study to examine the extent to which they mediate the relationship between motor skills and internalising problems.

Motor skills and emotional regulation may also have shared biological underpinnings rather than a cause-and-effect relationship (Nicolson, Fawcett, & Dean, 2001). However,

monozygotic twin and sibling studies which account for shared biological influences have found that twins or siblings with movement difficulties report greater internalising problems compared to their non-affected twin/sibling (Moruzzi et al., 2010; Piek et al., 2007; Waszczuk et al., 2016). This highlights the importance of unique environmental factors experienced by those with poor motor skills, such as those posited in the EESH. Furthermore, longitudinal studies have found that poor motor skills in childhood are predictive of greater internalising problems in later life (Lingam et al., 2012; Sigurdsson, Van Os, & Fombonne, 2002). In the current study, we adopt an understanding consistent with the majority of recent studies in which a causal association between motor skills and internalising problems is widely theorised (Cairney et al., 2013). Though correlational and cross-sectional designs may be unable to allow for causal conclusions, they serve to efficiently identify possible targets for experimental methodologies that can determine cause-and-effect associations.

The early childhood period (4 to 6 years) is characterised by key developmental changes. Children at this age are in the early-to-mid preoperational stage of cognitive development, meaning they are largely egocentric (Piaget, 1970). Therefore, they often lack the metacognitive skills necessary make accurate comparative judgements and tend to provide inaccurate (often unrealistically positive) self-perceptions (Marsh, Ellis, & Craven, 2002). However, important cognitive developments result in the child developing more accurate self-judgements as they enter the concrete operational stage of development, typically occurring around 7 years of age (Piaget, 1970). Parallel with these cognitive developments, this period is also characterised by important psychosocial developments for most children, namely attending school. Though the age at which children begin formal schooling may vary, the tasks undertaken at school become more demanding as the child progresses from early childhood into later stages of childhood education. In conjunction with increased cognitive demands, schooling in later childhood also features increased demands on

both fine and gross motor skills. For example, children will develop and refine their handwriting skills and take part in structured play that requires coordinated movement such as ball sports. This increased demand compared to schooling in early childhood may result in movement difficulties being more easily noticed (Barnett, 2014; Cairney, Hay, Faught, Wade, et al., 2005). Children with poor motor skills may begin to perceive themselves as less competent than their typically developing peers. At the same time, these peers may start to recognise children with limited motor skills, which increase the risk of interpersonal problems such as peer victimization (Campbell et al., 2012; Piek et al., 2005). These important psychosocial developments may have implications for the mechanisms through which motor skills impacts internalising problems posited by the EESH; the strength of the relationships within the EESH may vary during different stages of development (Mancini, Rigoli, Cairney, et al., 2016). Perceived self-competence during early childhood may not mediate the relationship between motor skills and internalising problems but has been shown to in adolescent populations (Rigoli et al., 2016).

It is currently unclear if these hypothesised differences between age groups can be attributed to different stages of development, or due to the use of different participants in each study. Longitudinal studies in this area often use a childhood measure of motor skills to predict levels of internalising problems at a later date (Sigurdsson et al., 2002). However, longitudinal methodologies may not be able to answer research questions which ask how these hypothesised relationships may vary across different points in time. This highlights the need for correlational and cross-sectional research designs which examine how relationships contained within the EESH may vary between different stages of development, the results of which can then be used to identify age-specific targets for intervention. The current study provided a novel solution to answer this research question by first testing the relationship between motor skills, perceived physical competence, perceived cognitive competence and

internalising problems of a sample of pre-primary aged children. Each of these variables were then measured again 18-months later, when these children had entered formal schooling. This allowed us to examine any model invariance between the two time points.

The current study aimed to test a key set of relationships posited by the EESH in a community sample of young children aged 4 to 6 years. This period is a crucial stage of motor and psychosocial development (Newman & Newman, 2014). It was hypothesised that a relationship between motor skills and internalising problems would be mediated by peer problems, perceived physical competence and perceived cognitive competence. Relationships between each pairing of these variables have been previously examined, but not in a single study. Therefore, it is not yet known whether these hypothesised mediating relationships contained within the EESH are supported empirically. Possible covariates such as age, gender and verbal IQ have been identified in previous research and are controlled in the current study (Wilson et al., 2013). Data were collected at two time-points spanning an 18-month period.

Method

Participants

Participants were recruited as part of a larger study evaluating a school-based psychomotor intervention program for young children, involving 12 schools located in metropolitan Western Australia (Piek et al., 2010). Children for this study were drawn from the control population only, to avoid contamination effects of the intervention received by the treatment group. Participation in the current study relied upon the completion of both child-rated and teacher-rated measures of psychosocial variables. Twenty-four participants were omitted from the current study due to the non-completion of measures. An additional three participants were excluded due to previously diagnosed physical or developmental difficulties that could impact their performance on outcome measures.

The final sample comprised a community sample of 197 children (102 males, 95 females) between 4 and 6 years of age who were enrolled in pre-primary school at Time 1 (*M*= 5.40 years, *SD* = 0.30 years). From this initial sample, 107 children (57 males, 50 females) now in Grade 1 completed the 18-month follow-up at Time 2.

Measures

Bruininks–Oseretsky Test of Motor Proficiency, Second Edition-Short Form (BOT-2SF) (Bruininks & Bruininks, 2005). The BOT-2SF is a standardised assessment used to measure a wide range of motor skills in individuals aged 4 to 21 years. Administered by a trained professional, the BOT-2SF is composed of 14 items taken from the long form which provide a composite score of general motor ability. The BOT-2SF is recommended for use in research settings, due to its quicker administration time (15-20 minutes) and high correlation with the long form (*r*= .80) (Bruininks & Bruininks, 2005). Standardised scores on the BOT-2SF range from 0 to 88; a score of ≤ 40 on the BOT-2SF indicates the child is at-risk of DCD. The present study used the total point score, as age and gender were statistically controlled in the proposed model. Previous studies indicate the BOT-2SF reports favourable reliability and validity (Bruininks & Bruininks, 2005; Tan, Parker, & Larkin, 2001).

Strength and Difficulties Questionnaire (SDQ) (Goodman, 1997). The SDQ is an informant-rated screening tool used to identify psychosocial problems in individuals aged 4 to 16 years. The SDQ contains 25 items measuring 5 subscales (conduct problems, inattention/hyperactivity, emotional symptoms, peer problems, and prosocial behaviour). Informants rate their level of agreement which each item using a 3-point scale (0 = *not true*, 1 = *somewhat true*, 2 = *certainly true*). This study used the teacher-rated version of the SDQ, and included the 'peer problems' subscale. Scores range from 0 to 10 with higher scores reflecting greater peer problems. The SDQ is widely used and reports good psychometric properties (Goodman, 2001; Stone et al., 2015).

The Pictorial Scale of Perceived Competence and Acceptance (PSPCSA) (Harter & Pike, 1984). The PSPCSA is one of few self-report measures of perceived competence and acceptance suitable for young children aged 4 to 7 years. The measure contains 24 items which measure 4 subscales (cognitive competence, physical competence, peer acceptance, and maternal acceptance). Children respond to statements accompanied by a supporting visual illustration using a 4-point scale; a score of 1 indicates the least amount of perceived competence, and a score of 4 indicating the highest amount of perceived competence. This study included the physical competence and cognitive competence subscales. Subscale scores (calculated using the mean of subscale items) range from 1 to 4, with higher scores reflecting greater perceived competence. The PSPCSA has been previously shown to have good reliability and validity (Harter & Pike, 1984; Mantzicopoulos, French, & Maller, 2004).

Social Skills Rating System (SSRS) (Gresham & Elliot, 1990). The SSRS is an informant-rated assessment used to measure social competence and problem behaviours in children aged 5 to 11 years. The measure contains 49 items which measure four social skill subscales (cooperation, assertion, responsibility, self-control) and two problem behaviour subscales (externalizing problems, internalising problems). Informants use a 3-point scale (0 = *never*, 1 = *sometimes*, 2 = very *often*) to rate the frequency of the child's behaviours. This study used the teacher-rated version of the SSRS, and included the internalising problems subscale only. Total scores range from 0 to 12. Higher scores reflect greater internalising problems. The SSRS reports favourable reliability and validity (Gresham & Elliot, 1990; Wilson et al., 2013).

Wechsler Preschool and Primary Scale of Intelligence, Third Edition - Revised (WPPSI-III) (Wechsler, 2002). The WPPSI-III is a standardised assessment of intelligence in children aged 2.5 to 7.25 years. Administered by a trained professional, children complete 14 subtests which yield a full-scale IQ, verbal IQ (VIQ), and performance IQ. This study

included the prorated VIQ subscale as a control variable in the model. The WPPSI-III has excellent psychometric properties and is regarded as the 'gold standard' measure of intelligence for young children (Wechsler, 2002).

Procedure

This study adhered to the ethical guidelines of the National Health and Medical Research Council of Australia, and was granted approval by the University Human Research Ethics Committee. Informed consent was obtained from participating schools, parents, and children involved in the study. The BOT-2SF, PSPCSA and WPPSI-III were administered over two sessions, by trained professionals over a two-week testing period at each school. In order to avoid fatigue, children were administered one to two tests per session. Each session lasted approximately 60 minutes. The SDQ and SSRS for each child were completed by their teacher.

Data Analysis

All data were analysed using version 22.0 of SPSS. Mediation analysis was conducted using the PROCESS macro (Hayes, 2013). The initial sample size (n = 197) met the recommended sample size estimate of 10 participants per parameter in the current mediation model comprised of 12 parameters (Kline, 2011). Due to participant attrition, the sample size at follow-up (n = 107) falls short of this recommendation. To improve the confidence in these effects, the current analysis used bootstrapping procedures that use a sample replacement strategy to create a large sample from the original data (10,000 iterations). Bootstrapping is amongst the most powerful methods to detect mediation (Preacher & Hayes, 2008). The statistical significance of the direct and indirect effect of each model was estimated using 95% bias corrected and accelerated (BcA) confidence intervals (CI); the interval must not contain a zero to assume a significant indirect effect (Hayes, 2013). This method is robust to non-normality of variables, and has been previously used in research investigating the

mediating effect of perceived social support on the relationship between motor skills and internalising problems in a community adolescent sample (Hayes, 2013; Mancini, Rigoli, Heritage, et al., 2016).

While a half-longitudinal design (Cole & Maxwell, 2003) was considered to examine the mediation models tested in our analyses, no evidence of Time 1 Motor Control predicting Time 2 Internalising Problems (after controlling for T1 internalising problems; i.e., *c*, or the total direct effect between measurement periods) was found, $F(2, 104) = 1.522$, $p = .223$. Therefore, we examined the prospect of model invariance examined cross-sectionally and elaborate on this finding in the Discussion.

Results

Descriptive Statistics

Means, standard deviations, observed range of scores, and reliability coefficients (where calculable) are presented in Table 1. Seven participants (3.5% of the initial sample) at Time 1 were identified as at-risk of DCD (at or below the 15th percentile), which is slightly lower than the population estimates of 5-6%. At Time 2, seven participants (6.5% of the Time 2 sample) were identified as at-risk of DCD. Two participants were identified as at-risk of DCD at both time-points. After controlling for age, gender, and VIQ, a significant weak negative association between motor skills and internalising problems was identified at both Time 1 and Time 2. Partial correlations between all study variables are provided in Table 2.

TABLE 1 HERE

TABLE 2 HERE

Participant Attrition

Approximately 45% ($n = 90$) of the original sample at Time 1 did not participate at Time 2. To identify if there were any differences between the retained and drop out samples, an independent samples t-test compared the Time 1 data of participants who dropped out ($n =$

90) to those who provided data at both time points (n = 107). Results indicated that there were no significant differences between groups on any of the measurement variables included in the present study, suggesting dropout was not systematic in nature.

Model Testing

Time 1 Model. In combination, the predictors included in the Time 1 model account for 45.18% of the variance in internalising problems, Model R^2 =.45, $F(7, 189) = 22.25$, $p<.001$, f^2 =0.82 (large effect). There was a significant indirect effect of motor skills on internalising problems via peer problems; b = -0.05, 95% *BcA CI* = -0.080 to -0.020. There was no significant indirect effect of motor skills on internalising problems via perceived physical competence or perceived cognitive competence; the confidence intervals for both these indirect pathways contained 0. The direct association between motor skills and internalising problems was no longer significant following the inclusion of the covariates and mediator variables; c' = -.001, 95% *BcA CI* = -0.03 to 0.03. In summary, the relationship between motor skills and internalising problems at Time 1 was mediated by peer problems, but not by perceived physical competence, or perceived cognitive competence. These relationships are presented in Figure 1.

FIGURE 1 HERE

Time 2 Model. For the data collected at 18-month follow-up, the predictors in this model accounted for 35.65% of the variance in internalising problems, Model R^2 = .36, $F(7, 99) = 7.83$, $p<.001$, f^2 =0.56 (large effect). Similar to the Time 1 model, there was a significant indirect effect of motor skills on internalising problems via peer problems; b = -0.07, 95% *BcA CI* = -0.31 to -0.11. There was an also an additional indirect effect via perceived physical competence; b = -0.01, 95% *BcA CI* = -0.040 to -0.002. There was no significant indirect effect via perceived cognitive competence. The direct association between motor skills and internalising problems at Time 2 was no longer significant

following the inclusion of the covariates and mediator variables, *c'*= 0.02, *BcA CI* = -0.030 to 0.070. In summary, the relationship between motor skills and internalising problems at 18-month follow-up was mediated by both peer problems and perceived physical competence.

FIGURE 2 HERE

Discussion

This study aimed to evaluate a key set of pathways contained within the EESH (Cairney et al., 2013). It was hypothesised that the relationship between motor skills and internalising problems in a community sample of young children would be mediated by peer problems, perceived physical competence, and perceived cognitive competence. This relationship was examined at two time-points spanning an 18-month period between early childhood and later childhood, to examine if this relationship varies across different stages of development. Results indicated that motor skills did not have a direct impact on internalising problems at either time-point after accounting for confounding factors (age, gender, and VIQ). Rather, motor skills indirectly impacted internalising problems via peer problems at Time 1, and via peer problems and perceived physical competence at Time 2. This study provided support for the EESH, as well as highlighting important implications for its application in community populations of young children.

A relationship between motor skills and internalising problems underpins the EESH. The current results elaborated on previous research that has identified this relationship across clinical populations (Skinner & Piek, 2001) and the full continuum of motor ability (Mancini, Rigoli, Cairney, et al., 2016). Peer problems was found to mediate the relationship between motor skills and internalising problems in the current community sample at Time 1 and Time 2. This is consistent with the EESH and previous studies that have found interpersonal factors (e.g. social skills and peer problems) to mediate this association (Bart, Hajami, & Bar-Haim, 2007; Francis & Piek, 2003; Wagner et al., 2012; Wilson et al., 2013). We also found a

stronger relationship between motor skills and peer problems at Time 2 than Time 1, suggesting that motor skills may become an increasingly important predictor of interpersonal problems throughout development. This is plausible, given the increased physical demands of children inside the classroom (e.g. handwriting) and outside the classroom (e.g. structured and unstructured play) throughout childhood. The ability to meet these demands are crucial in the development of social skills and positive peer interactions (Barnett, 2014; Cairney, Hay, Faught, Wade, et al., 2005; Smyth & Anderson, 2000). Consequently, children with poor motor skills may experience greater peer difficulties as they continue to struggle to meet the increasing physical demands of childhood and schooling. This is important, as peer problems are a well-established risk factor for internalising problems in children (Ladd & Troop-Gordon, 2003; Reijntjes, Kamphuis, Prinzie, & Telch, 2010). Studies using older samples of DCD (Hill, Brown, & Sorgardt, 2011) and community populations (Rigoli et al., 2016) have further highlighted the long-term role of interpersonal factors in the relationship between motor skills and internalising problems.

Perceived physical competence only mediated the association between motor skills and internalising problems at Time 2. This highlights an additional pathway in which motor skills are associated with internalising problems in later childhood compared to early childhood, supporting the importance of the developmental transition from pre-primary to formal schooling (Marsh et al., 2002; Piaget, 1970). During early childhood, children may not yet have developed an accurate sense of their competence. However, in later childhood, they reach important cognitive milestones that allow for a more refined sense of perceived self-competence. For children with poor motor skills, they may begin to see themselves as less physically competent than their peers. This is particularly important as perceived physical competence is an important predictor of internalising problems in primary school children (Orth, Robins, & Widaman, 2012; Ulrich, 1987). Perceived physical competence may be an

important target in psychomotor interventions with primary school-aged children. In one intervention study, McIntyre et al. (2014) found that improving motor skills resulted in improved perceived physical competence in an adolescent sample. Similar interventions could consider targeting a younger population and should also include internalising problems as an additional outcome measure.

Perceived cognitive competence did not mediate the association between motor skills and internalising problems in the current study. No significant relationship between motor skills and perceived cognitive competence was found. This is contrary to previous research which had found that primary school-aged children and adolescents with poor motor skills have lower levels of perceived cognitive competence compared to their peers (Miyahara & Piek, 2006; Viholainen et al., 2014). However, these studies enlisted older samples of children, where cognitive ability may be a more important determinant of self-competence (e.g., comparisons of test scores with peers). Another possibility is that the physical demands at school at Time 2 may not yet be demanding enough for children with poor motor skills to fall behind noticeably, as participants had just entered their first year of formal schooling where these skills begin to be refined. For example, children with DCD often report difficulty handwriting, which can contribute to academic underachievement as they fall behind in school (Piek et al., 2007). Future research could examine the role of perceived cognitive competence in an older sample of children who are required to use more refined motor skills during schooling.

The current study found weaker associations between motor skills and both domains of perceived self-competence than previous studies. One possible explanation may be that this research used a younger sample of children. However, methodological explanations should also be considered. The poor levels of internal reliability of the measures of perceived self-competence used in this study is a noteworthy limitation. There are several theoretical

and measurement issues regarding the measurement of young children's self-competence (Strein & Simonson, 1999) and the current study further highlights the issue. Despite these issues, the PSPCSA is one of few self-report measures suitable for this target population, and is widely used (Mantzicopoulos et al., 2004). The use of bootstrapping procedures was used to minimize the prospect of unreliable point estimates. However, it is plausible that the high levels of measurement error in both perceived physical competence and cognitive competence may have attenuated the true relationship between variables.

The two periods of data collection allowed us to test the hypothesised model at two different time points using the same sample of participants. Previous cross-sectional studies often examine a sample at one point in time only (e.g. Wilson et al., 2013). Unlike longitudinal studies that seek to understand how one variable at an initial point in time can predict another variable at a later point in time (Lingam et al., 2012), the current study examined possible model invariance across time points. Future studies using a larger sample may be able to employ more powerful statistical procedures to test for model invariance or longitudinal changes. The current results support a change in the type of relationship between variables at Time 2 compared to Time 1.

The mediation model examined in the current study cannot be used to imply causality; instead, it supports the validity of causal arguments related to the EESH. Missiuna and Campbell (2014) recommended that evidence-based interventions be used as a means of establishing causal pathways, while also providing support to populations in need of psychomotor intervention. Preliminary evidence suggests that psychomotor intervention programs can improve motor skills, self-concept, and report a trend towards lower anxiety (Peens, Pienaar, & Nienaber, 2008). The current findings provide direction for tailoring age-appropriate psychomotor intervention/prevention programs. Specifically, interventions for young children could promote positive peer interactions that could be combined with efforts

to improve perceived physical competence for older children. School-based intervention programs can also facilitate an awareness of the link between motor skills and psychosocial difficulties for teachers who may work to enhance protective factors for students with movement difficulties. For example, facilitating environments to enhance interpersonal skills or self-competence.

While significant, the variables included in the current study accounted for only a moderate proportion of variance in participants' internalising problems. This is consistent with the understanding that the aetiology of child psychopathology is multi-factorial (Koplewicz & Klass, 1993). Furthermore, the decision to enlist a teacher-rated screening measure of peer problems also limits the current findings. Measures of psychosocial functioning may differ between informants (De Los Reyes & Kazdin, 2005), and the SDQ Peer Problems subscale only comprises five items that capture a broad domain of interpersonal difficulties such as peer victimization, social skills and social isolation (Goodman, 1997). Future research could include multiple-informant measures and more comprehensive measures of interpersonal difficulties.

The EESH framework includes additional psychosocial factors that were beyond the scope of the current study (e.g. stress, physical activity, social support). There is preliminary evidence to support the role of these factors (Cairney et al., 2013). However, further evaluation is important; these factors may account for additional variance in internalising problems and may similarly differ across stages of development. As the aim of current study was to test a specific component of the framework proposed by Cairney et al. (2013), only internalising problems was included as an outcome variable. However, recent studies have suggested that motor skills may also be a plausible cause of externalizing problems (King-Dowling et al., 2015; Wagner et al., 2012). Future studies may utilize the EESH as a

framework to understand the impact of motor skills on both internalising and externalizing problems.

Conclusion

The current study provided support for indirect relationships between motor skills and internalising problems via peer problems (at early childhood and later childhood), and perceived physical competence (at later childhood only). This provides support for the EESH and has important implications for our understanding of the framework; relationships specified in this framework may differ across stages of development. These findings also highlight the importance of age-appropriate targets in psychomotor interventions. Future research is required to further understand how the indirect relationship between motor skills and internalising problems may vary between other key stages of development.

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Table 1

Descriptive Statistics for the Study Variables at Initial Data Collection (Time 1) and 18-Month Follow-up (Time 2)

	Time 1 (N = 197)				Time 2 (N = 107)			
	M	*SD*	Range	α	*M*	*SD*	Range	α
Motor Skills (Total Score) [a]	46.32	9.87	9 – 69	-	61.44*	7.95	30 – 73	-
Motor Skills (Standard Score)	55.52	7.91	9 – 76	-	57.56*	9.00	33 – 75	-
Peer Problems	1.33	1.84	0 – 8	.733	0.95	1.43	0 – 6	.714
Perceived Physical Competence	3.24	0.53	1.50 – 4	.600	3.43*	0.45	2.17 – 4	.461
Perceived Cognitive Competence	3.48	0.42	2 – 4	.556	3.61*	0.30	2.67 – 4	.343
Internalizing Problems	2.22	2.52	0 – 11	.874	1.82	2.07	0 – 8	.838
Age (years)	5.40	0.30	4.86 – 6.07	-	6.91	0.28	6.36 – 7.47	-
Verbal IQ	94.46	12.22	72 – 130	-	94.50	11.68	72 – 130	-

Note. *Significant difference between Time 1 and Time 2 mean scores, calculated using paired samples *t* test (p<.05). [a] Total score was used as age and gender were statistically accounted for in the model.

Table 2

Partial Correlations Between Study Variables, After Controlling for Age, Gender, and Verbal IQ at Initial Data Collection (Time 1) and 18-month Follow-up (Time 2).

	Time 1 (*N* = 197)					Time 2 (*N* = 107)				
	1	2	3	4	5	1	2	3	4	5
1. Motor Skills	-					.675**[a]				
2. Peer Problems	-.299**	-				-.420**	.316**[a]			
3. Perceived Physical Competence	.133	-.114	-			.203*	-.116	.454**[a]		
4. Perceived Cognitive Competence	.157	-.173*	.539**	-		-.012	-.078	.254**	.200*[a]	
5. Internalizing Problems	-.168*	.610**	.066	.012	-	-.196*	.553**	-.234*	-.093	.194*[a]

Note. *p<.05. **p<.001. [a] Zero-order correlation between Time 1 and Time 2 observations of variable.

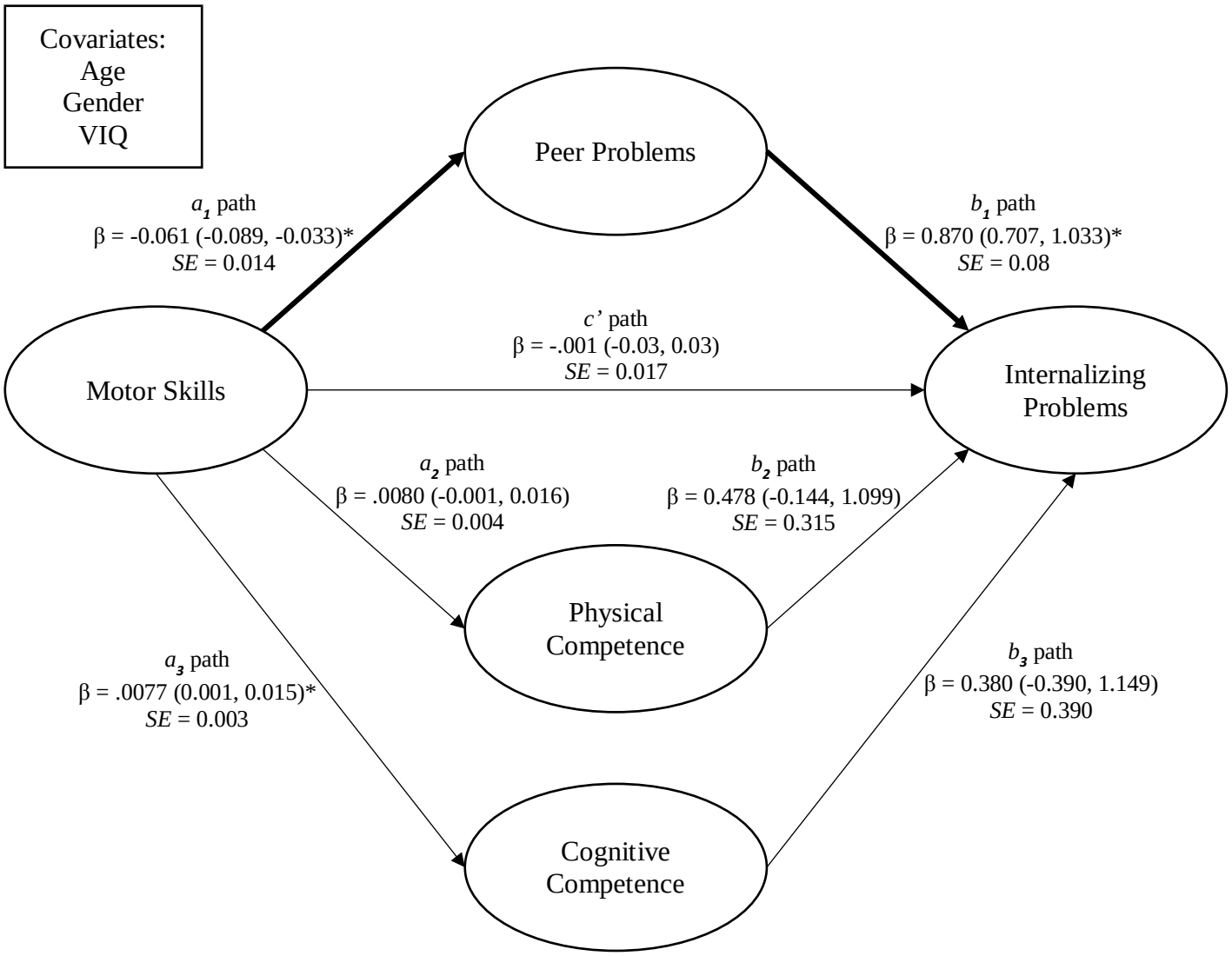

Figure 1. Mediation model in which peer problems mediates the association between motor skills and internalizing problems in a sample of children aged 4 – 6 years (*N* = 197). Mediation pathway is depicted in bold. 95% bias-corrected accelerated confidence intervals are provided in parentheses. β = standardized coefficient; SE = standard error. **p*<0.05.

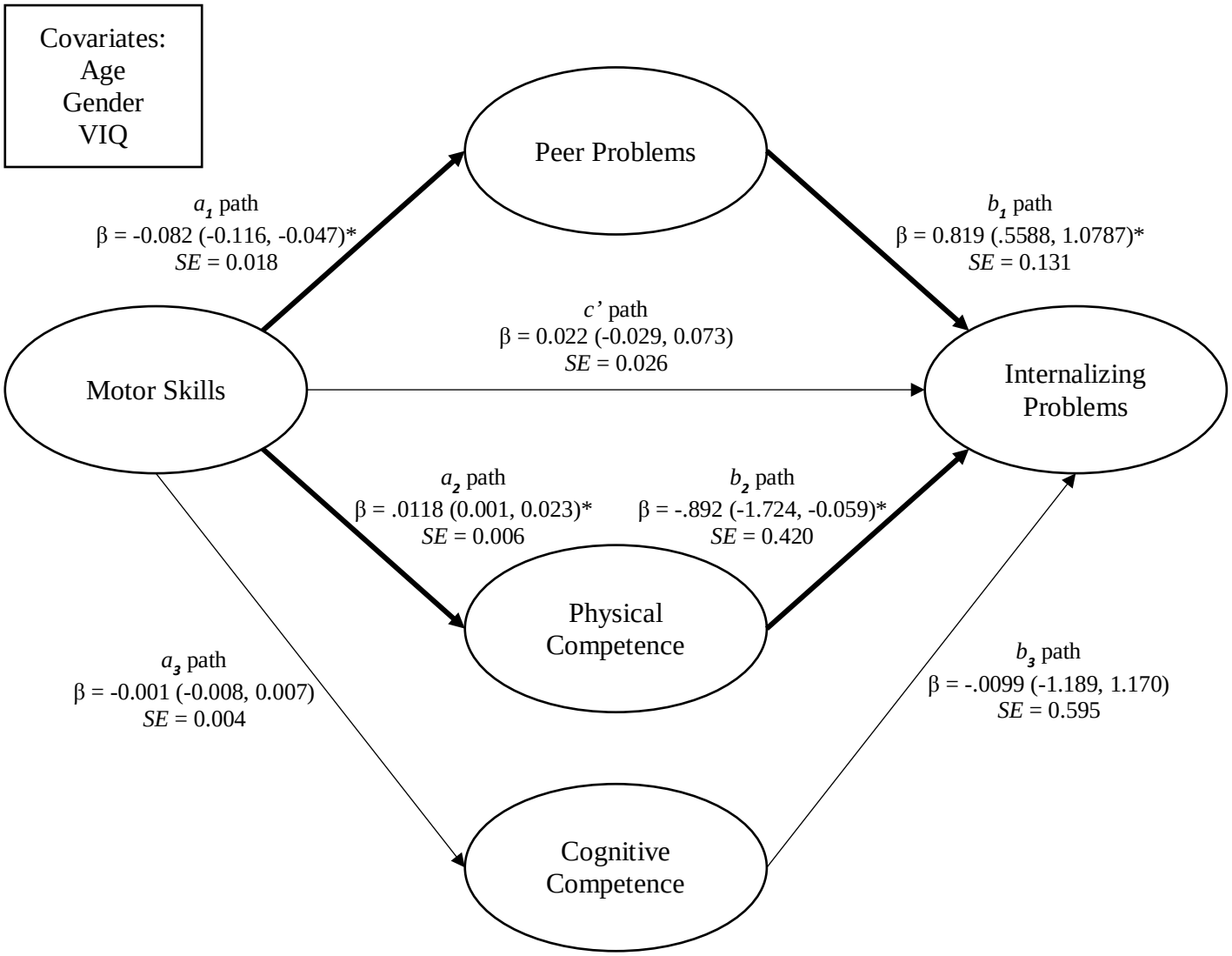

Figure 2. Mediation model in which peer problems and perceived physical competence mediates the association between motor skills and internalizing problems in a sample of children at 18-month follow up, now aged 4.5 to 7.5 years (N = 107). Mediation pathways are depicted in bold. 95% bias-corrected accelerated confidence intervals are provided in parentheses. β = standardized coefficient; SE = standard error. *p<0.05.

Publication Three

Mancini, V. O., Rigoli, D., Roberts, L. D., Heritage, B., & Piek, J. P. (In Press). The relationship between motor skills, perceived self-competence, peer problems and internalizing problems in a community sample of children. *Infant and Child Development.* doi:10.1002/icd.2073

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The Relationship between Motor Skills, Perceived Self-Competence, Peer Problems and Internalizing Problems in a Community Sample of Children

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Abstract

Poor motor skills have been associated with a range of interpersonal and intrapersonal difficulties, including poor self-competence, peer problems, and internalizing problems such as anxiety and depression. The Elaborated Environmental Stress Hypothesis provides a theoretical framework for understating these relationships. Studies have recently begun to evaluate this framework; however ongoing empirical investigation is required. Currently, the extent to which these relationships may differ across factors such as gender remains unclear. The current study tests an indirect effect of motor skills on internalizing problems via peer problems and perceived self-competence in a community sample of 164 children (81 male; 83 female) aged 7 to 12 years. A combination of clinician-administered, self-report and parent-rated measures were used. Regression analysis using PROCESS indicated that the relationship between motor skills and internalizing problems was not moderated by gender. Motor skills did have an indirect effect on internalizing problems via perceived scholastic competence and peer problems. Results provide partial support for part of the Elaborated Environmental Stress Hypothesis; perceived scholastic competence and peer problems are mechanisms through which motor skills are related to internalizing problems in school-aged children. This study highlights potentially important targets for psychomotor interventions for this age group.

Keywords: Motor Skills, Environmental Stress Hypothesis, Psychosocial, Internalizing Problems, Perceived Self-Competence, Peer Problems

Introduction

Studies have highlighted an important link between motor skills and psychosocial outcomes in children (Mancini, Rigoli, Cairney, Roberts, & Piek, 2016). It has been shown that children with poor motor skills, such as developmental coordination disorder (DCD; American Psychological Association, 2013) are at greater risk for a range of both interpersonal (e.g. peer victimization, poor social skills, low levels of social support) and intrapersonal (e.g. low self-competence) psychosocial difficulties (Missiuna et al., 2014). While each of these difficulties may be problematic for a child's overall wellbeing, they may also contribute to the development of additional issues such as internalizing problems including anxiety and depression (Lingam et al., 2012; Skinner & Piek, 2001). As children with poor motor skills such as DCD may experience a range of these psychosocial difficulties, it is not surprising that these children often report higher levels of internalizing problems compared to their typically developing peers (Skinner & Piek, 2001). This association has also been found in adolescent and adult age groups (Skinner & Piek, 2001; Hill & Brown, 2013). Furthermore, childhood motor skills are predictive of psychosocial functioning in later life (Piek, Barrett, Smith, Rigoli, & Gasson, 2010; Sigurdsson, Van Os, & Fombonne, 2002). In one example, Hill and Brown (2013) compared a sample of adults diagnosed with DCD in childhood to a sample of typically developing adults. The DCD sample reported greater internalizing problems in adulthood compared to their typically developing counterparts.

Within the motor coordination literature, there are several interchangeable definitions that have been used to describe populations of children characterized by having significant problems with motor coordination (e.g. DCD, motor impairment, movement difficulties, motor coordination problems, at-risk for DCD). While some studies use multiple sources and the full diagnostic criteria to identify cases, most research studies do not (Cairney, Rigoli, & Piek, 2013). Regardless of the terminology used, each of these studies define a group of individuals based on the presence of poor motor skills. However, to avoid confusion with the studies that have used the full diagnostic criteria to identify DCD, we use the term 'poor motor skills' in this paper to encompass studies that use differing terminology and operationalization.

Though a relationship between motor skills and internalizing problems has been well-established across a range of research designs and populations, less is known about why this relationship exists. One possible explanation is that the abilities to make coordinated movements and to regulate emotions are underpinned by shared biological factors (Nicolson,

Fawcett, & Dean, 2001). However, given that psychopathology is multi-factorial, environmental factors have also been cited as having an important role in the development of internalizing problems (Koplewicz & Klass, 1993; Moruzzi et al., 2010; Pearsall-Jones et al., 2011).

Growing evidence supports the important role of unique environmental factors in the relationship between motor skills and internalizing problems (Pearsall-Jones et al., 2011; Waszczuk, Leonard, Hill, Rowe, & Gregory, 2016). For example, a monozygotic twin study by Piek et al. (2007) compared the depressive symptomology of 24 pairs of monozygotic child and adolescent twins who were discordant for DCD. After accounting for shared genetic and environmental influences, results indicated that the twins with DCD reported higher levels of depression compared to their unaffected sibling. The authors posited that the twins with DCD experienced higher levels of depression as their poor motor skills exposed them to unique environmental experiences that were not experienced by their unaffected sibling. It was posited that these unique environmental experiences included the development of poor self-perceptions, negative peer relations and lower levels of social support (Piek et al., 2007).

The recently proposed Elaborated Environmental Stress Hypothesis (Cairney et al., 2013) is a causal framework that offers one explanation as to why children with poor motor skills are at greater risk of internalizing problems. According to this framework, the presence of poor motor skills exposes the child to interpersonal and intrapersonal psychosocial consequences (e.g. difficulties with peers, poor self-competence), and these psychosocial consequences subsequently contribute to the development of internalizing problems (Cairney et al., 2013). Negative interpersonal and intrapersonal experiences are both well-established risk factors for internalizing problems. The Elaborated Environmental Stress Hypothesis acknowledges that while there may be a direct association between poor motor skills and internalizing problems (e.g., via shared biological factors), the relationship between motor skills and internalizing problems is largely indirect; these psychosocial factors mediate/moderate this relationship.

This framework (see Cairney et al., p. 233) consists of multiple pathways between factors, making it difficult to evaluate the entire framework in a single study. Rather, recent tests of the Elaborated Environmental Stress Hypothesis have evaluated different components embedded within the broader framework and provided support for these relationships. These studies have commonly investigated the mediating association of both interpersonal and intrapersonal factors including social skills, peer relationships and self-perceptions in age

groups ranging from young children to adults (e.g. Mancini, Rigoli, Heritage, et al., 2016; Rigoli, Piek, & Kane, 2012; Wilson et al., 2013).

One intrapersonal psychosocial consequence experienced by children with poor motor skills is a lower level of perceived self-competence. Studies have shown that children with poor motor skills rate their own physical abilities as lower than their typically developing peers (Piek, Dworcan, Barrett, & Coleman, 2000). This may not be surprising considering the physical difficulties experienced by children with poor motor skills. However, perceived self-competence is multidimensional and other studies have identified that children and adolescents with poor motor skills also perceive themselves as less competent in other domains such as academic achievement, physical appearance, social acceptance, and global self-competence (Piek, Baynam, & Barrett, 2006; Rose, Larkin, Parker, & Hands, 2015; Rigoli et al., 2012; Skinner & Piek, 2001). Children's self-perceptions are closely linked with internalizing psychopathology; poor perceived self-competence is a risk factor for internalizing problems (Cole, Jacquez, & Maschman, 2001). The Environmental Stress Hypothesis proposes that perceived self-competence may have an indirect impact on the relationship between motor skills and internalizing problems in children.

Children with poor motor skills also commonly experience a range of interpersonal problems. For example, studies have shown that they experience higher levels of peer victimization, lower social skills and social support, and are less likely to participate in group play compared to their typically developing peers (Cairney, Kwan, Hay, & Faught, 2012; Campbell, Missiuna, & Vaillancourt, 2012; Francis & Piek, 2003; Stephenson & Chesson, 2008). These peer problems have been shown to pose an additional risk factor for the development of internalizing problems and may indirectly effect the association between motor skills and internalizing problems.

To date, studies which have provided a test of the Elaborated Environmental Stress Hypothesis have considered the possible indirect impact of motor skills on internalizing problems via the previously mentioned psychosocial factors, while controlling for potential extraneous variables. Gender is one variable that has been statistically controlled in most of these studies (e.g. Mancini, Rigoli, Heritage, et al., 2016; Rigoli et al., 2016; Rigoli et al., 2012; Wilson et al., 2013). However, a limitation of this approach is that the potential interaction effects of gender with these other factors may be overlooked. The potential interactions of gender with these environmental factors have been acknowledged as a possible area for future development of the Elaborated Environmental Stress Hypothesis (Cairney et al., 2013), but are yet to be sufficiently tested.

Previous studies provide evidence to support the suggestion that gender may moderate the relationships between motor skills, psychosocial factors and internalizing problems found in the Elaborated Environmental Stress Hypothesis. Studies often find a higher prevalence of DCD in males compared to females. However, the male: female ratio has been shown to vary between 2:1 and 7:1 (American Psychological Association, 2013, p. 75). This suggests that a greater proportion of males may experience the psychosocial consequences of poor motor skills. However, it should be noted that gender-typed socialization patterns may further contribute to the hypothesized moderating effects of gender. For example, sporting ability is regarded as the most important determinant of social status for male children, whereas female children deem appearance as the most important (Chase & Dummer, 1992; Coakley, 2007). As sporting ability requires a high degree of motor proficiency, males with poor motor skills may experience greater psychosocial consequences. Inversely, the presence of good motor skills may be considered a protective factor against such consequences. Gender has been previously found to moderate the association between bullying and self-worth in a sample of children with poor motor skills; the effect of peer victimization on the self-worth of girls was significantly greater compared with boys (Piek, Barrett, Allen, Jones, & Louise, 2005). The experiences of males and females differ on many of the psychosocial domains included in the framework, including peer problems, self-competence, and internalizing problems (Chaplin, Cole, & Zahn-Waxler, 2005; Derdikman-Eiron et al., 2011; Hankin & Abramson, 2001; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Piek, Barrett, Allen, Jones, & Louise, 2005; Rose et al., 2015). As gender differences have been observed among individual components of the Elaborated Environmental Stress Hypothesis, it can be hypothesized that gender may moderate the association between relationships between these factors. Previous research has found that factors such as age and socioeconomic status (SES) may confound the relationship between factors (Rigoli et al., 2012). Consequently, age, SES and attention and hyperactivity difficulties were also measured in the current study.

Previous studies have identified both interpersonal and intrapersonal mechanisms through which motor skills are related to internalizing problems. However, few studies have examined both factors in a single research design, and in a sample of school-aged children. In one recent study using a community sample of pre-primary aged children examined at two time-points (pre-primary and 18-month Grade One follow-up), Mancini, Rigoli, Roberts, Heritage, and Piek (submitted) found that peer problems mediated the relationship between motor skills and internalizing problems at pre-primary age. At 18-month follow-up, both peer problems and perceived physical appearance mediated the relationship between motor skills

and internalizing problems. A possible explanation for these results is that as children experience ongoing psychosocial development, motor skills may become an increasingly important determinant of self-competence throughout childhood and later life. In addition, a child's motor difficulties may become more noticeable as their peers continue a typical trajectory of motor development, leading to a decrease in self-competence (Mancini et al., submitted). These findings suggest that the possible mechanisms through which motor skills are associated with internalizing problems may be dynamic and change across different stages of biological and psychosocial development. Therefore, it is important that studies continue to evaluate the framework using a range of age-groups.

The current study aims to test the Elaborated Environmental Stress Hypothesis, by investigating the hypothesized indirect role of peer problems and perceived self-competence, and moderating role of gender in the relationship between motor skills and internalizing problems in a community sample of school-aged children. Previous studies often used DCD samples to investigate the psychosocial consequences of poor motor skills (e.g., Francis & Piek, 2003; Hill & Brown, 2013; Lingam et al., 2012; Skinner & Piek, 2001; Wagner, Bös, Jascenoka, Jekauc, & Petermann, 2012). However, there is growing recognition that the relationship between motor skills and psychosocial wellbeing may not be confined to only those with clinical motor difficulties such as developmental coordination. Recent studies which have used community populations have identified a negative association between motor skills and psychosocial factors across the full continuum of motor ability (Mancini, Rigoli, Heritage, Roberts, & Piek, 2016; Pearsall-Jones, Piek, Rigoli, Martin, & Levy, 2011; Rigoli et al., 2016; Wilson, Piek, & Kane, 2013). For example, Wagner, Bös, Jascenoka, Jekauc and Petermann (2012) found that peer problems mediate the relationship between motor skills and internalizing problems in children aged 5 to 11 years with DCD. Wilson et al. (2013) identified a similar relationship whereby social skills mediated the relationship between motor skills and internalizing problems in a community sample of children aged 4 to 6 years. Several other studies using community populations have found that there is a negative association between motor skills and internalizing problems across the full continuum of motor ability (Mancini, Rigoli, Heritage, Roberts, & Piek, 2016; Pearsall-Jones, Piek, Rigoli, Martin, & Levy, 2011; Rigoli et al., 2016; Wilson, Piek, & Kane, 2013).

Furthermore, studies which use clinical populations tend to overestimate the association between variables (Rigoli et al., 2012). Instead, these relationships are best understood as a continuum where lower levels of motor skills are associated with poorer psychosocial outcomes (Mancini, Rigoli, Cairney, et al., 2016). Inversely, higher levels of

motor skills are associated with better psychosocial outcomes. Most studies using community populations tend to identify small to moderate, negative relationships between motor skills and internalizing problems (Mancini, Rigoli, Heritage, et al., 2016; Rigoli et al., 2016; Wilson et al., 2013). Further research in community populations is important as previous research has recognized that non-clinical populations can also benefit from psychomotor intervention (Piek et al., 2015).

To date, no study has tested both indirect and moderating pathways posited by the Elaborated Environmental Stress Hypothesis. This study will test the following hypothesis: The relationship between motor skills and internalizing problems will be mediated by peer problems and perceived self-competence, and this indirect effect will be moderated by gender.

Method

Participants

Convenience sampling procedures were used to recruit potential participants across seven independent schools, located in metropolitan Western Australia. The participating schools were recruited after they responded to an expression of interest distributed to independent schools in the area. A demographic and medical history questionnaire completed by parents was used to identify ineligible children (n = 22) who had previous diagnoses of general delayed development or another medical condition that affects development (i.e. pervasive developmental disorder, autism spectrum disorder and down syndrome). Trained research assistants worked with children with reading difficulties (e.g. dyslexia, or English as a second language) and provided verbalised instructions. A final sample of 164 children (80 males, 84 females), aged 7 to 12 years (M = 9.93 years, SD = 1.10 years) participated in the current study.

Based on previous findings (e.g. Mancini, Rigoli, Heritage, et al., 2016; Wilson et al., 2013) which enlist community populations to test similar mediation models, we anticipated the impact of motor skills on internalizing problems to be a small-to-medium effect size. A priori power analysis using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) software indicated that a sample of approximately 220 children would be required to detect a small-to-medium sized effect. The current sample size falls short of this recommended sample size.

Measures

Movement Assessment Battery for Children–2 (MABC-2; Henderson, Sugden, & Barnett, 2007). The MABC-2 is a widely used standardized assessment designed to measure motor skills in children. The assessment is administered by a trained professional, and is split

into three age bands (age band one – 3 to 6 years; age band two – 7 to 10 years; age band three – 11 to 16 years). The assessment comprises eight tasks that measure three motor domains (manual dexterity, aiming and catching, and balance), which can be combined to provide an overall indication of motor skills.

The MABC-2 provides a total raw score and a standardized score, which adjusts for age differences. A total standardized score below the 16th percentile indicates the child is at-risk of DCD. Previous studies indicate the MABC-2 has good psychometric properties (Brown & Lalor, 2009; Ellinoudis et al., 2011; Henderson et al., 2007). Internal reliability of the three motor domains range from .81 to .88, and .90 for the total score (Wuang, Su, & Su, 2012).

The Self-Perception Profile for Children (SPPC; Harter, 1985). The SPPC is a 36-item, self-report questionnaire that measures a child's self-perceptions across six specific domains: scholastic competence, social acceptance, athletic competence, physical appearance, behavioral conduct, and global self-worth. Each item in the SPPC comprises two opposing statements (e.g., "Some children often forget what they have learned" and "Other children are able to remember all things easily"). Participants first select the statement they feel is most consistent with their self, before rating whether the statement is "*somewhat true*" or "*very true*" of them. Items are scored on a 4-point scale; higher scores indicate a higher self-perception on that construct. Previous studies indicate the SPPC has good psychometric properties; overall internal reliability of the measure's scales range from .74 to .92 (Muris, Meesters, & Fijen, 2003; Skinner & Piek, 2001).

Strengths and Difficulties Questionnaire (SDQ-P; Goodman, 1997). The SDQ is a screening questionnaire used to identify behavioral and emotional problems in individuals between 4 and 16 years of age. The current study used the parent-rated SDQ. Parents use a 3-point scale (0 = *not true*, 1 = *somewhat true*, 2 = *certainly true*) to indicate the degree to which their child demonstrates each of the behavioral attributes specified in each of the 25-items. The SDQ is comprised of five subscales (conduct problems, inattention/hyperactivity, emotional symptoms, peer problems, and prosocial behavior). The peer problems subscale was included in the current study as a measure of interpersonal difficulties, the emotional symptoms subscale was included as a measure of internalizing problems and the inattention/hyperactivity subscale was used as a measure of attention and hyperactivity difficulties. The SDQ is widely used and has good psychometric properties; overall internal reliability coefficients range from .80 to .87 for parent-rated versions (Goodman, 2001; Stone et al., 2015; Stone, Otten, Engels, Vermulst, & Janssens, 2010).

Socio-Economic Indexes for Areas (SEIFA; Australian Bureau of Statistics, 2013). The SEIFA is a comprehensive measure of SES that ranks suburbs in Australia based on relative socio-economic advantage and disadvantage. New data is obtained every five years as part of the Australian population census. SEIFA index scores range from 1 to 10, with higher scores indicating higher SES. The current study used the postcode of participant's residences as a measure of SES. The average index score for metropolitan Western Australia is 7.88 (*SD*= 2.20), which is comparable to the average score for participants in the current study (*M*= 7.40, *SD* = 1.88).

Procedure

Ethics approval was granted by the University Human Research Ethics Committee and participating schools' administrative bodies. Informed consent was provided by children, parents and schools prior to the commencement of the study. Parents of participating children completed the SDQ and a developmental history questionnaire which were returned to the researchers. The MABC-2 was individually administered by a trained examiner. The SPPC was completed in a classroom setting under the supervision of a trained examiner. The total duration of testing was approximately 50 minutes per child. All data collection took place at the participating schools.

Data Analysis

All data were analyzed using version 22.0 of SPSS (IBM Corporation, Armonk, NY, USA). Mediation analysis was conducted using the PROCESS macro (Hayes, 2013). The 95% bias-corrected and accelerated (BcA) confidence intervals (CI) of the direct and indirect effect were estimated using 10,000 iterations, where the lower-bound (LCI) and upper-bound (UCI) confidence intervals not including zero was indicative of statistical significance. This method is robust to non-normality of variables and has been used in previous research investigating the indirect effect of perceived social support on the relationship between motor skills and internalizing problems in a community adolescent sample (Mancini, Rigoli, Heritage, et al., 2016). Motor skills were specified as the independent variable. Peer problems and each of the six domains of perceived self-competence were proposed as mediator variables. Internalizing problems was the dependent variable. Age, SES and attention and hyperactivity difficulties were included as covariates. Gender was initially proposed as a moderator factor, but was later included as a covariate also. Raw scores for measures were used as the proposed model statistically accounted for the effects of age and gender.

Results

Descriptive Statistics

Seven participants (4.27% of the sample; 5 males, 2 females) were at-risk for DCD, scoring below the 16th percentile on the MABC-2. Twenty-five participants (15.24% of the sample; 8 males, 17 females) scored in the high to very high range on the emotional symptoms measure of the SDQ; six of these children were found to be at-risk for DCD on the MABC-2. Means, standard deviations, reliability coefficients (where calculable) score ranges, and a series of independent sample *t* tests between males and females are presented in Table 1. Bivariate correlations between measurement variables are provided in Table 2.

Model Testing

It was hypothesized that the indirect relationship between motor skills and internalizing problems would be moderated by gender, after controlling for age, SES and attention and hyperactivity difficulties. Contrary to this hypothesis, the current results of the moderated mediation analysis revealed that gender did not significantly interact (i.e., 95% confidence intervals including zero) with any of the variables included in the model.

Though gender did not moderate any of the relationships between measurement variables, significant differences between the mean scores of males and females on several of the included variables were observed (see Table 1). Males reported significantly higher levels of athletic competence, social competence, global self-worth, and lower internalizing problems compared to females. Therefore, gender was included as an additional covariate in a model that tested for an indirect effect of motor skills on internalizing problems.

In combination, the predictors accounted for 33.12% of the variance in internalizing problems, Model R^2 = .33, $F(12, 151) = 6.23$, $p < .001$, which was reflective of a large effect size, f^2 = 0.495 (Cohen, 1992). Motor skills had an indirect effect on internalizing problems via peer problems (β = -0.0096 [95% *BcA LCI* = -0.0243; *UCI* = -0.0012]), and perceived scholastic competence (β = -0.0075 [95% *BcA LCI* = -0.0227; *UCI* = -0.004]). Motor skills did not have a significant indirect effect on internalizing problems via the remaining five dimensions of perceived self-competence (athletic, social, physical, behavioral, and global), as the bias-corrected intervals contained a null value of zero. The direct effect of motor skills on internalizing problems remained significant after controlling for the effect of the mediator variables and covariate, *c*' = -0.0391 (95% *BcA LCI* = -0.0690; *UCI* = 0.0092), p = .011. In summary, motor skills demonstrated both a direct effect, and significant indirect effects on motor skills via peer problems and perceived scholastic competence, after controlling for age,

gender, SES and attention and hyperactivity difficulties. This is visually presented in Figure 1.

Discussion

The overall aim of this study was to provide a test of the Elaborated Environmental Stress Hypothesis (Cairney et al., 2013) in a community sample of children aged 7 to 12 years. Specifically, we investigated the potential indirect role of peer problems and perceived self-competence and the moderating role of gender in the relationship between motor skills and internalizing problems. In the current sample, gender did not moderate the hypothesized association between variables. Motor skills was found to have an indirect effect on internalizing problems via peer problems and perceived scholastic competence. These results provided partial support for the Elaborated Environmental Stress Hypothesis, and highlight potentially important psychosocial factors to consider when understanding the relationship between motor skills and internalizing problems in primary school-aged children.

To date, there appears to be no published research that has tested both moderating and mediating components of the Elaborated Environmental Stress Hypothesis in a single analysis. The current results revealed that the hypothesized indirect relationship was not moderated by gender. This suggests the relationships specified in the Elaborated Environmental Stress Hypothesis in the current study may be comparable between male and female primary school-aged children. However, previous research by Piek et al. (2005) found that gender moderated the relationship between peer problems and self-worth in children with poor motor skills; the impact of peer victimization on the self-worth of female participants was significantly greater compared to males. It should be noted that the outcome measure of self-worth measured using the SPPC in Piek et al.'s (2005) study is different to the outcome of internalizing problems using the SDQ in the current study, which also included subscales of the SPPC as hypothesized mediating variables. Nonetheless, both factors are integral components of the Elaborated Environmental Stress Hypothesis.

Despite the absence of a significant interaction effect, males reported significantly higher levels of athletic competence, social competence, global self-worth, and lower internalizing problems compared to females. This may be due to the current sample size providing an adequate statistical power to compare mean scores for males and females, but underpowered to detect interaction effects. Previous research has identified similar gender differences in perceived self-competence and internalizing problems in school-aged children (Cohen et al., 1993; Jacobs et al., 2002; Rose et al., 2015). At this age, this is most commonly attributed to common gender role socialization by parents, teachers, peers and media (Jacobs

et al., 2002). To account for such differences, gender was subsequently included as a control variable in this study.

An indirect effect on internalizing problems via peer problems was found to be significant in the current study. This is consistent with previous research that has found the relationship between motor skills and internalizing problems to be mediated by peer problems in school-aged children (Wagner et al., 2012; Wilson, et al., 2013). According to these findings, poor motor skills appear to be a risk-factor for greater peer problems (i.e., difficulty making friends, social isolation, and peer victimization) which then lead to greater internalizing problems (Campbell et al., 2012). This is of concern, as previous studies have indicated that children with poor motor skills may be excluded from structured and unstructured physical play, limiting their ability to develop their motor proficiency, interact with peers, and participate in healthy physical exercise (Cairney et al., 2012). The current study also identified a moderate association between peer problems and perceived social competence. It is possible that peer problems such as social isolation and peer victimization may have adverse implications for a child's self-competence.

The current study also tested the potential indirect effect of motor skills on internalizing problems via six separate domains of perceived self-competence: scholastic, athletic, social, physical, behavioral and global. Previous studies have shown that children with poor motor skills perceive themselves as less competent across a range of domains (Vedul-Kjelsås, Sigmundsson, Stensdotter, & Haga, 2012). The current results indicated that there was an indirect effect via perceived scholastic competence, but none of the other domains of perceived self-competence.

The negative association between motor skills and perceived scholastic competence in the current community sample is consistent with previous studies that identified children and adolescents with DCD to report lower levels of perceived scholastic competence when compared to their typically developing peers (Cantell et al., 2003; Skinner & Piek, 2001; Vedul-Kjelsås et al., 2012; Viholainen et al., 2014). For example, Skinner and Piek (2001) found that both children and adolescents with DCD perceived themselves to be less competent than their typically developing peers across a range of areas, including perceived scholastic competence; the DCD populations also reported greater internalizing symptoms. The current findings extend upon this research by providing evidence of an indirect relationship between motor skills and internalizing problems via perceived scholastic competence, using a community sample of school-aged children. One plausible explanation for this finding is that children with poor motor skills are more likely to fall behind in the

classroom setting due to difficulties associated with fine motor skills such as handwriting (Kirby, Sugden, Beveridge, & Edwards, 2008; Viholainen et al., 2014). Another plausible explanation that cannot be ruled out from the current study includes the presence of co-occurring learning difficulties which are also common in children with DCD (Dewey, Kaplan, Crawford, & Wilson, 2002).

Lower levels of perceived self-competence, including in the scholastic domain, are a risk factor for greater internalizing problems (Cole et al., 2001). The current findings add to this research by highlighting that these associations may be formed in childhood, and potentially persist into adolescence (Skinner & Piek, 2001).

Motor skills did not have an indirect relationship with internalizing problems via any of the other domains of perceived self-competence examined in the current study. However, these associations have been reported in previous studies (Rose et al., 2015; Vedul-Kjelsås, 2012). In the current study, perceived athletic competence was associated with motor skills but not with internalizing problems. Previous studies have similarly identified a positive association between motor skills and perceived athletic competence (e.g., Cantell et al., 2003; Rose et al., 2015). Positive self-competence has also been identified to have a protective effect for a child's psychosocial wellbeing (Rose et al., 2015) and was partially supported as several domains of perceived self-competence were negatively associated with internalizing problems; however perceived athletic competence was not one of these domains.

Though gender did not moderate the hypothesized indirect relationship between motor skills and internalizing problems, previous research has suggested that motor skills may affect the self-competence of males and females differently (Rose et al., 2015). One plausible explanation for the current findings can be attributed to the use of a community sample of school-aged children in the current study. Based on the a-priori power analysis, the current study may have had insufficient statistical power to detect a small-to-moderate effect size. Studies which use community populations tend to identify weaker relationships between variables (e.g. Mancini, Rigoli, Heritage, et al., 2016; Wilson et al., 2013). This may explain why the already underpowered study could not identify the associations that have been previously examined in previous studies which use clinical populations, or larger samples (Rigoli et al., 2012; Rose et al., 2015). There is also some evidence that suggests the relationship between motor skills, perceived self-competence, and internalizing problems may become stronger through the lifespan (Skinner & Piek, 2001). Children with poor motor skills may be exposed to an accumulating number of situations which may result in a more pronounced negative impact on their perceived self-competence by the time they reach

adolescence. For example, Skinner and Piek (2001) found that adolescents with DCD reported significantly lower levels of global self-worth compared to children with DCD. However, more research is needed to better understand how the psychosocial mechanisms through which motor skills relate to internalizing problems may differ across key developmental periods. Though the current research is limited by its cross-sectional research design, previous research has identified childhood motor skills predict psychosocial well-being in later life (Hill & Brown, 2013; Lingam et al., 2012; Rose et al., 2015). Future research using larger and older community populations could further evaluate the indirect relationship between motor skills and internalizing problems via multiple domains of perceived self-competence that was partially supported by the current study.

These studies and the current findings highlight the need for childhood psychomotor intervention which target both the physical and psychosocial consequences of poor motor skills. Untreated psychosocial difficulties may persist, even after the physical symptoms may have improved. Psychomotor interventions which target both the physical and psychosocial consequences of poor motor skills have been shown to facilitate improvements in both these areas (Peens, Pienaar, & Nienaber, 2008; Smits-Engelsman et al., 2013). However, Noordstar, van der Net, Voerman, Helders, and Jongmans (2017) found that an integrated perceived competence and motor intervention (n = 20) was equally as effective at improving children's self-perceptions as a motor intervention only (n = 11) in children with DCD. A limitation of the Noordstar et al. (2017) study was the relatively small sample size, and the large intra-group variability in the improvement in motor skills and self-competence in children with DCD. Piek et al. (2015) identified that a universal psychomotor intervention for young children had additional benefits to their psychosocial functioning, with participants demonstrating higher levels of prosocial behavior post-intervention. Early intervention strategies may also strengthen protective factors which may minimize the impact of motor skills on internalizing problems. As childhood represents an important period of motor and psychosocial development and intervention, further research is needed to examine the possible psychosocial mechanisms through which motor skills are associated with internalizing problems, which can then be targeted in intervention programs. The current findings highlight the potential benefit of targeting peer problems and perceived scholastic competence in future universal psychomotor intervention studies.

The model tested in the current study accounted for around 30% of the variance in participant's internalizing problems. This finding highlights the important role of additional unmeasured variables in the development of internalizing problems in school-aged children.

However, these findings reflect the understanding that the etiology of psychopathology across the lifespan is multi-factorial, and involves the complex interaction between biological, psychological, and environmental factors (Koplewicz & Klass, 1993). It is also important to note that a community sample was used to test the hypothesized relationships. Children with DCD report greater internalizing problems compared to their non-DCD peers (Missiuna et al., 2014; Skinner & Piek, 2001); the use of a community population in this study may explain why the current findings identified only a small-to-moderate association between motor skills and internalizing problems. Future research could provide a similar test of the Elaborated Environmental Stress Hypothesis using clinical populations.

The current study controlled for important confounding factors such as age, gender and attention and hyperactivity difficulties. However, a limitation of this study is that it did not account for intelligence (IQ). Previous studies have identified a link between DCD and intellectual difficulties which may also have their own co-occurring psychosocial consequences (Cook, Greenberg, & Kusche, 1994; Fliers et al., 2008; Sibley & Etnier, 2003). Previous studies have found that motor skills remain an important predictor of internalizing problems even after accounting for factors such as attention and hyperactivity difficulties or IQ (Goulardins et al., 2015; Rigoli et al., 2012; Wilson et al., 2013). However, this same research also highlights a need to account for such possible confounding factors. Future studies could address this by including additional measures of IQ. The current study was also unable to account for biological factors, which may be of importance in the development of both motor skills and emotional difficulties (Moruzzi et al., 2010). Twin and sibling studies have also highlighted the potential importance of underlying biological mechanisms in the relationship between motor skills and emotional difficulties (Moruzzi et al., 2010; Piek et al., 2007; Waszczuk, Leonard, Hill, Rowe, & Gregory, 2016). For example, a twin/sibling study by Waszczuk et al. (2016) identified a moderate relationship between motor skills and internalizing problems, where shared familial genetic and environmental influences accounted for approximately half of the variance in internalizing problems. However, non-shared environmental influences explained the remaining variance. It is recognized that biological factors alone cannot completely explain the association between motor skills and internalizing problems (Moruzzi et al., 2010).

The current study uses both child-reported and parent-reported measures. Previous research has identified that measures of psychosocial functioning may be discrepant between informants, though parents tend to provide more consistent evaluation of symptoms and impact compared to child self-report (Van Roy, Groholt, Heyerdahl, & Clench-Aas, 2010).

Therefore, the present study enlisted parent ratings of peer problems and internalizing problems. Though the current findings are congruent with the causal Elaborated Environmental Stress Hypothesis framework, the cross-sectional and correlational nature of this research design limits the ability to make causal conclusions based on these findings alone. Growing experimental and longitudinal evaluation of the Elaborated Environmental Stress Hypothesis is ongoing (e.g. Wagner,, Jekauc, Worth, & Woll, 2016).

The various pathways specified within the Elaborated Environmental Stress Hypothesis have only recently started to be empirically tested. Within this growing body of research, studies have found support for several of these pathways, across a range of different samples (Mancini, Rigoli, Heritage, et al., 2016; Rigoli et al., 2016; Wilson et al., 2013). However, the existing literature has not yet facilitated a comprehensive understanding of the Elaborated Environmental Stress Hypothesis. Further research is required to identify how this framework functions across different populations, such as different age groups and in clinical/community samples. Research such as the current study, which evaluate the indirect effects of hypothesized interpersonal and intrapersonal psychosocial factors and test for potential moderating factors (i.e. gender) provide an important contribution to how the relationship between motor skills and internalizing problems can be understood.

Understanding the psychosocial mechanisms through which motor skills may indirectly impact internalizing problems facilitates the ability to develop more effective psychomotor interventions. This type of intervention has been shown to be an effective intervention strategy for children with poor motor skills (Peens et al., 2008) and community populations (Piek et al., 2015). Though the role of biological factors cannot be dismissed, these psychosocial mechanisms may be more effectively targeted by interventions.

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Table 1

Descriptive Statistics for Measurement Variables for Total Sample, and Split by Gender

	Total Sample (N = 164)				Males (n = 80)				Females (n = 84)			
	M	SD	α	Range	M	SD	α	Range	M	SD	α	Range
Motor Skills	80.46	10.31	-	43 - 103	80.06	11.40	-	43 – 100	80.85	9.21	-	51 – 103
Scholastic Competence	16.84	4.48	.820	6 – 24	17.42	4.07	.785	8 – 24	16.31	4.85	.884	6 – 24
Athletic Competence	18.04	4.53	.814	6 – 24	19.76 [a]	3.58	.725	9 – 24	16.40 [a]	4.75	.822	6 – 24
Social Competence	17.82	4.46	.822	6 – 24	18.77 [b]	3.96	.822	6 – 24	16.90 [b]	4.76	.814	6 – 24
Physical Appearance	18.45	4.31	.807	7 – 24	19.04	4.06	.794	8 – 24	17.87	4.51	.812	7 – 24
Behavioral Competence	17.99	3.89	.813	8 – 24	18.15	3.52	.783	10 – 24	17.83	4.25	.834	8 – 24
Global Self-worth	19.31	3.92	.795	6 – 24	20.10 [b]	3.35	.754	9 – 24	18.55 [b]	4.31	.807	6 – 24
Peer Problems	1.27	1.41	.455	0 – 7	1.33	1.54	.536	0 – 7	1.21	1.27	.356	0 – 5
Internalizing Problems	2.18	2.22	.753	0 – 10	1.79 [b]	2.03	.774	0 – 10	2.55 [b]	2.31	.728	0 – 9
Age	9.40	1.09	-	7 – 12	9.43	1.09	-	7 – 12	9.38	1.11	-	7 – 12
Socioeconomic Status	7.40	1.88	-	2 – 10	7.48	1.91	-	2 – 10	7.32	1.92	-	2 – 10
Attention and Hyperactivity Difficulties	3.36	2.54	.784	0 – 10	3.50	2.45	.752	0 – 10	3.23	2.62	.812	0 – 10

Note. Raw scores used for all measures. Independent samples t test indicated significant differences between males and females on perceived athletic competence ($p < .001$)[a], perceived social competence, perceived global self-worth and internalizing problems ($p < .05$)[b].

Table 2

Bivariate Correlation Matrix for Measurement Variables (n = 164).

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Motor Skills	-												
2. Scholastic Competence	.212*	-											
3. Athletic Competence	.146	.326**	-										
4. Social Competence	.162*	.374**	.284*	-									
5. Physical Appearance	.044	.312*	.469**	.261*	-								
6. Behavioral Competence	.042	.424**	.320**	.347*	.402**	-							
7. Global Self-Worth	.074	.238	.468**	.327**	.626**	.467**	-						
8. Peer Problems	-.183*	-.086	-.192	-.336*	-.007	-.083	.041	-					
9. Internalizing Problems	-.294*	-.225*	-.447**	-.142	-.246*	-.007	-.144	.345**	-				
10. Age	.158*	.067	.056	.151	-.012	.026	.166*	-.019	-.018	-			
11. Gender	.038	-.126	-.372**	-.209**	-.133	-.041	-.199*	-.041	.173*	-.020	-		
12. SES	.033	.097	-.034	.104	-.007	.099	.086	.050	.084	.082	-.041	-	
13. Attention and Hyperactivity Difficulties	-.106	-.172*	-.016	.039	-.011	-.173*	-.067	.193*	.174*	-.055	-.128	.022	-

Note. Raw scores used for all measures. $p < .05$*. $p < .001$**. SES = socioeconomic status. Age, Gender, SES and Attention Difficulties were enlisted as control variables in the current study.

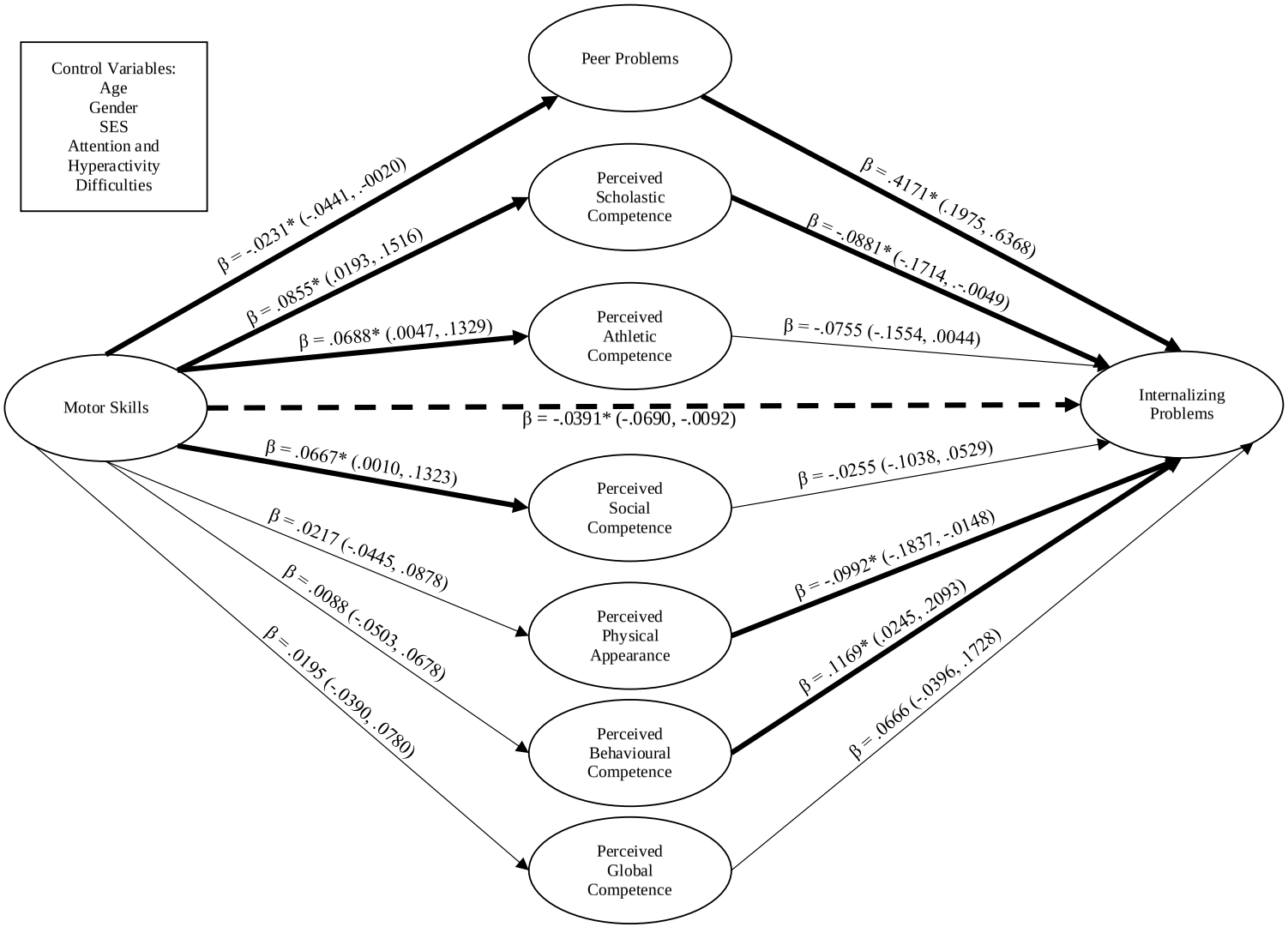

Figure 1. Mediation model in which the association between motor skills and internalizing problems is partially indirectly effected by peer problems and perceived scholastic competence, in a sample of school-aged children (*N*= 164). Significant pathways are depicted in bold. Note. *$p < .05$. β = Standardized coeffient. 95% bias-corrected confidence intervals provided in parentheses. SES = socioeconomic status.

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The Relationship between Motor Skills, Perceived Social Support, and Internalizing Problems in a Community Adolescent Sample

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Objectives: Poor motor skills are associated with a range of psychosocial consequences, including internalizing (anxious and depressive) symptoms. The Elaborated Environmental Stress Hypothesis provides a causal framework to explain this association. The framework posits that motor skills impact internalizing problems through an indirect effect via perceived social support. However, empirical evaluation is required. We examined whether motor skills had an indirect effect on anxious and depressive symptoms via perceived family support domains.

Methods: This study used a community sample of 93 adolescents (12–16 years). Participants completed measures of motor skills, perceived social support across three dimensions (family, friend, and significant other), depressive symptoms, and anxious symptoms. Age, gender, verbal IQ, and ADHD symptoms were included as control variables.

Results: Regression analysis using PROCESS revealed that motor skills had an indirect effect on depressive symptoms via perceived family support, but not by perceived friend support or significant other support. The negative association between motor skills and anxious symptoms was not mediated by any perceived social support domain.

Conclusions: Findings are consistent with previous literature indicating an association between motor skills and internalizing problems. However, we identified a different pattern of relationships across anxious and depressive symptoms. While anxiety and depressive symptoms were highly correlated, motor skills had an indirect effect on depressive symptoms via perceived family support only. Our findings highlight the importance of family support as a potential protective factor in the onset of depressive symptoms. This study provides partial support for the Elaborated Environmental Stress Hypothesis, however further research is required.

Keywords: motor skills, adolescents, motor development, internalizing problems, anxiety, depression, movement

BACKGROUND

Motor skills have an important connection with psychosocial wellbeing. Studies have demonstrated that children who have clinical motor impairments, such as developmental coordination disorder (DCD), are at greater risk of experiencing poor psychosocial outcomes, compared to their non-DCD peers. This includes less enjoyment in daily tasks (Bart et al., 2011), low self-esteem (Miyahara and Piek, 2006), less developed social support and friendships (Smyth and Anderson, 2000; Skinner and Piek, 2001), poor social skills (Kanioglou et al., 2005), social isolation and social problems (Smyth and Anderson, 2000; Chen et al., 2009), academic underachievement (Alloway, 2007), peer victimization/bullying (Campbell et al., 2012), decreased quality of life (Hill et al., 2011), withdrawal (Chen et al., 2009), physical inactivity, and obesity (Cairney et al., 2005). In addition, poor motor skills are also associated with symptoms of internalizing disorders such as depression and anxiety (Skinner and Piek, 2001; Francis and Piek, 2003; Lingam et al., 2012; Cairney et al., 2013). This association between poor motor skills and internalizing symptoms could be attributed to common neurodevelopmental etiology between motor skills and emotional regulation (Nicolson et al., 2001; Ekornas et al., 2010). However, each of the previously identified psychosocial consequences of poor motor skills are well-established risk factors for the development of internalizing problems in their own right. Cairney et al. (2013) posited that poor motor skills give rise to these various psychosocial consequences, which in turn results in increased internalizing problems, and these relationships form the basis of their recently proposed Elaborated Environmental Stress Hypothesis. This theoretical framework proposes that the relationship between motor skills and internalizing symptoms is predominantly indirect; poor motor skills may lead to various psychosocial consequences in the individual's surrounding environment (e.g., lower social support, low self-competence, peer victimization, etc.) which subsequently gives rise to increased internalizing symptoms (see Cairney et al., 2013). The model places emphasis on environmental, rather than biological, factors linking motor skills to internalizing problems. In a monozygotic twin study by Piek et al. (2007), twins with DCD were compared to their unaffected co-twin, granting the ability to control for shared genetic factors as well as shared environment. Results demonstrated higher levels of depressive symptoms in the DCD twin compared to their unaffected co-twin. These findings provide support for the Elaborated Environmental Stress Hypothesis; the authors concluded that the differences in depressive symptoms are due to unique environmental stressors associated with DCD.

The Elaborated Environmental Stress Hypothesis (see Cairney et al., 2013, p. 233 for a visual representation) is comprised of multiple direct, mediating, and moderating pathways between motor skills and internalizing symptoms. The complexity of this model has resulted in studies evaluating parts of the model, rather than the model in its entirety. These recent studies have provided support for various pathways embedded within the broader Elaborated Environmental Stress Hypothesis. For example, Wilson et al. (2013) found that the relationship between motor skills and internalizing symptoms in a community sample of young children (4–6 years of age) was mediated by social skills. The authors identified that higher levels of motor skills were associated with higher levels of social skills, which in turn related to a decrease in internalizing symptoms. Rigoli et al. (2012) found the relationship between motor skills and internalizing problems was mediated by levels of self-concept in a normative adolescent sample, another key pathway embedded within the broader Elaborated Environmental Stress Hypothesis. The results of a recent randomized control trial (RCT) by Piek et al. (2015) provided the first intervention study to empirically evaluate the Elaborated Environmental Stress Hypothesis. The authors evaluated the efficacy of the *Animal Fun* universal intervention program aimed at promoting motor and social development in young children (aged 4–6 years). Results demonstrated a lasting increase in prosocial behavior in the intervention group, but not the control group; this increase remained at 6-month and 18-month follow up. The relationships between observed variables were consistent with the pattern of relationships posited by the Elaborated Environmental Stress Hypothesis. These recent empirical developments provide preliminary support for the various pathways specified in the broader causal framework. However, given the recent conceptualization of the model, not all of the pathways contained in the model have yet been empirically evaluated. Therefore, it is important to continue to provide ongoing evaluation of the model.

Early research in the area of poor motor skills often used clinical samples of children with DCD to identify the associated psychosocial consequences (Skinner and Piek, 2001). While studies employing this comparative approach continue to provide important findings, motor skills are best understood as a continuous, rather than dichotomous construct (Wassenberg et al., 2005). More recent developments in the literature have highlighted that the psychosocial implications of motor skills are not limited to children with DCD, but are present across the broader continuum of motor skills (Rigoli et al., 2012; Wilson et al., 2013; Piek et al., 2015). There is a negative linear relationship between internalizing symptoms and motor skills, across the full continuum of movement. In other words, poorer motor skills are associated with increased internalizing symptoms and better movement ability is associated with lower internalizing symptoms. Studies that have utilized broader community samples are able to address the methodological problems that exist when attempting to dichotomize motor skills into clinical (DCD) and non-clinical (not DCD) categories (Hattori et al., 2006). Furthermore, focussing on the extreme end of the motor skill continuum may overestimate the relationship between constructs in the wider population (Rigoli et al., 2012).

Motor skills are considered to be a relatively stable construct, with a predictable pattern of development, stability, and decline over the lifespan (Leversen et al., 2012). The majority of motor coordination literature focuses on motor development in childhood. Childhood represents a critical period for motor development, and often the period in which atypical motor skills are noticed. However, poor motor skills in childhood can persist into adolescence and later life; therefore it is important to consider older populations. Recent literature has identified

that the psychosocial implications of poor motor skills extend beyond childhood, into adolescence (Skinner and Piek, 2001; Sigurdsson et al., 2002; Rigoli et al., 2012; Viholainen et al., 2014) and adulthood (Hill and Brown, 2013; Poole et al., 2015). Longitudinal studies have also identified that childhood motor problems can predict psychosocial problems (including internalizing disorders) in later life (Sigurdsson et al., 2002; Lingam et al., 2012; Poole et al., 2015). Skinner and Piek (2001) suggested that the psychosocial consequences of poor motor skills may become more pronounced with age; adolescents with DCD reported higher levels of anxious symptoms than children with DCD. The adolescent DCD group also reported higher levels of anxiety compared to the adolescents without DCD. A secondary finding was that participants with DCD reported lower levels of perceived social support when compared to their non-DCD peers. A limitation of this study was that participants were dichotomized into DCD and non-DCD groups, therefore a linear relationship between motor skills, perceived social support, and internalizing problems could not be tested.

The role of social support in the etiology of internalizing problems in adolescence is well-established. High levels of perceived social support may also act as a protective factor in the onset of internalizing symptoms. Inversely, lower levels of perceived social support are associated with increased internalizing symptoms. In their community sample of 390 students aged 10–15 years, Stewart and Suldo (2011) identified perceived social support from parents, peers, and teachers each uniquely predicted variance in internalizing symptoms. However, perceived parent support emerged as the strongest predictor of all indicators, accounting for 6% of unique variance in their regression model. Similarly, the authors also identified parental support to be the largest unique predictor of externalizing behavior, and also life satisfaction. Rueger et al. (2010) also investigated the impact of perceived social support from various sources (parents, teachers, classmates, close friends, and school) on levels of anxiety and depression in middle school students. Perceived parental support was the most important predictor of all outcomes. As individuals receive support from multiple sources, it is important to consider perceived social support as a multi-factorial construct (Uchino et al., 1996). This approach can also help to identify the most important types of perceived social support.

Anxious and depressive symptoms are often considered concomitantly within the literature. This reflects their shared etiology, similar presentation of symptoms, and high levels of comorbidity (Brady and Kendall, 1992; Kessler and Walters, 1998; Seligman and Ollendick, 1998). The Elaborated Environmental Stress Hypothesis as described by Cairney et al. (2013) conceptualizes internalizing problems as an umbrella term comprised of both anxious and depressive symptoms. Consequently, some studies in the motor coordination literature measure internalizing problems as a single variable (Wilson et al., 2013), or as a latent factor driven by two observed constructs: anxious symptoms and depressive symptoms (Rigoli et al., 2012). However, within the social support literature, studies have identified different relationships between perceived social support and anxious and depressive symptoms. Perceived social support is often found to be associated with depressive symptoms, but less consistently associated with anxious symptoms (Haeffel and Mathew, 2010; Rueger et al., 2010; Väänänen et al., 2014). Consequently, research investigating the relationship between perceived social support and internalizing symptoms should consider anxious and depressive symptoms as separate outcome variables.

Through the reviewed evidence, a relationship between motor skills, perceived social support, and both anxious and depressive symptoms in adolescence has been identified. The Elaborated Environmental Stress Hypothesis provides a model in which these relationships may be framed. It posits perceived social support as a key intermediary factor between motor skills and internalizing symptoms. Lower levels of motor skills are associated with lower perceived social support, which then gives rise to increased levels of internalizing symptoms. In other words, this particular section of the Elaborated Environmental Stress Hypothesis suggests that motor skills has an indirect effect on internalizing problems via perceived social support. However, this is yet to be empirically tested.

STUDY AIMS

The aim of the present study was to empirically evaluate a portion of the Elaborated Environmental Stress Hypothesis by Cairney et al. (2013). Specifically, we tested the proposed indirect pathway from motor skills to internalizing symptoms via perceived social support, in a community sample of adolescents. We also controlled for potential confounding variables of attention deficit/hyperactivity disorder (ADHD), verbal IQ (VIQ), age and gender. ADHD has demonstrated similar psychosocial consequences as DCD (Piek et al., 2007) and has high rates of comorbidity with DCD (Goulardins et al., 2015). We included a parent-report measure that allowed us to statistically account for ADHD symptoms. Verbal IQ (VIQ) was first included as a screening tool to exclude participants with general delayed development (Lingam et al., 2012; Rigoli et al., 2012). Excluding these participants is also important for the present study which utilizes self-report measures. Previous literature has also identified a negative association between VIQ and internalizing symptoms (Rajput et al., 2011). Therefore, we also included VIQ as a control variable. Age and gender were also included as control variables based on previous findings (Sigurdsson et al., 2002; Lingam et al., 2010, 2012).

Based on the reviewed literature, we propose two hypotheses. Hypothesis one states that after controlling for age, gender, VIQ, and ADHD symptoms, motor skills will have an indirect effect on depressive symptoms, via perceived social support from friends, family, and a significant other. Hypothesis two states that after controlling for these same control variables, motor skills will have an indirect effect on anxious symptoms via each of the three domains of perceived social support.

METHODS

Participants

A community sample of 93 adolescents aged 12–16 years ($M = 14.21$ years, $SD = 1.09$) took part in the present study. Participants completed a battery of cognitive, psychosocial, and

motor skills assessments as part of a larger research project (Rigoli et al., 2012). There were 55 males and 38 females. Participants were recruited through a combination of public advertisements and through 5 randomly selected secondary schools located in metropolitan Perth, Western Australia. Participants were required to have a Verbal Comprehension Index (VCI) score of 70 or above on the Wechsler Intelligence Scale for Children-IV (WISC-IV; Wechsler, 2003). This was to exclude any adolescents whose difficulties may be attributed to general delayed development (Geuze et al., 2001). All included participants had no diagnosis of physical disability, chronic illness, or medical conditions that impact development.

The a-priori power analysis for a linear multiple regression analysis to test for mediation indicated that a sample size of 109 participants was required in order to detect a medium effect size in a model with 8 predictors (four control variables, motor skills, and the 3 domains of perceived social support). The present sample of 93 participants falls slightly short of this recommended value. However, the robustness of the bootstrapped estimation methods used in the analysis would assist in addressing this potential limitation.

Measures

The Movement Assessment Battery for Children Second Edition (MABC-2)

The MABC-2 (Henderson et al., 2007) is a standardized instrument used to measure and describe movement difficulties in children between 3 and 16 years of age across three age bands (3–6 years; 7–10 years; 11–16 years). Motor coordination is measured across three domains; manual dexterity, aiming and catching ability, and balance, which are combined to provide an indication of overall motor ability. The assessment is independently administered by a trained professional, and takes approximately 30 min to complete the eight tasks. Age-based standardized scores are derived for each of the domains and an overall total test score. A child is deemed to be "at risk" of having a movement difficulty if their total test score places them between the 5th and 15th percentile; scores below the 5th percentile suggest a severe movement difficulty. The present study used the standardized total test score of the MABC-2. Previous validation studies of the MABC-2 have reported the measure to demonstrate good test retest reliability for each domain and total standardized scores, inter-rater reliability, criterion-related and discriminant validity (Henderson et al., 2007).

The Multidimensional Scale of Perceived Social Support (MSPSS)

The MSPSS (Zimet et al., 1988) is a widely used, 12 item self-report measure of perceived social support adequacy. The measure provides a subjective assessment of social support from three subscales: family, friends, and a significant other. Participants are asked to report the extent to which they agree with each statement using a 7-point scale (1 = *very strongly disagree*, to 7 = *very strongly agree*). An example item is "*I get the emotional help and support I need from my family.*" Subscale scores are calculated by averaging all responses, with higher scores indicating a higher degree of perceived social support from that particular source. Each of the three subscales of the MSPSS demonstrates good internal reliability, and the three factor structure has been validated with adolescent populations (Canty-Mitchell and Zimet, 2000; Walker et al., 2002). Cronbach's alpha for the present sample is 0.88 for the family subscale, 0.88 for the friend subscale, and 0.88 for the significant other subscale.

The Mood and Feelings Questionnaire—Child Version (MFQ)

The MFQ (Costello and Angold, 1988) is a 33-item self-report questionnaire designed for children and adolescents to report depressive symptoms experienced over the two weeks prior to completing the questionnaire. Responses are recorded by using a 3-point scale (0 = *not true*, 1 = *sometimes true*, 2 = *true*). Total scores range from 0 to 66 with higher scores indicating higher depressive symptoms. The MFQ was designed for use with both clinical and non-clinical populations of children and adolescents, and has been widely validated (Costello and Angold, 1988; Wood et al., 1995; Kuo et al., 2005). Consistent with previous reports of high internal reliability (Costello and Angold, 1988), Cronbach's alpha for the MFQ in the present study was 0.92, indicating good internal reliability.

The Spence Children's Anxiety Scale (SCAS)

The SCAS comprises 38 items designed to measure symptoms of anxiety across 6 subscales: panic attack, agoraphobia, separation anxiety, social phobia, physical injury fears, obsessive compulsive disorder, and generalized anxiety. Responses are recorded by using a 4-point scale (0 = *never*, to 3 = *always*). A total SCAS score is calculated by summing the responses to all 38 items. This total score of the child self-report version was used in the present study. The SCAS has been used in samples of adolescents up to 19 years of age and demonstrates good levels of internal reliability (Spence, 1997), test-retest reliability, convergent and discriminant validity (Spence, 1998; Muris et al., 2000; Essau et al., 2002). Cronbach's alpha for the SCAS in the present study was 0.89, indicating good internal reliability.

Wechsler Intelligence Scale for Children- Fourth Edition (WISC-IV)

The WISC-IV (Wechsler, 2003) is a standardized assessment of cognitive ability for children aged 6–16 years 11 months. The WISC-IV provides an indication of cognitive ability across 4 domains: verbal comprehension, perceptual reasoning, working memory, and processing speed. The WISC-IV is widely used, and considered to be the gold-standard in cognitive assessment for children. It has excellent psychometric properties (Wechsler, 2003). We used the VCI subscale of the WISC-IV in the present study.

Strengths and Weaknesses of ADHD Symptoms and Normal Behavior (SWAN)

The SWAN (Swanson et al., 2006) is a parent-rated assessment of ADHD symptoms. This 18-item measure involves observations based on the last month, asking the parent to rate their child's behavior compared to similarly aged children. A 7-point scale is used, with scores ranging from 3 (*far below average*) to −3 (*far*

above average). An overall score is calculated by averaging the total of all 18 items, with higher scores indicating higher ADHD symptoms. The SWAN has been previously supported as an accurate measure of ADHD symptoms in the general population (Martin et al., 2006; Polderman et al., 2007). Cronbach's alpha for the SWAN in the present study was 0.96, indicating excellent internal reliability.

Demographic Variables

Single item measures of age and gender were also collected.

Procedure

The study followed the National Health and Medical Research Council of Australia ethical guidelines. Prior to commencing the study, ethics approval was granted by the relevant University Human Research Ethics Committee and the relevant bodies of the participating schools. Informed consent was obtained from both the adolescent participants and their parents. Participants were then independently assessed by a trained assessor over a period of two sessions (approximately 4.5 h in total). The self-report psychosocial questionnaires were completed by participants, and the parent-report questionnaires by parents. Assessments were conducted at either the family home or at university facilities, selected at the discretion of the families.

RESULTS

Means, standard deviations, ranges, and bivariate correlations for the observed variables in this study are provided in **Table 1**. Five adolescents (5.4% of the total sample) were identified as having significant movement difficulty on the MABC-2 (at or below the 5th percentile). This is comparable to population estimates of 5–6% (American Psychiatric Association, 2013). Two adolescents were identified as at-risk for movement difficulty (between the 6th and 15th percentile). Ten adolescents scored in the clinical range for depression on the MFQ (a score of 29 and above). Seven participants scored in the subclinical range for anxiety on the SCAS (1 standard deviation above the normative mean), and an additional five participants scored in the clinical range (more than 1.5 standard deviations above the normative mean). Two of the five adolescents identified as having significant movement difficulty scored in the clinical range for both the MFQ and the SCAS. One of the two adolescents identified as at-risk for movement difficulty scored in the subclinical range for the SCAS.

Mediation Analysis

Tests of mediation using the PROCESS macro (Hayes, 2013) were conducted in SPSS. The direct and indirect effect of each model were estimated with 10,000 bootstrapped 95% bias-corrected and accelerated (BcA) confidence intervals to assess for statistical significance, as this method is robust to non-normality for the indirect path estimation. Two models were tested, one predicting depressive symptoms and the other predicting anxious symptoms. In each model motor skills scores were specified as the independent variable, and social support from family, friends, and a significant other as the mediator variables, with, gender, age, and ADHD symptoms as covariates.

Depressive Symptoms

In combination, the predictors included in the total model account for approximately 26.36% of the variance in depressive symptoms, Model R^2=0.26 $F_{(8,\ 84)} = 3.76$, $p < 0.001$, and a large effect (Cohen, 1992). Motor skills did not have an indirect effect on depressive symptoms via perceived friend support, or perceived significant other support, as the confidence intervals of both indirect pathways included zero. There was a significant indirect effect of motor skills on depressive symptoms via perceived family support; $ab = -0.34$, 95% *BcA CI* = −0.90 to −0.024. The association between motor skills and depressive symptoms was lessened but remained significant after the inclusion of the covariates and mediator variables, $c' = -0.86$, 95% *BcA CI* = −1.67 to -0.05. The direct effect, after controlling for the effect of the mediator variables and covariates, was therefore a significant predictor of depressive symptoms. In summary, we identified a direct effect from motor skills to depressive symptoms, and also an indirect effect via perceived family support. These relationships are presented in **Figure 1**.

Anxious Symptoms

For the mediation model with anxious symptoms as the outcome variable, motor skills, the three domains of perceived social support, and the covariates accounted for approximately 19.77% of the variance in anxious symptoms, Model R^2=0.20, $F_{(8,\ 84)} = 2.59$, $p = 0.014$, and a moderate to large effect (Cohen, 1992). There was no significant indirect effect of motor skills on anxious symptoms via any domain of perceived social support, as all confidence intervals for the *ab* path estimates included zero within their boundaries. The direct effect of motor skills was significant after accounting for the effect of the mediator variables and the covariates, $c' = -1.45$, 95% *BcA CI* = −2.44 to −0.46. These relationships are presented in **Figure 2**.

DISCUSSION

The aim of the current study was to empirically evaluate a key part of the recently proposed Elaborated Environmental Stress Hypothesis by Cairney et al. (2013). This causal framework posits that poor motor skills give rise to internalizing problems via the intermediary effect of various personal and social factors. Few studies have empirically examined this framework since it was conceptualized. Therefore, the current study is important in adding to existing research. We specifically sought to evaluate whether the relationship between motor skills and internalizing symptoms was mediated by perceived social support in a community adolescent sample. Hypothesis one stated that the relationship between motor skills and depressive symptoms would be mediated by perceived social support from friends, family, and a significant other, after controlling for age, gender, VIQ, and ADHD symptoms. This hypothesis was partially supported. Motor skills had a direct effect on depressive symptoms, and an indirect effect via perceived family support. Hypothesis two stated that the relationship between motor skills and anxious symptoms would be mediated by perceived social support from friends, family, and a significant other, after controlling for age, gender, VIQ, and ADHD symptoms. This

TABLE 1 | Means, standard deviations (*SD*), observed range of scores, and bivariate correlations between variables ($N = 93$).

Variable	Descriptives			Bivariate correlations (Pearson's *r*)													
	Mean	*SD*	Range	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. MABC-2 Total Test Score[a]	10.63	2.57	3–16	–													
2. MABC-2 Manual Dexterity[a]	9.57	2.47	3–15	0.657**	–												
3. MABC-2 Aiming and Catching[a]	11.03	2.73	4–16	0.656**	0.071	–											
4. MABC-2 Balance[a]	11.42	2.98	4–14	0.780**	0.264*	0.423**	–										
5. MSPSS Total[bc]	5.72	0.88	2–7	0.242*	0.195	0.058	0.302**	–									
6. MSPSS Family Support[bd]	5.78	1.15	1–7	0.223*	0.088	0.180	−0.247*	0.753**	–								
7. MSPSS Friend Support[bd]	5.69	1.05	2–7	0.226*	0.223*	0.006	0.263*	0.758**	0.260*	–							
8. MSPSS Significant Other Support[bd]	5.68	1.11	2–7	0.129	0.160	−0.055	0.213*	0.873**	0.500**	0.585**	–						
9. MFQ Total[be]	13.48	10.43	1–48	−0.329**	−0.108	−0.319**	−0.307**	−0.215*	−0.347**	−0.138	−0.020	–					
10. SCAS Total[be]	21.77	12.49	1–67	−0.324**	0.003	−0.371**	−0.314**	−0.018	−0.106	−0.054	0.119	0.720**	–				
11. WISC-IV VCI[a]	106.63	11.25	81–132	0.152	0.075	0.048	0.155	0.055	−0.004	0.117	0.023	−0.155	−0.185	–			
12. Age (Years)	14.21	1.09	12–17	−0.114	−0.069	−0.066	−0.095	−0.054	−0.101	−0.063	0.036	0.161	0.187	−0.167	–		
13. Gender	–	–	–	−0.069	0.235*	−0.397**	−0.007	0.261*	−0.038	0.359**	0.319**	0.079	0.179	−0.018	0.021	–	
14. ADHD Symptoms[bc]	-1.00	1.02	-3.0–1.22	−0.040	−0.143	0.058	0.011	0.051	−0.030	0.120	0.043	0.170	0.029	−0.284*	0.093	−0.212	–

*MABC-2, Movement Assessment Battery for Children, Second-Edition; MSPSS, Multidimensional Scale for Perceived Social Support; MFQ, Mood and Feelings Questionnaire; SCAS, Spence Children's Anxiety Scale; WISC-IV, Wechsler Intelligence Scale for Children; VCI, Verbal Comprehension Index; ADHD, Attention Deficity Hyperactivity Disorder. *$p < 0.05$ (two-tailed). **$p < 0.001$ (two-tailed).*

[a]*Standard Score.*

[b]*Raw Score.*

[c]*Scores are calculated by averaging the total of all items in the measure.*

[d]*Scores are calculated by averaging the relevant subscale items in the measure.*

[e]*Scores are calculated by summing all items in the measure.*

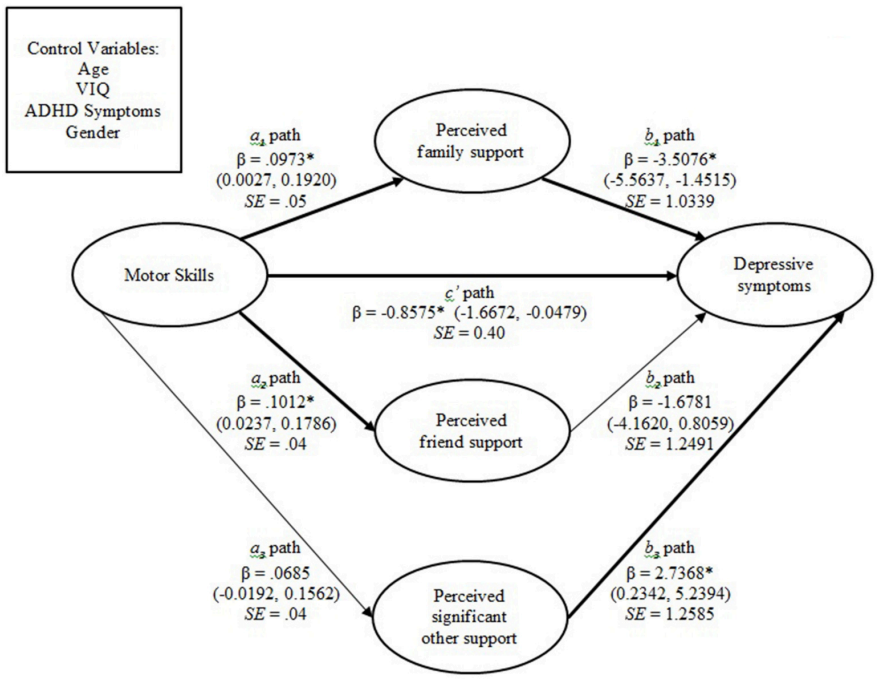

FIGURE 1 | Mediation model in which perceived family support partially has an indirect effect on the association between motor skills and depressive symptoms. Significant pathways are depicted in bold. $^{*}P < 0.05$. Note: 95% bias-corrected confidence intervals provided in parentheses. β, Standardized coefficient; SE, standard error.

hypothesis was not supported. Motor skills had a direct effect on anxious symptoms, but did not have an indirect effect on anxious symptoms via any domain of perceived social support.

Similar studies that have used measures of internalizing symptoms have found comparable results to the present study. For example, Wilson et al. (2013) found social skills mediated the relationship between motor skills and internalizing symptoms in young children. The authors measured internalizing symptoms as a single construct. Other studies have considered measures of anxious and depressive symptoms as observed variables which are driven by the latent construct of internalizing symptoms (Rigoli et al., 2012). The use of internalizing symptoms as an umbrella term for anxious and depressive symptoms is widely supported (Brady and Kendall, 1992; Kessler and Walters, 1998; Seligman and Ollendick, 1998), though there are several distinctions in the etiology and impact of anxious and depressive symptoms. Our findings highlight the need to examine the importance of perceived social support for adolescents on anxious and depressive symptoms separately. Previous studies in adolescent populations have also noted stronger and more consistent negative linear associations between perceived social support and depressive symptoms, compared to anxious symptoms (Haeffel and Mathew, 2010; Rueger et al., 2010; Väänänen et al., 2014). Analyses that unify anxious and depressive symptoms into internalizing symptoms may risk attenuating the relationship between variables. Furthermore, the Elaborated Environmental Stress Hypothesis includes a range of secondary psychosocial consequences that give rise to internalizing problems; it may be important to consider the differential impacts of these other factors on anxious and depressive symptoms.

While both mediation models accounted for significant variance, a substantial proportion of variance in anxious and depressive symptoms was unaccounted for. This suggests that there are additional factors that contribute to the formation of anxious and depressive symptoms in adolescents. We only investigated a portion of the Elaborated Environmental Stress Hypothesis. Multiple factors posited to mediate and/or moderate the association between motor skills and internalizing symptoms were untested in the present study. It is likely that future studies that look at several factors embedded within the Elaborated Environmental Stress Hypothesis will account for additional variance in internalizing symptoms. This is consistent with the understanding that the etiology of internalizing symptoms across the life span is influenced by multiple factors (Koplewicz and Klass, 1993).

Consistent with previous literature, the current study identified a direct association between motor skills and both anxious and depressive symptoms. This relationship is fundamental to the Elaborated Environmental Stress Hypothesis.

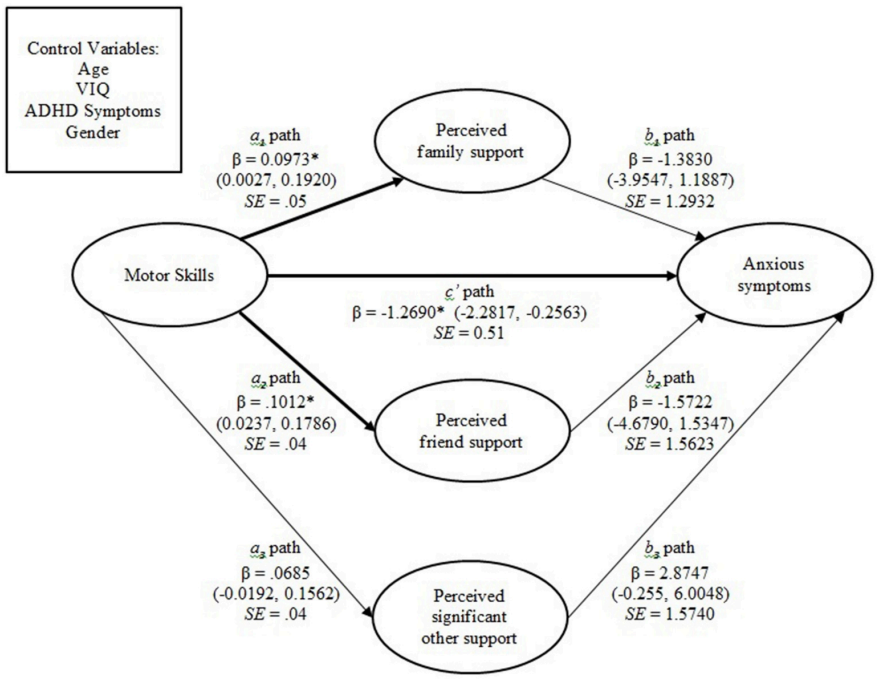

FIGURE 2 | Mediation model in which there is no indirect relationship between motor skills and anxious symptoms. Significant pathways are depicted in bold. $^{*}P < 0.05$. Note: 95% bias-corrected confidence intervals provided in parentheses. β, Standardized coefficient; SE, standard error.

Cairney et al. (2013) originally developed this framework for use in the child DCD population. However, more recent studies have also provided support for its use in broader community populations (Rigoli et al., 2012; Wilson et al., 2013; Viholainen et al., 2014; Piek et al., 2015). The present study adds to this literature, enlisting a community sample of adolescents and providing partial support for this framework.

In the present study, we specifically focused on perceived social support as a possible secondary consequence. It has been suggested that higher levels of motor skills are associated with higher levels of perceived social support, as it increases the chances for positive peer interactions and formation of friendships (Cairney et al., 2013). Similarly, the presence of poor motor skills may lead to frustration from family members and teachers, who may incorrectly attribute the individual's difficulties as inattention, task avoidance, or laziness (Missiuna et al., 2006). The individual may then perceive a decrease in perceived social support from these sources. Our current findings are congruent with previous research, as we identified a positive linear association between motor skills and perceived social support (from friends and family).

The association between perceived social support and internalizing symptoms in adolescence is well-researched. Higher levels of perceived social support are associated with lower internalizing symptoms (Rueger et al., 2010; Stewart and Suldo, 2011; Väänänen et al., 2014). This has been attributed to high levels of perceived social support providing a protective factor that allows an individual to more effectively handle potentially stressful events (Dumont and Provost, 1999). Perceived social support has been found to be more strongly associated with depressive symptoms compared to anxious symptoms (Haeffel and Mathew, 2010; Rueger et al., 2010; Väänänen et al., 2014). Consistent with these findings, the present results indicate a negative linear association between perceived social support (from family and a significant other) and depressive symptoms; no measure of perceived social support was significantly associated with anxious symptoms.

Perceived social support is multi-factorial (Rueger et al., 2010); therefore we measured perceived social support across three domains relevant to adolescents (friends, family, and a significant other). This allowed us to identify any differences between types of perceived social support and their relationship with motor skills and internalizing symptoms. For the mediation model predicting depressive symptoms, motor skills had an indirect effect on depressive symptoms via perceived family support only. Similarly, perceived family support had the strongest association with depressive symptoms, compared to perceived support from friends and a significant other. The results of the present study indicate that while there is a positive association between motor skills and perceived family support and perceived friend support, only perceived family support was significantly negatively associated with depressive symptoms. The present

findings are consistent with previous literature, which has identified family (particularly parents) as the strongest predictor of depressive symptoms and mental health in adolescents (Rueger et al., 2010; Stewart and Suldo, 2011).

This study enlisted a sample of adolescents between 12 and 16 years of age. Consequently, perceived family support may have been the strongest predictor of depressive symptoms due to the central role that family has during early adolescence (Morris et al., 2007). Previous studies have identified a transition in attachment patterns during adolescence, where individuals begin to draw on peers for social support (Noller et al., 2013). The participants in this study were in the early-to-mid stages of adolescent development and the transition from family support to other types of social support may still be underway. It is also equally plausible that perceived family support may be important in an adolescent sample as the family structure (particularly parents) may serve as a "secure base" for individuals to draw support from while they continue to explore and develop peer relationships throughout adolescence (Noller et al., 2013). An awareness of the shifting changes in attachment styles throughout the lifespan provides an important consideration for future studies seeking to explore the relationship between motor skills, perceived social support, and mental health outcomes in different age groups. For example, we may posit that perceived social support from friends, rather than family, may be a stronger predictor of mental health in older adolescent/adult samples. However, other studies have found that perceived family support was a stronger protective factor in depressive symptoms when compared to perceived friend support in adults aged 21–30 years (Pettit et al., 2011). Further empirical investigation is required, specifically within the context of motor skills.

An interesting observation to note was the significant positive association between perceived social support from a significant other and depressive symptoms (see **Figure 1**), suggesting that higher levels of perceived social support from a significant other is related to higher levels of depressive symptoms, which is inconsistent with previous literature. Additional investigation of this relationship is required in order to determine if these findings can be replicated.

This present study employed a cross-sectional, correlational research design to test a recently proposed causal framework. While the associations between motor skills, perceived family support, and depressive symptoms are congruent with the Elaborated Environmental Stress Hypothesis, the present research design was unable to identify temporal precedence between variables, as data was collected at a single point in time. While changes in perceived social support are generally considered to predispose changes in depressive symptoms, it is important to note that there is some research suggesting that depressive symptoms may influence perceived social support (Leskelä et al., 2008). Consequently, further longitudinal and experimental research is required in order to permit causal conclusions. While we employed robust bootstrapping procedures to address the potential limitation of a sample of 93 participants, enlisting a larger sample of adolescents in future studies is advised, particularly as it will allow for the testing of multiple variables and more rigorous analyses.

CONCLUSION

This study evaluated a key pathway specified by the recently proposed Elaborated Environmental Stress Hypothesis, the potential indirect effect of perceived social support between motor skills and internalizing symptoms. We identified an important, direct relationship between motor skills and both depressive and anxious symptoms in a community adolescent sample. There were no indirect effects between motor skills and anxious symptoms via perceived social support from friends, family, or a significant other. However, there was an indirect effect between motor skills and depressive symptoms, via perceived family support only. This study provides partial support for the Elaborated Environmental Stress Hypothesis. The present findings increase our understanding of how motor skills, perceived social support, and internalizing symptoms interact in a community adolescent sample. This has particular implications for the prevention of psychosocial problems in young people with poor motor skills. For example, improving perceived family support may serve as a protective factor that mitigates increased depressive symptoms. Programs aimed at improving the psychosocial outcomes of young people with motor difficulties could potentially include components that seek to improve support from family.

AUTHOR CONTRIBUTIONS

VM was the primary author of the article, who wrote the majority of the manuscript/conducted analysis. DR was responsible for the larger study of which the current data is part of, and also provided feedback on the manuscript. BH provided supervision and assisted in the methodological procedures of the research. LR and JP provided supervision and feedback regarding the process of the research and the subsequent manuscript.

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The relationship between motor proficiency and mental health outcomes in young adults: A test of the Environmental Stress Hypothesis

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ABSTRACT

Growing evidence has highlighted the importance of motor proficiency in relation to psychosocial outcomes including self-perceived competence in various domains, perceived social support, and emotional areas such as anxiety and depression. The Environmental Stress Hypothesis-elaborated (Cairney, Rigoli, & Piek, 2013) is a proposed theoretical framework for understanding these relationships and recent studies have begun examining parts of this model using child and adolescent populations. However, the extent to which the relationships between these areas exist, persist or change during early adulthood is currently unclear. The current study aimed to investigate the Environmental Stress Hypothesis in a sample of 95 young adults aged 18–30 years and examined the mediating role of physical self-worth and perceived social support in the relationship between motor proficiency and internalising symptoms. The McCarron Assessment of Neuromuscular Development (McCarron, 1997) was used to assess motor proficiency, the Depression Anxiety Stress Scale (Lovibond & Lovibond, 1995) provided a measure of internalising symptoms, and the Physical Self Perceptions Profile (Fox & Corbin, 1989) and the Multidimensional Scale of Perceived Social Support (Zimet, Dahlem, Zimet, & Farley, 1988) were used to investigate the possible mediating role of physical self-worth and perceived social support respectively. Potential confounding variables such as age, gender and BMI were also considered in the analysis. Structural Equation Modelling revealed that perceived social support mediated the relationship between motor proficiency and internalising symptoms, whereas, the mediating role of physical self-worth was non-significant. The current results provide support for part of the model pathways as described in the Environmental Stress Hypothesis and suggest an important relationship between motor proficiency and psychosocial outcomes in young adults. Specifically, the results support previous literature regarding the significant role of perceived social support for mental well-being and suggest that an intervention that considers social support may also indirectly influence mental health outcomes in young adults who experience movement difficulties.

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1. Introduction

There is a growing body of evidence showing that motor skill impairment in childhood may be a significant risk factor for poorer social and emotional outcomes (Lingam et al., 2012). Although a number of studies have highlighted this in child and adolescent samples (Missiuna et al., 2014), there is very limited research involving adult populations. Studies investigating the relationship between motor proficiency and mental health outcomes in adulthood are crucial given research that challenges the once widely-held assumption that children would "grow out of" movement difficulties (Cantell, Smyth, & Ahonen, 2003; Losse et al., 1991). Furthermore, Hill and Brown (2013) more recently revealed an increased risk for mental health difficulties (e.g., depression and anxiety) in adults with movement problems, specifically, those with developmental coordination disorder (DCD); impaired motor function in the absence of a neurological condition, interfering with activities of daily living, and impacting academic/vocational/leisure activities (American Psychiatric Association, 2013).

Although there is evidence for a link between motor proficiency and emotional symptoms, more research is needed to understand the nature of this association. Twin studies in children and adults have suggested that biological influences are important when understanding the etiological underpinnings of the relationship between motor and internalising problems, for example, genetic factors shared between coordination and emotional symptoms (Moruzzi et al., 2010; Waszczuk, Leonard, Hill, Rowe, & Gregory, 2016). In a recent twin study of young adults, Waszczuk et al. (2016) also found that non-shared environmental influences accounted for approximately one third of the phenotypic association between coordination difficulty and anxiety and depressive symptoms. However, research has only begun to uncover the possible environmental role for the relationship between motor skills and internalising symptoms.

Longitudinal studies have demonstrated a significant relationship between early motor skills and later emotional symptoms, providing some evidence for the role of environmental factors when understanding this relationship (Piek, Barrett, Smith, Rigoli, & Gasson, 2010; Shaffer, Schonfeld, O'Connor, Stokman, Trautman, Shafer, & Ng, 1985; Sigurdsson, Van Os, & Fombonne, 2002). This notion has also been supported by research employing monozygotic twin designs which allow the effects of genes and shared environment to be controlled (Pearsall-Jones, Piek, Rigoli, Martin, & Levy, 2011; Piek et al., 2007). These studies found increased levels of depressive and anxiety symptoms in child and adolescent twins with probable DCD compared to their co-twin without DCD (Pearsall-Jones et al., 2011; Piek et al., 2007).

While acknowledging the role of genetic influences in moderating the increased risk for emotional difficulties in individuals with poor motor skills, the Environmental Stress Hypothesis model proposed by Cairney, Veldhuizen, and Szatmari (2010) suggests that as children with movement difficulties are exposed to a number of negative psychosocial consequences (e.g., difficulties at school and with peers), these subsequently contribute to negative self-evaluations, which in turn, may lead to anxiety or depressive symptoms. The model was also recently elaborated to include physical inactivity and obesity as potential mediating factors in the relationship between motor proficiency and internalising symptoms (Cairney, Rigoli, & Piek, 2013). Importantly, negative self-perceptions are proposed to play a significant role in understanding the increased risk for emotional difficulties within the 'environmental stress' framework. Indeed, results have shown that children with poor motor skills rate their perceptions of their own abilities, especially concerning athletic competence, lower than their peers (Piek, Dworcan, Barrett, & Coleman, 2000). Lower self-perceptions in non-athletic areas such as academic achievement, physical appearance and social acceptance have also been reported by children and adolescents with movement difficulties (Piek, Baynam, & Barrett, 2006; Rose, Larkin, & Berger, 1997; Rose, Larkin, Parker, & Hands, 2015; Skinner & Piek, 2001). This is concerning when we know that a child's evaluation of themselves is closely linked with mental health outcomes such as depression (Cole, Martin, & Powers, 1997).

There is much less research regarding the impact of movement problems, such as those associated with DCD, in adulthood. The few studies so far suggest that the associated difficulties experienced by children also exist for adults, for example, difficulties with handwriting and organisational skills (Kirby, Sugden, Beveridge, & Edwards, 2008) in addition to tasks specific to adolescents and adults, such as learning to drive (Kirby, Sugden, & Edwards, 2011). A recent longitudinal study of young adults with DCD found lower participation in everyday activities, as well as lower quality of life, and life satisfaction (Tal-Saban, Ornoy, & Parush, 2014).

Recently, studies have also provided preliminary evidence for poorer mental health in adults with DCD and have examined some possible factors that may mediate this relationship (Hill & Brown, 2013; Kirby, Williams, Thomas, & Hill, 2013). In their study examining depression and anxiety in adults previously diagnosed with DCD, Hill and Brown (2013) also recorded the amount and nature of exercise that these individuals undertook. The adults with DCD reported reduced levels of physical exercise compared to their typical peers, however, after controlling for this, the DCD group still demonstrated significantly more symptoms of depression and anxiety. The authors also noted some limitations of the preliminary study, such as a lack of information about other potential mediators (for example BMI, cardiovascular fitness), and the need for a motor assessment battery to measure current motor ability (Hill & Brown, 2013).

Kirby et al. (2013) compared a sample of adults with DCD who were either employed or unemployed, and examined life satisfaction, general health and symptoms of anxiety and depression in these adults. It was found that both employed and unemployed groups reported high levels of depressive symptoms and rated their satisfaction with life quite poorly, but the unemployed group reported significantly more depressive symptoms and less satisfaction (Kirby et al., 2013). The results also identified high levels of anxiety in both groups. However, the authors noted the inability to establish causality and the direction of their findings. Nevertheless, these studies provide some preliminary examination of the Environmental

Stress Hypothesis in adults and possible risk and protective factors in the relationship between movement and emotional problems.

Previous research has reported poorer physical self-perceptions in child DCD samples (Cairney et al., 2005). Furthermore, the significant role of perceived athletic competence in predicting depressive symptoms in these children has also been highlighted (Francis & Piek, 2003). Thus, it is plausible that physical self-perceptions also have an important role in understanding the links between movement and emotional problems in adults. In fact, previous research has identified relationships between physical self-concept and depression and anxiety in adult samples (Knapen et al., 2005; Van de Vliet et al., 2002). Knapen et al. (2005) reported improvement in physical self-concept in a nonpsychotic psychiatric adult sample following psychomotor treatment, and found that this improvement in physical self-concept was correlated with improved self-esteem, and improved depression and anxiety. It was argued that their findings supported the Exercise and Self-Esteem Model, based on Bandura's self-efficacy theory, which proposes that improvements in physical self-concept lead to enhancements in global self-esteem (Knapen et al., 2005). In turn, increased global self-esteem can lead to a reduction of depression and anxiety symptoms.

The Environmental Stress Hypothesis also proposes that social resources have an important role in understanding the relationship between motor proficiency and emotional areas. Research using child and adolescent samples has revealed increased risk for interpersonal difficulties for those with movement problems, such as lower sociometric preference scores (i.e., a measure of peer preferences) in play settings when rated by their peers, and greater teacher-rated peer exclusion (Livesey, Lum Mow, Toshack, & Zheng, 2011), as well as peer-victimization (Campbell, Missiuna, & Vaillancourt, 2012). Not surprisingly, there is also evidence for lower levels of self-perceived social acceptance and support (e.g., Schoemaker & Kalverboer, 1994; Skinner & Piek, 2001). Harter's research suggests that good social support may buffer the effects of lower self-perceived competence, protecting against lowered global self-worth and therefore, possible internalising problems. Research regarding the link between motor proficiency and social support in adult populations is limited, however, the role of social support in predicting mental health outcomes such as depression is well established (Schroevers, Ranchor, & Sanderman, 2003).

The current study examines the mediating role of physical self-worth and perceived social support in the relationship between motor proficiency and mental health outcomes using a non-clinical sample of young adults. Studies involving community normative samples are important to show that the relationships are not just confined to clinical groups or individuals with movement difficulty, but rather, that they appear on a continuum, ranging from individuals who demonstrate difficulty in these areas to those who perform well. Recently, mediation studies have begun to test these pathways using normative samples. Furthermore, more studies are needed to examine the possible mechanisms through which motor proficiency may be related to the internalising domain and also how these may change throughout the lifespan. It is hypothesised that physical self-worth and perceived social support will mediate the relationship between motor proficiency and internalising symptoms in the current sample of young adults.

2. Method

2.1. Participants

The current study involved a convenience sample of 95 young adults (60 females, 35 males) aged between 18 and 30 years (M = 21.73, SD = 3.16). Participants were recruited through a combination of techniques, including the distribution of flyers and emails to staff and students at three Western Australian Universities. Snowball sampling procedures were also used, with initial participants encouraged to pass the study details on to their peers.

2.2. Measures

2.2.1. McCarron Assessment of Neuromuscular Development (MAND, McCarron, 1997)

The MAND is a test of motor performance, comprising five fine motor and five gross motor tasks, for individuals aged 3.5 years to adult (McCarron, 1997). Raw scores are based on absolute qualitative and/or quantitative performance for each task, and are scaled to the participants' age and sex (for two strength-related tasks) according to conversion tables For adults, relevant subtest standard scores are averaged and converted to factor standard scores, namely, Persistent Control, Muscle Power, Kinesthetic Integration, and Bimanual Dexterity (McCarron, 1997). The MAND total raw score (sum of subtest raw scores) is used to convert to a total standard score. A standard score of 100 (SD = 15) represents an average score and scores below 85 indicate movement difficulty. The MAND's total standard score, comprising both fine and gross motor skills, was used for the current study. The MAND has demonstrated good reliability and validity (McCarron, 1997).

2.2.2. Depression Anxiety Stress Scale (DASS-21; Lovibond & Lovibond, 1995)

The DASS-21 self-report questionnaire is designed to measure three symptom subscales of depression, anxiety and stress in adults. Each subscale comprises seven items and uses a 4-point Likert response format, rating severity or frequency of each state over the past week. The DASS-21 total score was used for the current study, with higher scores representing greater emotional symptoms. Using a large nonclinical sample, Henry and Crawford (2005) demonstrated evidence for the sound reliability and validity of the DASS-21.

2.2.3. The Physical Self-Perception Profile (PSPP; Fox & Corbin, 1989)

Self-perceptions in the physical domain were measured using the PSPP, a 30 item questionnaire comprising four subdomains of self-perceived sport competence, physical condition, attractive body, and physical strength, as well as a global subscale of physical self-worth. The questionnaire uses a structured alternate format shown to eliminate socially desirable responding. Each subscale comprises six items, with a total possible score ranging from 6 to 24 per subscale. Higher scores represent positive perceptions in the various domains. The physical self-worth subscale was used in the current study to reflect feelings of pride, respect, and satisfaction with the physical self. The PSPP has demonstrated to be a reliable and valid measure of physical self-perceptions (Hagger, Asçi, & Lindwall, 2004; Page, Fox, Biddle, & Ashford, 1993)

2.2.4. The Multidimensional Scale of Perceived Social Support (MSPSS; Zimet, Dahlem, Zimet, & Farley, 1988)

The MSPSS is a 12 item scale which assesses perceptions of social support adequacy across three domains including, family, friends, and significant other. Respondents are asked to indicate their agreement with items on a 7-point Likert scale ranging from very strongly disagree to very strongly agree. The total MSPSS score was used for the current study, with higher scores indicating a higher degree of perceived social support. The MSPSS was originally developed to assess social support in an undergraduate sample, however, studies have also demonstrated that the MSPSS is psychometrically sound in diverse samples including adolescents (Canty-Mitchell & Zimet, 2000), youth (Bruwer, Emsley, Kidd, Lochner, & Seedat, 2008), older adults (Stanley, Beck, & Zebb, 1998), as well as in clinical and nonclinical samples (Cecil, Stanley, Carrion, & Swann, 1995).

2.2.5. Body mass index

Weight and height were recorded using standard protocols, in order to determine body mass index (BMI). BMI was calculated as weight in kilograms divided by the square of height in metres (weight/height^2).

2.3. Procedure

This study followed the National Health and Medical Research Council of Australia (NHMRC) ethical guidelines, and was granted joint approval from the Curtin University, University of Notre Dame, and University of Western Australia Human Research Ethics Committees. Prospective participants provided informed consent before completing the study. The study comprised two components. Firstly, participants completed an online questionnaire which included a battery of psychosocial questionnaires, and demographic information. Participants were able to complete this component of the study using any internet-enabled device, prior to completing the second component of the study. The second component of the study required participants to be individually tested by a trained examiner, who assessed participants' height and weight, as well as levels of motor proficiency using the MAND. Sessions were conducted in a controlled setting (i.e., lab setting free from distractions) at University.

2.4. Data analysis

Structural equation modeling (SEM) was used to test the hypothesis that physical self-worth and perceived social support mediate the relationship between motor proficiency and internalising symptoms. The mediation model consists of 11 free parameters (seven path coefficients, three disturbances, and one variance). In order to reliably test the SEM, at least 5–10 participants has been recommended for each parameter (Kline, 2005). The present sample size of 95 provides around nine participants per parameter, which is within the recommended range. Standard errors for each path coefficient and the two indirect effects were estimated with a bootstrapping procedure based on 1000 draws as implemented by Mplus (Version 5.2; Muthén & Muthén & Muthén, 2008).

Prior to the SEM, bivariate correlations between study variables and potential confounders were computed in order to determine whether the latter variables needed to be controlled when estimating path coefficients for the SEM. Also, the bivariate correlations among the latent variables in the SEM were computed in order to determine the viability of the mediation analysis. If there were no relationship between motor proficiency and internalising symptoms, for instance, then there would be no relationship to mediate.

3. Results

3.1. Descriptives

Table 1 shows the means, standard deviations, and ranges for the study variables.

3.2. Correlations

Given that obesity is also included within the Environmental Stress Model, the potential confounding role of body mass index (BMI) was considered. However, to impact the relationships, a potential control variable needs to be significantly correlated with at least two of the four indicators. BMI and age did not satisfy this condition and therefore were not controlled

Table 1
Means, standard deviations (SD) and range of scores.

	Mean	SD	Range
MAND total standard score	96.03	10.13	63.0–129.0
DASS-21 total score	14.52	10.39	1.0–56.0
MSPSS total score	67.84	12.41	17.0–84.0
PSPP physical self-worth	14.43	3.92	6.0–23.0
Body mass index	22.48	3.94	16.9–37.80

Table 2
Bivariate correlations between potential control variables (age, gender, and BMI) and the latent study variables (N = 94).

	Age	Gender	BMI
1. Motor proficiency	0.01	−0.45***	−0.13
2. Internalising symptoms	−0.08	0.12	−0.01
3. Perceived social support	0.18	0.06	0.01
4.Physical self-worth	0.03	−0.33**	0.06

** $p < 0.01$.
*** $p < 0.001$.

for. The pattern of significant correlations in Table 2 indicates additional significant pathways from gender to motor proficiency and physical self-worth. These pathways were therefore included in the SEM to control for the potentially confounding effect of gender on the relationship between motor proficiency and physical self-worth.

The bivariate correlations among the latent variables are reported in Table 3. The bivariate correlation between motor proficiency (as measured by the MAND total standard score) and internalising symptoms (as measured by the DASS total score) was significant; as were the correlations between motor proficiency and perceived social support (as measured by the MSPSS total score), perceived social support and internalising symptoms, and physical self-worth (as measured by the PSPP physical self-worth total score) and internalising symptoms. There was no significant correlation between perceived social support and physical self-worth, and the correlation between motor proficiency and physical self-worth was significant only at the one-tailed level. The pattern of correlations among the latent variables indicates the viability of using SEM to analyse the pathways among them.

3.3. SEM analysis

If perceived social support mediates the relationship between motor proficiency and internalising symptoms, then the 'motor proficiency → social support' and the 'social support → internalising symptoms' pathways must both be significant, which they were. The significance of these pathways, however, is a necessary but not sufficient condition for mediation. The overall 'motor proficiency → social support → internalising symptoms' indirect effect must also be significant, which it was (−0.108, $p = 0.039$); and the significant bivariate correlation between motor proficiency and internalising symptoms should be reduced to non-significance, which it was (from $p = 0.008$ to $p = 0.383$). Thus perceived social support was a significant mediator of the relationship between motor proficiency and internalising symptoms in the current model.

If physical self-worth mediates the relationship between motor proficiency and internalising symptoms, then the 'motor proficiency → physical self-worth' and the 'physical self-worth → internalising symptoms' pathways must both be significant; however, the motor proficiency → physical self-worth pathway was not significant (−0.019, $p = 0.627$), contributing to a non-significant 'motor proficiency → physical self-worth → internalising symptoms' indirect effect. Thus physical self-worth was not a significant mediator of the relationship between motor proficiency and internalising symptoms in the current model (Fig. 1).

Table 3
Bivariate correlations among the latent variables (N = 95).

	1	2	3
1. Motor proficiency			
2. Internalising symptoms	−0.27**		
3. Perceived social support	0.29**	−0.42***	
4. Physical self-worth	0.19	−0.35**	0.06

** $p < 0.01$.
*** $p < 0.001$.

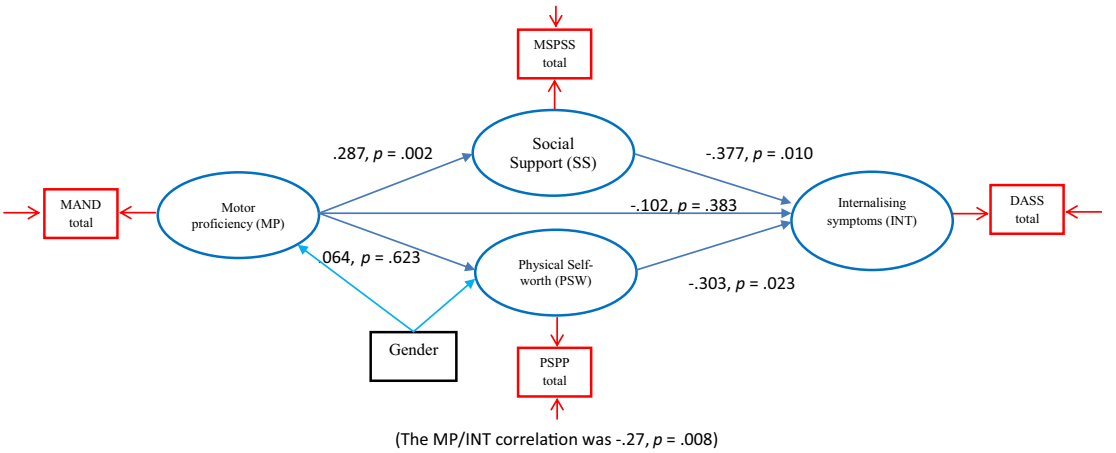

Fig. 1. Motor proficiency predicts levels of perceived social support and levels of physical self-worth, which in turn predict internalising symptomatology. The structural model is in blue; the ovals represent psychological constructs, and the blue arrows represent causal pathways. The measurement model is in red; the inward-pointing red arrows represent the error variances inherent in measuring the psychological constructs (the blue ovals) with psychometric instruments (the red boxes), and the outward-pointing red arrows represent factor loadings. The black box represents an observed variable that is measured without error. For each of the psychometric instruments, error variance is set to Var(1 – rel) and the factor loading is set to SD$\sqrt{}$rel where 'rel' represents the reliability of the instrument. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4. Discussion

The current results provide support for the Environmental Stress Hypothesis (Cairney et al., 2013) which was used as an overarching framework to further understand the relationship between motor proficiency and emotional functioning in a young adult population. Previous research has also provided support for the Environmental Stress Hypothesis in younger populations, for example, a cross-sectional study of 4- to 6-year-olds demonstrated the mediating role of social skills between motor coordination and internalising symptoms (Wilson, Piek, & Kane, 2013). The mediating role of self-perceptions in an adolescent sample has also been found (Mancini, Rigoli, Heritage, Roberts, & Piek, 2016; Rigoli, Piek, & Kane, 2012).

In the current study, the results revealed an important mediating role for perceived social support when understanding the link between motor proficiency and emotional outcomes in young adults. This finding supports previous research in younger populations that found poorer outcomes in the social domain (e.g., peer difficulties, reduced social acceptance) for individuals who experience movement difficulties (Livesey et al., 2011; Schoemaker & Kalverboer, 1994; Skinner & Piek, 2001).

The current results also highlight the negative impact that lower perceived social support can have on mental health. It is known that individuals with movement problems are more likely to withdraw from social participation, particularly physical and sporting participation (Cairney et al., 2005), which may subsequently contribute to reduced perceived social support experienced by these individuals. Therefore, it appears that prevention and intervention programs for young adults with movement difficulties should consider social support as an important factor when addressing or enhancing mental health outcomes in these individuals.

In the current study, physical self-worth was not a mediating factor in the relationship between motor proficiency and emotional symptoms. Conversely, in a study of adolescents, Schmidt, Blum, Valkanover, and Conzelmann (2015) found that physical self-concept did mediate the relationship between motor ability and the psychosocial outcome of self-esteem. It was noted that their findings highlighted the importance of satisfaction with one's own body and appearance and the impact of this on mental well-being during adolescence, a developmental period when significant physical changes occur and uncertainties arise about one's body (Schmidt et al., 2015). While it is important to note that the self-esteem construct in Schmidt et al.'s study is not equivalent to the psychosocial outcome variable of the current study, the results from the current study may suggest possible developmental changes in the relationship between motor proficiency and mental well-being across the life-span, specifically, in terms of potential risk and protective factors that are important in understanding the relationship. Therefore, the examination of these relationships in a young adult sample presents a significant strength of this study.

It is important to note that a limitation of the present study is its cross-sectional nature, and as such, the results cannot imply causality nor the direction of the relationships. In addition, possible biological factors cannot be ruled out. Indeed, twin studies have provided evidence for the important role of biological influences, and have suggested that approximately half of the genetic liability may be shared between coordination and emotional symptoms such as anxiety (Moruzzi et al., 2010; Waszczuk, Leonard, Hill, Rowe, & Gregory, 2016). For example, cerebellar dysfunction has been associated with both movement skills and emotional regulation (Diamond, 2000; Schutter & van Honk, 2009). Other unmeasured factors may also play

an important role in explaining the relationship, for example, physical activity and participation. This is consistent with the understanding that the aetiology of psychopathology across the lifespan is multi-factorial involving a complex interplay of biological, psychological and environmental factors, and that these complex relationships should be considered. Furthermore, the current study did not collect information regarding other potentially confounding conditions (e.g., learning difficulties, attention deficit hyperactivity disorder), or other specific life events (e.g., occurring during the DASS-21 rated period in the past week), presenting as limitations. Finally, the study employed a predominantly university student sample which may also limit the generalisability of the findings.

The current study highlights the importance of future longitudinal or experimental research to examine the complex relationships between motor proficiency and psychosocial outcomes, and importantly, consider the relationship developmentally and across the lifespan, as well as the impact on typical and atypical development (i.e., examining these relationships in both DCD and non-DCD samples (Hill & Brown, 2013). For the current sample of young adults, the literature does not provide sufficient support for examining the four MAND subscales (persistent control, muscles power, kinaesthetic integration and bimanual dexterity, based on 39 7-year-old children), or fine and gross motor scores (based on 31 mentally disabled adults) individually in this context (McCarron, 1997). An analysis of MAND scores for 1215 17 year olds did not support either factor structure (Hands, Larkin, & Rose, 2013). It is recommended that future research consider the potential influences of fine versus gross motor skills on psychosocial outcomes, separately, as it is possible that this may contribute to differential findings regarding the proposed Environmental Stress pathways (Piek et al., 2006).

Research has only begun to explore the proposed Environmental Stress pathways and a comprehensive examination of the possible mediating factors has yet to be conducted, and is important to provide much needed information to inform interventions. Importantly, literature has also shown that not all those individuals who experience movement problems report increased emotional problems. Therefore, future studies considering individual differences and potential protective factors are important. Given evidence to suggest that the link between motor proficiency and mental health outcomes continues into adulthood, it is clear that early intervention and preventative efforts may represent crucial protective factors in promoting healthy mental well-being in later years for those individuals who experience movement problems.

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Discussion

Despite research as early as the 1930s identifying a possible link between motor development and emotional factors (Schilder, 1939), substantial growth in this area only started after the formal recognition of DCD in 1987 (APA, 1987). As part of this movement, researchers started to recognise that the ability to perform accurate and coordinated movements has important implications for psychosocial development. The attainment of developmentally appropriate movement milestones (i.e. crawling, walking) provides opportunities for positive psychosocial development (Piek, 2006; Piek, Barrett, Smith, Rigoli, & Gasson, 2010; Poole et al., 2015b). For example, young children who participate in structured and unstructured play with peers are granted the opportunity to refine social skills, develop peer relationships and foster a sense of self-competence. Consequently, those who lack the necessary age-appropriate motor skills required to meet the demands of their environment tend to experience additional psychosocial difficulties (Lingam et al., 2012; Skinner & Piek, 2001). While there has been significant growth in the amount of empirical research establishing an association between motor skills and internalising problems, this area has been limited by a lack of complementary theoretical development. Cairney et al. (2010) attempted to address this limitation by tailoring Pearlin's Stress Process Framework (1989) to describe the indirect mechanisms through which DCD may be a cause of internalising problems in children. This was referred to as the 'Environmental Stress Hypothesis', and was later expanded by Cairney et al., (2013) and referred to as the 'Elaborated Environmental Stress Hypothesis'. While promising, many of the indirect pathways through which motor skills are hypothesised to be associated with internalising problems in the framework remain empirically untested.

According to the Elaborated Environmental Stress Hypothesis, an individual with poor motor skills is consequently exposed to a cascade of negative interpersonal and intrapersonal consequences, and it is the manifestation of these psychosocial consequences that lead to increased internalising problems (Cairney et al., 2010; Cairney et al., 2013); the manifestation of these psychosocial factors then mediates and moderate the association between motor skills and internalising problems. Very few empirical studies have tested the indirect relationship between motor skills and internalising problems hypothesised by the Elaborated Environmental Stress Hypothesis (Mancini et al., submitted; see Appendix D for summary of studies). Only five empirical studies had tested the indirect relationship between motor skills and internalising problems contained within the Elaborated Environmental Stress

Hypothesis, prior to the publication of the four mediation studies included in this thesis. Each of these studies offered a unique evaluation of the framework by testing different interpersonal and intrapersonal factors posited to mediate or moderate the association between motor skills and internalising problems (Mancini et al., submitted). However, several additional pathways of the framework were yet to be evaluated; other pathways that had been identified in specific cohorts (e.g., in 4 to 6-year-old children) had not been validated in other age groups.

This thesis presented a series of papers to address the lack of current empirical support for the Elaborated Environmental Stress Hypothesis, particularly within community populations and across varying stages of development. The results of these studies highlighted the persistent association between motor skills and internalising problems in four different community populations spanning from early childhood (4 to 6 years) to adulthood (18 to 30 years), and provided support for at least some of the indirect pathways through which this association is posited to occur according to the Elaborated Environmental Stress Hypothesis. This has significant implications for our understanding of the association between motor skills and internalising problems, and for intervention strategies that aim to improve motor skills and psychosocial functioning.

The first study of the current thesis reviewed the current literature pertaining to the Elaborated Environmental Stress Hypothesis. Results highlighted that although the framework had been designed to understand the psychosocial consequences of children with DCD, preliminary studies had identified support for the framework in community populations. An additional finding was that despite evidence supporting the persistence of movement difficulties and psychosocial difficulties into later life, there have been only a few attempts to explore these relationships within these older samples.

A central aim of the current thesis was to contribute to this area of research by testing specific indirect pathways of the Elaborated Environmental Stress Hypothesis that were yet to be evaluated in each of the target populations enlisted. Examples of interpersonal factors that were found to mediate the relationship between motor skills and internalising problems included peer problems (Study Two and Three) and social support (Study Four and Five). This supports previous findings regarding the importance of the social domain in these relationships, specifically, social skills have been found to mediate the association between motor skills and internalising problems (Wilson et al., 2013). Intrapersonal factors such as perceived self-competence and self-

concept were also identified as mediating factors in Study Two and Study Three of the current thesis, also supporting findings from previous research (Rigoli et al., 2012; Viholainen et al.,2014).

In Study Two peer problems mediated the association between motor skills and internalising problems. However, at 18-month follow-up, peer problems and perceived physical competence mediated this association, but not perceived cognitive competence. This finding may also be explained by particularly young children not yet having developed an adequate sense of self-competence, which will typically form around 6 to 7 years of age (Piaget, 1953, 2000).

In Study Three, we found a slightly different association in a sample of 7 to 12-year- old children; the association between motor skills and internalising problems was mediated by peer problems and perceived scholastic competence, but not physical competence. One possible reason for these findings is that children in the later stages of primary school may place greater value on their academic abilities compared to their younger counterparts. The ability to integrate these studies help to provide an evaluation of the Environmental Stress Hypothesis across different periods of development, particularly in the absence of long-term longitudinal research which is required to generate more comprehensive findings. However, the preliminary findings from Study Two that analyses data from the same sample at two time-points, suggests that the pathways contained within the framework may differ across key periods of development. This notion is also consistent with literature supporting the dynamic nature of psychosocial development across the lifespan (Piaget, 1959).

Study Four tested the mediating role of perceived social support on internalising problems in an adolescent population. The results revealed a partial indirect effect of perceived familial support on the relationship between motor skills and depressive symptoms. This partial indirect effect might be explained by unaccounted factors that have been previously shown to mediate this relationship in adolescents such as perceived self-competence (Rigoli et al., 2012; Viholainen et al., 2014). In Study Five, the indirect pathways through perceived social support and perceived physical self-worth were investigated in a sample of young adults aged 18 to 30. Results indicated that the relationship between motor skills and internalising problems was fully mediated by perceived social support after controlling for age, gender and BMI. There was no significant indirect pathway via perceived physical self-worth. The results of Studies Four and Five are partially consistent with the results of the previous two studies. While they

also highlight the indirect effect of motor skills on internalising problems via interpersonal factors, no significant pathways via intrapersonal factors (i.e., perceived self-competence) were identified. One possible explanation is that motor skills may be less important when determining self-competence in later life compared to childhood. However, it is important to highlight that other studies using adolescent populations have found associations between motor skills and self-worth, meaning that further investigation is required (Rigoli et al., 2012; Viholainen et al., 2014). The results of these studies suggest that certain interpersonal factors (i.e., perceived social support) may persistently provide an indirect pathway through which motor skills may impact internalising problems. Such factors may be important targets for intervention and prevention programs, regardless of the age of the target population.

Implications for Intervention

As the Elaborated Environmental Stress Hypothesis describes the various pathways through which motor skills are associated with internalising problems, it can also be used to aid in the design and evaluation of intervention programs (Cairney et al., 2013). Many earlier intervention programs predominantly focused on addressing the physical difficulties experienced by those with poor motor skills (Pless & Carlsson, 2000). However, these interventions did not account for the negative psychosocial consequences experienced by those with poor motor skills that have since been well-established (Cairney et al., 2013; Cairney et al., 2010; Missiuna & Campbell, 2014; Skinner & Piek, 2001). Awareness of the additional psychosocial difficulties commonly experienced by those with poor motor skills has influenced the development of combined psychosocial and motor skills intervention programs that seek to improve both motor and psychosocial functioning.

The tests of the Environmental Stress Hypothesis conducted as part of this thesis provided support for several psychosocial factors that appear to mediate the association between motor skills and internalising problems. Interventions that aim to improve these psychosocial consequences have the capacity to ‘interrupt’ the trajectory of poor motor skills to internalising problems (Missiuna & Campbell, 2014). The papers included in this thesis highlight interpersonal factors, namely perceived social support and peer problems, that may serve as effective targets for intervention. The inclusion of efforts to improve these interpersonal factors as part of motor skills intervention programs is particularly important considering these interpersonal factors mediated the association between motor skills and internalising problems in each of the child, adolescent

and adult populations that were tested. Intrapersonal factors (like perceived self-competence) were also found to mediate this association in middle childhood (but not in the adult sample). These pathways were also weaker than the interpersonal factors that were examined. This suggests that the effectiveness of combined psychosocial and motor skills intervention during early childhood may be enhanced by adopting greater focus on interpersonal psychosocial factors. Intervention programs in later development should continue to target interpersonal factors, but could also include intrapersonal factors such as perceived self-competence. The earlier stages of development also represent a crucial time for prevention efforts that could promote positive self-concept and peer relationships before they become problematic. It is important to note that previous research has advocated for the inclusion of strategies to improve perceived self-competence in populations with poor motor skills (Mandich et al., 2003). Peens et al. (2008) found that children with DCD may benefit from independent movement and self-concept interventions, but obtain optimal benefit when both motor and psychosocial domains are targeted. The efficacy of targeting perceived self-competence in universal motor skill intervention programs is yet to be tested, but may prove to be important.

Each of the mediation models in this thesis enlisted community populations to test the indirect pathways in the Environmental Stress Hypothesis. Each study highlighted the presence of an association between motor skills, psychosocial and emotional factors across the full continuum of motor ability in child, adolescent and adult populations. These results suggest that the possible benefit of combined psychosocial and motor skills intervention programs may not be confined to only those with poor motor skills. While previous combined psychosocial and motor skills intervention programs often targeted DCD populations (e.g. Peens et al., 2008), Piek et al. (2015) recently evaluated the effectiveness of a school-based universal combined psychosocial and motor skills intervention program for children aged 4 to 6 years. Results indicated that participation in the *Animal Fun* program (Piek, Straker, et al., 2010) could result in improved social and behavioural outcomes, as well as improve motor performance (Piek et al., 2015; Piek et al., 2013). Framed within the Environmental Stress Hypothesis, this intervention program fosters the development of positive psychosocial outcomes that can buffer the negative emotional consequences of poor motor skills. Not all the factors found to mediate the association between motor skills and internalising problems in this thesis have been included in a combined psychosocial and motor skills intervention. However, the results of this thesis provide preliminary support for their potential efficacy. As mentioned previously, several

pathways in the Environmental Stress Hypothesis require further exploration that may lead to the identification of additional targets for intervention. For example, a recent movement intervention with adolescents with motor difficulties also increased physical self-perceptions (McIntyre et al., 2015).

Strengths of the Current Research

The conceptualisation of the Environmental Stress Hypothesis by Cairney et al. (2010; 2013) was informed by a series of studies that predominantly examined the association between only two of the factors that exist within the entire framework. Consequently, the important indirect pathways between motor skills and internalising problems that characterise the framework had been empirically under-examined. Very few studies had previously tested these indirect relationships (Rigoli, Piek, & Kane, 2012; Wagner, Bös, Jascenoka, Jekauc, & Petermann, 2012; Wilson, Piek, & Kane, 2013). The studies presented in this thesis addressed this limitation by testing several of these additional indirect pathways. The results provided important empirical support for the framework and furthered the understanding of how motor skills are associated with internalising problems. None of the current studies included in this thesis, or any other published study has tested all the pathways through which motor skills is posited to be associated with internalising problems in the framework, largely due to the complex number of relationships between numerous variables depicted in Figure 1. Previous research (e.g. Wilson et al., 2013) tested an indirect association between motor skills and internalising problems via social skills, and found that this was a fully mediated relationship. However, such studies are limited in their ability to discriminate important predictors from unimportant predictors and cannot investigate the potential interaction effects of multiple mediator variables that often occur concomitantly in daily life. Each of the four mediation studies included in the current thesis have included multiple mediator variables. For example, Study Five examined the potential mediating effect of social support and physical self-worth on the association between motor skills and internalising problems in a sample of adults aged 18 to 30 years of age. While both mediating variables were negatively associated with internalising problems, only social support mediated the association. The benefit of such studies is that the relative strength of hypothesised mediators can be judged against one another, allowing for the identification of targets likely to maximise the effectiveness of

intervention efforts. Ongoing inclusion of multiple indirect pathways is recommended for future studies testing the Environmental Stress Hypothesis, further exploring the interaction between mediator variables given the well-established links between these interpersonal and intrapersonal psychosocial factors (e.g. social support and social skills).

Despite a growing number of studies that show the consequences of poor motor skills persist throughout childhood and into later life, much of the research in this area continues to focus on childhood. This reflects the tendency for motor skill problems to be commonly identified and treated during childhood. However, as the dynamic nature of psychosocial development throughout the lifespan is well-documented, the generalisability of findings in childhood to later life are somewhat limited. The studies presented in this thesis contribute valuable information to the literature by testing components of the Elaborated Environmental Stress Hypothesis in four distinct populations that range from early childhood (4 to 6 years) to adulthood (18 to 30 years). The results revealed some shared commonality; most importantly an association between motor skills and internalising problems was identified in each of the populations. However, some important differences in the indirect association between motor skills and internalising problems were also found that may have been overlooked had there been a focus on only one age-group. This represents a significant strength, and highlights the need for longitudinal studies in future.

The current study highlighted an important link between motor skills and internalising problems in four different community populations. This represents an additional strength of the current research, as a tendency for research to focus on clinical populations (in this case, individuals with DCD) may lead to the overestimation of the association between motor and internalising domains (Rigoli et al., 2012). Furthermore, this process may also minimise the experience of individuals who still experience internalising difficulties despite not having met criteria for a movement disorder. Roebers and Kauer (2009) argued that correlational research in community populations is an important step in identifying the specific nature of the relationship between motor and psychosocial domains, which was addressed in the current research. The results of the mediation models included in this thesis have also justified the use of universal intervention programs rather than interventions only for those with a clinical disorder.

Limitations and Directions for Future Research

Limitations specific to each study are included in each of the published manuscripts. Overall, a general limitation of the studies presented in this thesis were the cross-sectional, correlational research designs that were used. This type of research cannot generate causal inferences, nor can it infer the directionality of relationships. However, future experimental and longitudinal research designs based on these correlational studies will be able to identify cause-and-effect relationships between motor skills, psychosocial factors and internalising problems. Missiuna and Campbell (2014) suggest that intervention programs can serve to establish causality while also potentially improving the psychosocial outcomes of those with poor motor skills. The studies included in the current thesis provide a preliminary suggestion that pathways in the framework may differ across different stages of development (Mancini et al., 2017). However, longitudinal studies are required to provide more conclusive support for this claim. To date, only one study has provided a longitudinal evaluation of the Environmental Stress Hypothesis, but investigated only direct pathways which did not allow for a longitudinal evaluation of the indirect pathways (Wagner et al., 2016).

Where possible, the studies accounted for variables that may confound the indirect associations between motor skills and internalising problems. However, factors such as ADHD symptoms and IQ were not accounted for in all studies. Accounting for these confounding variables in future research is necessary. There is a strong overlap between motor difficulties and difficulties with attention and hyperactivity (Goulardins et al., 2015); up to 50% of those with DCD also meet criteria for ADHD (Fliers et al., 2008; Pitcher, Piek, & Hay, 2003). Children with DCD have also been shown to experience co-occurring learning difficulties that can amplify the severity of additional psychosocial and emotional difficulties (Jongmans, Smits-Engelsman, & Schoemaker, 2003). Even after accounting for such difficulties, studies have continued to identify a significant association between motor skills and internalising problems (e.g., Rigoli et al., 2012). Co-occurring difficulties is something that has been accounted for in only some of the current studies. In study four, ADHD symptoms were included as a control variable. In each of the mediation studies included as part of this thesis, prospective participants were also excluded from the study if there was a diagnosed neurodevelopmental disorder (e.g., global developmental delay). A general limitation of most of the currently available literature is that not all studies examine such potential

confounding factors. Future studies could control for these factors and also potentially test whether pathways in the Environmental Stress Hypothesis differ due to the presence of different co-occurring issues (e.g. DCD + ADHD compared to DCD only).

The current studies provide an important, but not exhaustive, evaluation of the Elaborated Environmental Stress Hypothesis. Rather, these studies provide support for several of the pathways through which motor skills are posited to be associated with internalising problems. Several additional components of the framework are lacking in empirical evaluation. Each of these are described below.

A core component of the Environmental Stress Hypothesis that has not been evaluated is 'stressors' (see Figure 3 in the Introduction); a construct intended to capture the sustained levels of stress that are a consequence of poor motor skills. The presence of poor motor skills is referred to as a "well-spring of stress" that leads to disruption and difficulty with activities of daily living and normal social engagements (Cairney et al., 2013, p226). The presence of constantly elevated levels of stress may then directly contribute to increased internalising problems, but also indirectly by depleting protective psychosocial factors through 'stress eroding effects' (Cairney et al., 2013). The notion of stress was central to the conceptualisation of the Environmental Stress Hypothesis, which was inspired by the Stress Process Framework (Pearlin, 1989; Pearlin, Menaghan, Morton, & Mullan, 1981). The lack of studies evaluating the 'stressors' component of the Environmental Stress Hypothesis exists due to the absence of a measure that can quantify the unique stress-related experiences of individuals with poor motor skills. The development of such a measure is required to provide adequate empirical evaluation of each of the pathways in the framework that are directly and indirectly linked to this construct.

It is important to acknowledge that the Elaborated Environmental Stress Hypothesis also features physical inactivity and obesity as additional constructs. A current limitation is that their indirect association with other components of the framework have been comparatively under-examined. However the association between motor skills, physical inactivity and obesity in children is well-established (Cairney, Hay, Faught, Wade, et al., 2005; Green et al., 2011; Rivilis et al., 2011). In Study Five, BMI was included as a control variable, though it was not significantly associated with either motor skills or internalising problems in a young adult sample. Future studies could potentially examine the role of physical inactivity and obesity in younger samples; the interaction of these factors with the psychosocial components of the framework are subject to further

investigation.

The causes of psychopathology are multifactorial (Koplewicz & Klass, 1993). While the Environmental Stress Hypothesis encapsulates many factors previously shown to contribute to internalising problems, there may be other environmental and biological factors that also contribute to internalising pathology beyond those that are included in the framework (Waszczuk et al., 2016). The correlational studies that formed this thesis identified weak to moderate associations between internalising problems and motor skills or psychosocial factors, meaning a substantial proportion of variance in internalising problems could not be accounted for by the variables included in these studies (e.g. Mancini, Rigoli, Heritage, et al., 2016). Further expansion of the Elaborated Environmental Stress Hypothesis is possible. The inclusion of additional evidence-based factors that may also play an important role in the association between motor skills and internalising problems could increase the overall predictive power of the framework. The flexibility of the Environmental Stress Hypothesis means that it could be easily modified to investigate the association between motor skills, psychosocial factors and other emotional outcomes. For example, a similar indirect pathway has been examined between motor skills and externalising problems (Wagner et al., 2012).

Conclusions

Through the series of papers that were presented in this thesis, important indirect associations between motor skills and internalising problems that exist across the full continuum of motor ability and beyond childhood into later life has been highlighted. These findings support the use of the Elaborated Environmental Stress Hypothesis (Cairney et al., 2013) as a theoretical framework to understand this association. The mediation models tested in the current studies revealed that in each of the different age populations, the social factors (perceived social support and peer problems) were consistently of greater importance than the intrapersonal factors (perceived self-competence) in explaining the increased risk for internalising problems that are associated with poorer motor skills. This was evidenced by the significant indirect effects of motor skills on internalising problems via these social factors. These were also comparatively stronger than the indirect effect via intrapersonal factors in all the studies. However, the role of intrapersonal factors (perceived self-competence) were supported in some of these studies and should not be discounted. Previous intervention research has found that targeting psychosocial factors can lead to improved outcomes for intervention recipients. The findings from the studies presented in this thesis highlight additional targets for future intervention programs. By targeting these

factors in addition to the traditional physical aspects, movement intervention programs can maximise the potential benefits of treatment and prevention to recipients.

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Appendix A

Confirmation of Author Contributions

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21 August 2017

To whom it may concern,

I, Vincent Mancini, was the major contributor to the conceptualisation and coordination of the research resulting in the following paper:

Mancini, V. O., Rigoli, D., Cairney, J., Roberts, L. D., & Piek, J. P. (2016). The elaborated environmental stress hypothesis as a framework for understanding the association between motor skills and internalizing problems: a mini-review. *Frontiers in Psychology, 7*.

I am the lead author, and it was primarily my responsibility to conceptualise, collect and analyse data, write and edit the paper above, which is included in my PhD thesis. This paper provided a review of the currently available literature pertaining to the Environmental Stress Hypothesis. Commensurate with the extent of my contribution, I am the first author on this paper.

Vincent Mancini: Date: 21/08/17

I, Doctor Daniela Rigoli, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Daniela Rigoli: Date: 25/8/17

I, Professor John Cairney, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

John Cairney: Date: October 3, 2017

I, Associate Professor Lynne Roberts, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Lynne Roberts: Date: 22/8/17

I, Emeritus Professor Jan Piek, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Jan Piek: Date: 12/9/17

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Mancini, V. O., Rigoli, D., Roberts, L. D., Heritage, B., & Piek, J. P. (2017) Psychosocial correlates of motor skills in young children: changes over an 18-month period. *British Journal of Educational Psychology. doi10.1111 bjep.12187/full*

I am the lead author, and it was primarily my responsibility to conceptualise, analyse data, write and edit the paper above, which is included in my PhD thesis. This paper investigated the relationship between motor skills, peer problems, perceived self-competence, and internalising problems, in a community sample of children aged 4 to 6 years, which was collected as part of the *Animal Fun* program conducted by Curtin University. Commensurate with the extent of my contribution, I am the first author on this paper.

Vincent Mancini: Date: 21/08/17

I, Doctor Daniela Rigoli, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Daniela Rigoli: Date: 25/8/17

I, Doctor Brody Heritage, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Brody Heritage: Date: 25/8/17

I, Associate Professor Lynne Roberts, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Lynne Roberts: Date: 22/8/17

I, Emeritus Professor Jan Piek, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Jan Piek: Date: 12/9/17

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21 August 2017

To whom it may concern,

I, Vincent Mancini, was the major contributor to the conceptualisation and coordination of the research resulting in the following paper:

Mancini, V. O., Rigoli, D., Roberts, L. D., Heritage, B., & Piek, J. P. (Accepted). The relationship between motor skills, perceived self-competence, peer problems and internalizing problems in a community sample of children. *Infant and Child Development.*

I am the lead author, and it was primarily my responsibility to conceptualise, collect and analyse data, write and edit the paper above, which is included in my PhD thesis. This paper investigated the relationship between motor skills, peer problems, perceived self-competence, and internalising problems, in a community sample of children aged 8 to 12 years, which was collected as part of my PhD for Curtin University. Commensurate with the extent of my contribution, I am the first author on this paper.

Vincent Mancini: Date: 21/08/17

I, Doctor Daniela Rigoli, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Daniela Rigoli: Date: 25/8/17

I, Doctor Brody Heritage, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Brody Heritage: Date: 25/8/17

I, Associate Professor Lynne Roberts, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

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I, Vincent Mancini, was the major contributor to the conceptualisation and coordination of the research resulting in the following paper:

Mancini, V. O., Rigoli, D., Heritage, B., Roberts, L. D., & Piek, J. P. (2016). The relationship between motor skills, perceived social support, and internalizing problems in a community adolescent sample. *Frontiers in Psychology, 7*. doi:10.3389/fpsyg.2016.00543

I am the lead author, and it was primarily my responsibility to conceptualise, analyse data, write and edit the paper above, which is included in my PhD thesis. This paper investigated the relationship between motor skills, perceived social support, and internalising problems, in a community sample of adolescents aged 12 to 16 years. Commensurate with the extent of my contribution, I am the first author on this paper.

Vincent Mancini: Date: 21/08/17

I, Doctor Daniela Rigoli, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Daniela Rigoli: Date: 25/8/17

I, Doctor Brody Heritage, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

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21 August 2017

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I, Vincent Mancini, was a major contributor to the conceptualisation and coordination of the research resulting in the following paper:

Rigoli, D., Kane, R. T., **Mancini**, V., Thornton, A., Licari, M., Hands, B., McIntyre, F., & Piek, J. (2017). The relationship between motor proficiency and mental health outcomes in young adults: A test of the Environmental Stress Hypothesis. *Human Movement Science*, 16-23. doi: 10.1016/j.humov.2016.09.004

I made a significant contribution to the data collection, analysis, drafting, writing and editing of the paper above, which is included in my PhD thesis. Commensurate with the extent of my contribution, I am the third author on this paper.

Vincent Mancini: Date: 21/8/17

I, Doctor Daniela Rigoli, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Daniela Rigoli: Date: 25/8/17

I, Doctor Robert Kane, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Robert Kane: Date: 1/9/2017

I, Doctor Ashleigh Thornton, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Ashleigh Thornton: Date: 1/9/2017.

I, Doctor Melissa Licari, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Melissa Licari: Date: 4/9/17

I, Professor Beth Hands, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Beth Hands: Date: 4/9/17

I, Associate Professor Fleur McIntyre, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Fleur McIntyre: Date: 27/8/17

I, Emeritus Professor Jan Piek, endorse Vincent Mancini's contribution to the abovementioned paper, as specified above.

Jan Piek: Date: 12/1/2017.

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From: Cedric (Frontiers Zendesk) <support@frontiersin.org>
Sent: Thursday, 17 August 2017 5:15 PM
To: Vincent Mancini
Subject: [Frontiers Zendesk] Re: Publication Inclusion in PhD Thesis

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Please type your reply above this line

frontiers Helpdesk support@frontiersin.org

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Cedric (Frontiers Zendesk)
Aug 17, 11:14 AM CEST

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Best regards

Cedric

IT Helpdesk Analyst

Vincent Mancini
Aug 17, 10:52 AM CEST

To Frontiers in Psychology

I am writing this email to request permission to include a publication in my Doctor of Philosophy (Clinical Psychology) degree for Curtin University, that has been published in this journal. The publication is titled:

Mancini, V. O., Rigoli, D., Cairney, J., Roberts, L. D., & Piek, J. P. (2016). The elaborated environmental stress hypothesis as a framework for understanding the association between motor skills and internalizing problems: a mini-review. Frontiers in Psychology, 7.

and

Mancini, V. O., Rigoli, D., Heritage, B., Roberts, L. D., & Piek, J. P. (2016). The relationship between motor skills, perceived social support, and internalizing problems in a community adolescent sample. Frontiers in Psychology, 7.

I would like to include this publication as a chapter in my PhD, which will be made available in hard-copy form in the Curtin University Library, and in Digital form on the Internet via the Australian Digital Thesis Program. All precautions will be taken to ensure the integrity of the material.

Regards,

Vincent Mancini

Vincent Mancini
Lecturer | PhD Candidate | School of Psychology and Speech Pathology | Faculty of Health Sciences
Curtin University

Email | vincent.mancini@postgrad.curtin.edu.au
Web | https://www.linkedin.com/in/vincent-mancini/

Latest Publication: Mancini, V. O., Rigoli, D., Roberts, L. D., Heritage, B., & Piek, J. P. (Accepted). Psychosocial correlates of motor skills in young children: changes over an 18-month period. British Journal of Educational Psychology.

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From: Begum, Jabeena - India <jbegum@wiley.com>
Sent: Monday, 11 September 2017 6:43 PM
To: Vincent Mancini
Subject: RE: BJEP 12187 -- Revised Proof for approval

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Best regards,
Jabeena

Jabeena Begum G (Ms.)
Production Editor
On behalf of Wiley
Email: jbegum@wiley.com

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From: Vincent Mancini [mailto:vincent.mancini@curtin.edu.au]
Sent: 07 September 2017 13:41
To: Begum, Jabeena - India
Subject: RE: BJEP 12187 -- Revised Proof for approval

Hello Jabeena,

The plan for this article will be to include the full article as a chapter in my PhD thesis, which will be archived at Curtin University. It will not be publicly available, and only available to staff and students of the university. However, if I am reading this correctly, I will not be able to include the article for a 12-month period?

Regards,
Vincent

Vincent Mancini
Lecturer | PhD Candidate | School of Psychology and Speech Pathology | Faculty of Health Sciences
Curtin University

Email | vincent.mancini@postgrad.curtin.edu.au
Web | https://www.linkedin.com/in/vincent-mancini/

Psychosocial correlates of motor skills in young children: changes over an 18-month period. *British Journal of Educational Psychology*.

From: Begum, Jabeena - India [mailto:jbegum@wiley.com]
Sent: Thursday, 7 September 2017 2:26 PM
To: Vincent Mancini <vincent.mancini@curtin.edu.au>
Subject: RE: BJEP 12187 -- Revised Proof for approval

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Thank you.

Best regards,
Jabeena

Jabeena Begum G (Ms.)
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From: Vincent Mancini [mailto:vincent.mancini@curtin.edu.au]
Sent: 05 September 2017 09:53
To: Begum, Jabeena - India
Subject: RE: BJEP 12187 -- Revised Proof for approval

Thank you Jabeena,

Also, can you please direct me to how I will go about obtaining permission to include this article in a PhD thesis?

Kind regards,
Vincent

Vincent Mancini
Lecturer | PhD Candidate | School of Psychology and Speech Pathology | Faculty of Health Sciences
Curtin University

Email | vincent.mancini@postgrad.curtin.edu.au
Web | https://www.linkedin.com/in/vincent-mancini/

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Latest Publication: **Mancini, V. O.,** Rigoli, D., Roberts, L. D., Heritage, B., & Piek, J. P. (*Accepted*). Psychosocial correlates of motor skills in young children: changes over an 18-month period. *British Journal of Educational Psychology*.

From: Begum, Jabeena - India [mailto:jbegum@wiley.com]
Sent: Tuesday, 5 September 2017 12:21 PM
To: Vincent Mancini <vincent.mancini@curtin.edu.au>
Subject: RE: BJEP 12187 -- Revised Proof for approval

Dear Dr Vincent Mancini,

Thank you for approving the article and providing the running head.

We will correct the running head and proceed the article with the publication.

Thank you.

Best regards,
Jabeena

Jabeena Begum G (Ms.)
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From: Vincent Mancini [mailto:vincent.mancini@curtin.edu.au]
Sent: 05 September 2017 08:36
To: Begum, Jabeena - India
Subject: RE: BJEP 12187 -- Revised Proof for approval

Hello Jabeena,

Thank you for sending me the proofs.

It looks like all of the changes have been correctly implemented.
To address the issue of the running head, please change it to:
(Motor Skills and Psychosocial Factors in Children)

Regards,
Vincent Mancini

Vincent Mancini
Lecturer | PhD Candidate | School of Psychology and Speech Pathology | Faculty of Health Sciences
Curtin University

Email | vincent.mancini@postgrad.curtin.edu.au
Web | https://www.linkedin.com/in/vincent-mancini/

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Latest Publication: **Mancini, V. O.,** Rigoli, D., Roberts, L. D., Heritage, B., & Piek, J. P. (*Accepted*) Psychosocial correlates of motor skills in young children: changes over an 18-month period. *British Journal of Educational Psychology*.

From: Begum, Jabeena - India [mailto:jbegum@wiley.com]
Sent: Monday, 4 September 2017 7:32 PM
To: Vincent Mancini <vincent.mancini@curtin.edu.au>
Subject: BJEP 12187 -- Revised Proof for approval

Dear Dr Vincent O. Mancini,

Hope you are well.

I am sharing with you the revised proof of the article for your review.

The running head of the article should not exceeds more than 50 characters including spaces as per the journal style. Currently, it (Motor skills and psychosocial factors in young children) has 55 characters. Hence, can you please provide the running head with 50 characters including space.

Please could you check and let me know whether all corrections are implemented correctly and the article is approved for publication.

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Best regards,
Jabeena

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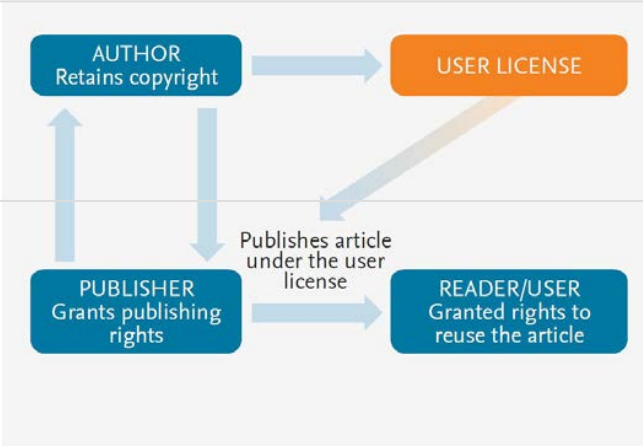

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Appendix C

Ethics Approval Document for Project

Memorandum

To	A/P Lynne Roberts, Psychology
From	Professor Peter O'Leary, Chair Human Research Ethics Committee
Subject	Protocol Approval **HR 216/2014**
Date	25 November 2014
Copy	Vincent Mancini, Psychology Emeritus Professor Jan Piek, Psychology Dr Brody Heritage, Psychology Dr John Cairney, Psychology

Office of Research and Development
Human Research Ethics Committee

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL hrec@curtin.edu.au

Thank you for providing the additional information for the project titled "*Motor coordination and Internalizing Symptoms: Investigating the Elaborated Environmental Stress Hypothesis.*". The information you have provided has satisfactorily addressed the queries raised by the Committee. Your application is now **approved**.

- You have ethics clearance to undertake the research as stated in your proposal.
- The approval number for your project is **HR 216/2014.** *Please quote this number in any future correspondence*.
- Approval of this project is for a period of four years **25-11-2014** to **25-11-2018**.
- Your approval has the following conditions:
  i) Annual progress reports on the project must be submitted to the Ethics Office.
- **It is your responsibility, as the researcher, to meet the conditions outlined above and to retain the necessary records demonstrating that these have been completed. See: Western Australian University Sector Disposal Authority (WAUSDA).**

Applicants should note the following:

It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants.

The attached **Progress Report** should be completed and returned to the Secretary, HREC, C/- Office of Research & Development annually.

Our website https://research.curtin.edu.au/guides/ethics/non_low_risk_hrec_forms.cfm contains all other relevant forms including:

- Completion Report (to be completed when a project has ceased)
- Amendment Request (to be completed at any time changes/amendments occur)
- Adverse Event Notification Form (If a serious or unexpected adverse event occurs)
- Western Australian University Sector Disposal Authority (WAUSDA)

Yours sincerely

Professor Peter O'Leary
Chair Human Research Ethics Committee

Standard conditions of ethics approval

These standard conditions apply to all research approved by the Curtin University Human Research Ethics Committee. It is the responsibility of each researcher named on the application to ensure these conditions are met.

1. **Compliance.** Conduct your research in accordance with the application as it has been approved and keep appropriate records.
    a. **Monitoring** - Assist the Committee to monitor the conduct of the approved research by completing promptly and returning all project review forms that are sent to you.
    b. **Annual report** - Submit an annual report on or before the anniversary of the approval.
    c. **Extensions** - If you are likely to need more time to conduct your research than is already approved, complete a new application six weeks before the current approval expires.
    d. **Changes to protocol** - Any changes to the protocol are to be approved by the Committee before being implemented.
    e. **Changes to researcher details** - Advise the Committee of any changes in the contact details of the researchers involved in the approved study.
    f. **Discontinuation** - You must inform the Committee, giving reasons, if the research is not conducted or is discontinued before the expected completion date.
    g. **Closure** - Submit a final report when the research is completed. Include details of when data will be destroyed, and how, or if any future use is planned for the data.
    h. **Candidacy** - If you are a Higher Degree by Research student, data collection must not begin before your Application for Candidacy is approved by your Faculty Graduate Studies Committee.
2. **Adverse events**. Consider what might constitute an adverse event and what actions may be needed if an adverse event occurs. Follow the procedures for reporting and addressing adverse events (http://research.curtin.edu.au/guides/adverse.cfm).Where appropriate, provide an adverse events protocol. The following are examples of adverse events:
    a. Complaints
    b. Harm to participants. This includes physical, emotional, psychological, economic, legal, social and cultural harm (NS Section 2)
    c. Loss of data or breaches of data security
    d. Legal challenges to the research
3. **Data management plan.** Have a Data Management Plan consistent with the University's recordkeeping policy. This will include such things as how the data are to be stored, for how long, and who has authorised access. See: Western Australian University Sector Disposal Authority (WAUSDA).
4. **Publication**. Where practicable, ensure the results of the research are made available to participants in a way that is timely and clear (NS 1.5). Unless prohibited from doing so by contractual obligations, ensure the results of the research are published in a manner that will allow public scrutiny (NS 1.3, d). Inform the Committee of any constraints on publication.
5. **Police checks and other clearances**. All necessary clearances, such as Working with Children Checks, first aid certificates and vaccination certificates, must be obtained before entering a site to conduct research.
6. **Participant information.** All information for participants must be approved by the HREC before being given to the participants or made available to the public.
    a. **University logo**. All participant information and consent forms must contain the Curtin University logo and University contact details for the researchers. Private contact details should not be used.
    b. **Standard statement**. All participant information forms must contain the HREC standard statement.

        This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HR 216/2014). The Committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or by emailing hrec@curtin.edu.au.

    c. **Plain language**. All participant information must be in plain language that will be easily understood by the participants.

Please direct all communication through the Research Ethics Office

CATHOLIC EDUCATION
WESTERN AUSTRALIA
EXECUTIVE DIRECTOR OF CATHOLIC EDUCATION

27 March 2015

Mr Vincent Mancini
c/o Professor Jan Piek
School of Psychology and Speech Pathology
Curtin University
GPO Box U1987
PERTH WA 6845

Dear Mr Mancini

RE: MOTOR COORDINATION AND INTERNALIZING SYMPTOMS: INVESTIGATING THE ELABORATED ENVIRONMENTAL STRESS HYPOTHESIS

Thank you for your completed application received 26 February 2015, whereby this project will test the 'Elaborated Environmental Stress Hypothesis' through a series of studies with children of varying ages. Such findings will help to inform future research and intervention strategies.

I give in principle support for the selected Catholic schools in Western Australia to participate in this valuable study. However, consistent with Catholic Education policy, participation in your research project will be the decision of the individual principal and staff members. A copy of this letter must be provided to principals when requesting their participation in the research.

The condition of Catholic Education Western Australia (CEWA) approval is that a final list of the Catholic schools you wish to participate in this research project is to be provided to CEWA before you can approach each school.

Responsibility for quality control of ethics and methodology of the proposed research resides with the institution supervising the research. CEWA notes that Curtin University Human Research Ethics Committee has granted permission for this research project until 25 November 2018 (Approval Number: HR 216/2014).

Any changes to the proposed methodology will need to be submitted for CEWA approval prior to implementation. The focus and outcomes of your research project are of interest to CEWA. It is therefore a condition of approval that the research findings of this study are forwarded to CEWA.

Further enquiries may be directed to Jane Gostelow at gostelow.jane@ceo.wa.edu.au or (08) 6380 5118.

I wish you all the best with your research.

Yours sincerely

Dr Tim McDonald

EXECUTIVE DIRECTOR OF CATHOLIC EDUCATION
50 Ruislip Street, Leederville WA 6007 | PO Box 198, Leederville WA 6903
T (08) 6380 5210
E mcdonald.tim@ceo.wa.edu.au **W** ceo.wa.edu.au

Appendix D

Summary of Studies Testing the Indirect Pathways of the Elaborated Environmental Stress Hypothesis Included in Mancini et al. (Submitted)

Table 1

Summary of Studies that Test the Mediating/Moderating Pathways between Motor Skills and Internalizing Problems Specified in the Elaborated Environmental Stress Hypothesis (*n* = 9)

Article Name	Type of Study	Sample Type	Sample *N*	Key variables examined	Key Findings
Wilson et al. (2013)	Correlational	Community sample – Children aged 4 to 6 years	*N* = 475 (234 males, 241 females)	Motor skills, social skills, internalizing symptoms	Social skills mediate the relationship between motor skills and internalizing problems.
Rigoli, Piek, and Kane (2012)	Correlational	Community sample – Adolescents aged 12 to 16 years	*N* = 93 (55 males, 38 females)	Motor skills, self-perceptions, emotional functioning	Self-perceptions mediate the relationship between motor skills and emotional functioning.
Rigoli et al. (2016)	Correlational	Community sample – Adults aged 18 to 30 years	*N* = 95 (35 males, 60 females)	Motor skills, perceived social support, perceived physical self-worth, internalizing symptoms	Perceived social support, but not perceived physical self-worth mediate the relationship between motor skills and internalizing symptoms.
Wagner et al. (2012)	Correlational	Case control – School-aged children aged 5 to 11 years	*N* = 70 (35 DCD: 27 males, 8 females; 35 age/gender matched control)	Motor skills, peer problems, internalizing problems, externalizing problems	Peer problems partially mediate the relationship between motor skills and internalizing/externalizing problems.
Mancini, Rigoli, Heritage, et al. (2016)	Correlational	Community sample – Adolescents aged 12 to 16 years	*N* = 93 (55 males, 38 females)	Motor skills, domains of perceived social support (friends, family, and significant other), depressive and anxious symptoms	Perceived social support from family mediate the relationship between motor skills and depressive symptoms. No significant relationship identified for anxious symptoms.
Piek et al. (2015)	Randomized controlled trial	Community sample – Children aged 4 to 6 years, with 6 months and 18 months follow up.	*Time 1 N* = 486 *Time 2 N* = 456 *Time 3 N* = 337	Motor skills, hyperactivity/inattention, total difficulties, prosocial behaviour, emotional symptoms, conduct problems	Universal combined psychosocial and motor skills intervention program appears to be effective in improving certain social and behavioural outcomes in young children.
Viholainen, Aro, Purtsi, Tolvanen, and Cantell (2014)	Correlational	Community sample – Female adolescents aged 12 to 16 years	*N* = 327	Motor skills, psychosocial well-being	School-related self-concept mediates the association between motor skills and psychosocial wellbeing in adolescent females
Mancini et al. (2017)	Correlational	Community sample – Children aged 4 to 6 years with 18-month follow-up	*N* =197 at Time 1 (102 males, 95 females); *N* = 107 at Time 2 (57 males, 50 females)	Motor skills, peer problems, perceived physical competence, perceived cognitive competence, internalizing problems	There was an indirect effect of motor skills on internalizing problems via peer problems at Time 1. At time, there was also an additional indirect effect via perceived physical competence.
Mancini et al. (In Press)	Correlational	Community sample – Children aged 7 to 12 years	*N* = 164 (80 males, 84 females)	Motor skills, peer problems, perceived self-competence (multiple domains)	There was an indirect effect of motor skills on internalizing problems via peer problems and perceived scholastic competence.