A CORRELATIONAL STUDY AMONG ATTENTIONAL CONTROL, REACTIVE STRESS TOLERANCE AND LOCOMOTOR SKILLS

by

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ABSTRACT

A CORRELATIONAL STUDY AMONG ATTENTIONAL CONTROL, REACTIVE STRESS TOLERANCE AND LOCOMOTOR SKILLS

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People have tended to overlook the relationships between scholastic and cognitive functions and fundamental movement skills. Previous researches mainly focused on analyzing the association of fundamental movement skills competency with cognitive development. In this cross-sectional correlational study, the associations between school children's attention properties and their motor control for six selected locomotor skills were examined.

101 schoolchildren from three local elementary schools were recruited to take a locomotor skill test, two reaction time tests and one stress tolerance test. Spearman's correlation analysis was used to assess the relationships between locomotor skills, reaction time tests and stress tolerance test at a significant level of $p \leq 0.05$ (two-tailed). The differences in the correlation coefficients between locomotor skills, attentional control and stress tolerance for boys and girl were also investigated. Age effect on the associations between locomotor skills and the attentional and stress control were controlled by using partial correlation analysis at a significant level of $p \leq 0.05$ (two-tailed).

In simple reaction time tasks, running was correlated with both premotor and motor reaction time and hopping was correlated with motor reaction time. In choice reaction time tasks, running and hopping were correlated with mean reaction time of correct reactions, hits and correct rejections. These results suggested that running and hopping might be associated with the development of motor program in which attention shifts reflexively or voluntarily to skill-relevant coordinative structures and there is inhibition of attention shifts to skill-irrelevant coordinative structures for better locomotor control. Boys might have better attention for motor control in locomotor skills that have not developed motor program and coordinative structures. Girls might have better attention for motor control in locomotor skills that have developed motor program and coordinative structures. The attention for motor control in hopping is most likely to be affected by age.

Running and hopping which have developed motor program for attentional control show better reactive stress tolerance. Stress might have positive effect on the running and hopping performance. For locomotor skills at beginner level that allocated a large portion of attention to control the movement might be more susceptible to be negatively affected by the stress. At the same locomotor skill level, boys have better reactive stress tolerance and might react more during running, horizontal jumping and hopping. Elder children might have advantageous in the attentional control for hopping movement under stress.

To summarise, when children at 6 to 9 years of age perform locomotor skills with well-established motor program are able to shift and allocate both reflexive and voluntary attention to points that can execute the locomotor movement effectively. Children executing these locomotor skills showed better control of stress on attention for motor execution and convert the stress into eustress which might have encouraging effect on locomotor performance.

Keywords: Attention, Stress tolerance, Locomotor skill, Motor control, Motor program

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I offer my regards and blessings to all of those who supported me in any respect during the completion of the study. Finally and most importantly, I dedicate this study to my family, especially my wife Maggie Yau and my mother Suyi Chang who stood by me sacrificially.

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LIST OF ABBREVIATIONS

ADHD	**:**	**Attention Deficit Hyperactivity Disorder**
ASD	**:**	**Autism Spectrum Disorder**
CS	**:**	**Coordinative Structure**
BOT-2	**:**	**Bruininks-Oseretsky test of Motor Proficiency - Second Edition**
COG	**:**	**Cognitrone**
COG-S11	**:**	**Cognitrone – test form 11**
DCD	**:**	**Developmental Coordination Disorder**
DOF	**:**	**Degree Of Freedom**
DT	**:**	**Determination Test**
DT-S1	**:**	**Determination Test – test form 1**
EF	**:**	**Executive Functioning**
ES	**:**	**Effect Size**
FMS	**:**	**Fundamental Movement Skill**
ICC	**:**	**Intra-Class Coefficient**
MABC-2	**:**	**Movement Assessment Battery for Children – Second Edition**
MMT	**:**	**Maastrichtse Motoriek Test**
MOT 4-6	**:**	**Motoriktest für Vier-bis Sechsjärige Kinder**
MRI	**:**	**Magnetic Resonance Imaging**
PDMS-2	**:**	**Peabody Developmental Scales – Second Edition**
PE	**:**	**Physical Education**

LIST OF ABBREVIATIONS (CONTINUE)

RT-S1	**:**	**Reaction Test – test form 1**
RST	**:**	**Reactive Stress Tolerance**
SD	**:**	**Standard Deviation**
TGMD-2	**:**	**Test of Gross Motor Development – Second Edition**
VTS	**:**	**Vienna Test System**

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CHAPTER 1 INTRODUCTION

Physical activity is one of the fundamental human behaviours for development and survival (Cavill, Kahlmeier, & Racioppi, 2006). It is a series of body movements produced by the continuous contraction of skeletal muscles. Performing regular physical activity is beneficial to human's physical and mental health as well as cognitive functioning (Cox et al., 2016; De Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2018; Hillman et al., 2014; Okely et al., 2014). It enhances the circulation of blood and oxygen to the brain and increases bone and muscle density and stress tolerance (Frischenschlager & Gosch, 2012). It can prevent humans from contracting common health problems such as poor posture, somatic illnesses, overweight and obesity, poor circulation and pathological behaviours (Hillman, Erickson, & Kramer, 2008; Kohl et al., 2012; Lipowski, Bulinski, & Krawczynski, 2009; Lipowski & Zaleski, 2015). However, motor skills shall be developed before engaging in physical activities because the proficiency of fundamental motor skills (FMS) is one of the critical factors affecting physical activity (Morgan, Graser, & Pangrazi, 2008; Okely, Booth, & Patterson, 2001; Williams et al., 2008). Therefore, people must learn FMS before undertaking regular physical activities.

In Hong Kong, Physical Education (PE) is a subject responsible for FMS development of children. It aims at providing a context for the development and application of sports and generic skills and sport-related values and attitudes (Curriculum Development Council, 2002). FMS are regarded as key learning activities in PE classes for children aged 6-9 years. Children are expected to develop their FMS, such as locomotor movement skills, stability movement skills and manipulative movement skills, through a series of fundamental movement learning activities.

Apart from physical activity's health benefits, its scholastic and cognitive functions are always overlooked by people. People generally misperceive the time spent on physical activities as adversely affecting children's academic study at school (Ahamed et al., 2007; Brustad, 1993; Lee & Dimmock, 1999; Mullane, 1989). Non-PE teachers prefer instructing other academic subjects to replace the PE classes for the sake of improving students' academic performance (Coe, Pivarik, Womack, Reeves, & Malina, 2006). However, some findings reported that physical activities and FMS have a positive influence, particularly on executive functions (Carson et al., 2016; Cox et al., 2016; Hinkle, Tuckman, & Sampson, 1993; Tuckman & Hinkle, 1986; Verburgh, Scherder, Van Lange, & Oosterlaan, 2016). Children who participated in physical activities showed better executive functions in terms of inhibition (Hillman et al., 2014; Schudder et al., 2014) and better planning abilities (van der Niet et al., 2015) than those who had not participated in any physical activities. Some researches found that plan-structured sport activities, such as tennis and football, are associated with the development of attention and inhibitory control (Alesi, Bianco, Luppina, Palma, & Pepi, 2016; Ishihara, Sugasawa, Matsuda, & Mizuno, 2017). Ishihara et al. (2017) demonstrated that a long duration of tennis coordination training led to better working memory and inhibitory control. Prior findings have shown that physical activity is associated with and may even improve children's academic performance and academic-related social and emotional development (Bushnell & Boudreau, 1993; Lin & Yang, 2015).

Payne and Issacs (2007) noted that FMS competency was positively associated with children's cognitive development. Piaget (1952, 1954) explained this association in his developmental theory; he asserted that self-produced locomotion facilitates infants' active explorations of their surroundings, enabling them to construct mental representations of their knowledge and experience. Diamond (2000) provided neuropsychological evidence of this association through neuro-imaging technology; he reported that both motor and cognitive performance shared the same brain structure, with co-activation of both the neo-cerebellum and prefrontal cortex during cognitive and physical activities. The brain structures serving cognitive and motor processes are not so distinct from each other (Diamond, 2000). Therefore, motor and cognitive skills reciprocally develop and interact (Iverson & Thelen, 1999; Satz & Fletcher, 1988).

Despite showing the possible associations between FMS and cognitive functions, these studies did not indicate the nature of such associations (that is, direct or indirect) (Darling, 2005; Ericsson, 2008; Jaakkola, Hillman, Kalaja, & Liukkonen, 2015). Wassenberg et al. (2005) added that this association might be affected by other factors such as gender, age and the nature of motor skill assessment (qualitative and quantitative) among others. Moreover, those previous studies focused on analysing the association of total FMS competency with cognitive development rather than each single motor skill. Therefore, the associations between each single motor skill and cognitive functions should be examined by controlling covariates that may mediate the strength of the associations. Understanding the cognitive functioning throughout the execution of each motor skill is as important as analysing the relationships between each single motor skill and the cognitive development and the factors affecting these relationships.

1.1 Aims and Objectives of this Study

As mentioned earlier, previous studies had generally examined the association between total FMS competence and cognitive development but had not well demonstrated the relationship between each locomotor skill and executive functions (in other words, a set of basic cognitive processes) in children, such as attentional control, cognitive inhibition, inhibitory control, working memory and cognitive flexibility. Moreover, those studies had not controlled the factors that might mediate the relationships between total locomotor competence or each locomotor skill and the executive functions in children, such as gender and age.

Six locomotor skills were chosen to investigate their relationships with attentional control and stress control. This study consisted of two objectives. Firstly, the associations between locomotor skills, the attentional control and stress control were investigated in schoolchildren. The possible factors (gender and age) that might affect the associations between the locomotor skills and the attentional and stress control of children were also evaluated. The purpose of the study was to get a better understanding of the correlations among locomotor skills, attentional control and stress control.

1.2 Importance of this Study

In Hong Kong, PE aims to educate children through physical activities which focus on developing the psychomotor domain, affective domain and cognitive domain of children (Sum & Dimmock, 2014). In Hong Kong's junior PE classes, children at Primary 1 to 3 develop their FMS competency through a series of FMS activities. Therefore, children who have participated in regular PE lessons should be benefitting from all three domains by learning FMS in PE lessons. However, the values of FMS in the cognitive domains are not well demonstrated. PE was thought to be non-cognitive and even contradictory to cognitive development (Kirk, 2014; Kirk & Tinning, 1990). Therefore, FMS and PE lessons are generally overlooked by parents, teachers and other stakeholders who inaccurately perceive PE lessons as adversely affecting children's cognitive development and academic achievements (Ahamed et al., 2007; Brustad, 1993; Mullane, 1989).

As stated earlier, some researchers had already found that FMS competency is positively associated with children's cognitive development (Darling, 2005; Ericsson, 2008;

Jaakkola et al., 2015; Payne & Issacs, 2007). However, these studies did not cover the following:

1. The nature of the relationships between each motor skill and cognitive functions (that is, direct or indirect relationship);
2. The types of motor skills that were related to cognitive functions; and
3. The aspect(s) of cognitive functions that were benefited from different motor skills.

The actual associations between the executive functions and each FMS are still uncertain. Therefore, the executive functions of children during the FMS execution should be investigated to enable them to attain an appropriate level of motor and executive functions through a series of FMS training. Since Colombo-Dougovito (2017) claimed that motor behaviours appear in a non-linear fashion with spontaneous movement becoming more stable and repetitive in the lower extremities, lower extremities' movement (that is, locomotor skills) act as a starting point for investigating the relationships between FMS and cognitive functions.

Attention, which is one of the executive functions, plays an essential role in selectively processing somatosensory input relevant to the movement goal (Goldberg & Segraves, 1987). Attentional control was chosen as a starting point for investigating the properties of executive functioning during the execution of FMS. Stress was found to increase anxiety and self-awareness of successfully executing the motor skill. Several researches found that stress might draw the children's additional attention to the mechanics of the motor movement (Anderson, 1982; Fitts & Posner, 1967), while Gray (2004) claimed that motor performance is more likely to deteriorate under conditions of increased state anxiety. Therefore, stress tolerance becomes so critical that it might affect the attentional control in motor control for locomotor skills.

In the long run, regular training in FMS might improve the attentional control and stress tolerance not only on the motor control of FMS but also on academic learning.

1.3 Research Questions

This study investigated the associations between the attentional control and stress tolerance and locomotor skills of children aged from six to nine years old. Prior to the investigation, the locomotor skill performance of children should be accurately assessed by experienced raters. The locomotor subtest of Test of Gross Motor Development - Second Edition (TGMD-2) (Ulrich, 2000) was adopted to assess the locomotor performance of schoolchildren in Hong Kong.

The reflexive and voluntary internal attention and reactive stress tolerance were assessed by the Vienna Test System (VTS) (Schuhfried, 2016). The following research questions can be answered after this study.

1. Are there any associations between the reflexive attention and each locomotor skill?
2. Are there any associations between the voluntary attention and each locomotor skill?
3. Are there any associations between reactive stress tolerance and each locomotor skill?
4. Do any factors (gender, age) interfere in the associations between locomotor skills, the attentional control and reactive stress tolerance in schoolchildren?

1.4 Structure of this Study

This study was divided into several sections. In the reviews of literature, the fundamental movement skills (FMS) was discussed, including its definition, importance, assessment methods and the mechanism of locomotor skill execution. The mechanism of locomotor skill execution was explained by the motor program theory. The reflexive and voluntary internal attention and reactive stress tolerance were also introduced, including their definition and importance to the motor control in locomotor skills. Besides, the relation between the attentional control and locomotor skill performance was reviewed from a neuropsychological perspective, which explained the co-activation and sharing of brain areas between cognitive functions and motor functions.

In the methodological section, the sampling method and a prior statistical power analysis were discussed prior to the introduction of the study. The chosen assessment tools for locomotor skills, reflexive and voluntary internal attention and reactive stress tolerance were introduced and explained together with their variables. The statistical methods for intra-rater and inter-rater reliability and the correlational analysis were also introduced.

Through the investigation of the associations among locomotor skills, the attention for motor control and the stress tolerance, the characteristics of the attention for motor control and the stress tolerance during locomotor skill execution were being better understood.

CHAPTER 2 LITERATURE REVIEW

In this section, the literature regarding the definition, importance, assessments and motor control of fundamental movement skills (FMS) were introduced. Executive functions and the definitions of the attentional control and reactive stress tolerance were also discussed.

2.1 Fundamental Movement Skills (FMS)

2.1.1 Definitions of FMS

Fundamental movement skills (FMS) are various kinds of basic movement patterns involving large muscle groups as well as core stabilisation that instruct the body to act accurately (Clarke, 2018; Curriculum Development Institute, 2007). They are the precursor patterns that form the basis of more complex skills used in specialised play, games and specific sports (Broomfield, 2011; Clarke, 2018; Gallahue, Ozmun, & Goodway, 2012; Haywood & Getchell, 2014; Kirk & Rhodes, 2011; Pang & Fong, 2009; Wickstrom, 1983). FMS also act as a 'control parameter' for further motor development (Bushnell & Boudreau, 1993).

Children attending kindergarten and junior classes of primary school (Primary 1 to 3) are aged from three to nine years old, which is a fast-growing period for them to develop their FMS. Nevertheless, the development of FMS would not be stopped although the child reaches nine years old. The children continue developing, acquiring and refining their motor skills over their lifespan (Clarke, 2018). The changes in the motor skills are sequential, continuous and age-related (Cech & Martin, 2012; Clarke, 2018).

FMS are categorised into three types: body management skills, gross motor skills and fine motor skills. Body management skills (also called stability skills) balance the body while in stillness and motion (Clarke, 2018). Static and dynamic balancing, rolling, landing, bending and stretching, twisting and turning, swinging and climbing are examples of body management skills. Children without enough competence in body management may have trouble in staying safe during physical activities and in developing other FMS (Clarke, 2018). Gross motor skills mainly use the larger muscle of the upper and lower body extremities and are subdivided into two types, namely locomotor skills and object control skills. Locomotor skills involve body movement in any direction from one point to another (Clarke, 2018), such as crawling, walking, running, hopping, leaping, jumping, galloping, skipping and swimming. Object control skills (also called manipulation skills) require a person to control apparatus and/or objects, such as balls, hoops, bats or ribbons, by hand, foot or other upper and lower extremities of the body. Throwing, catching, kicking, striking, bouncing and dribbling are examples of object control skills. Fine motor skills are the coordination of small muscles in movement, usually involving the synchronisation of forearms, hands and fingers with the eyes. They play a significant role in developing basic self-help skills such as handwriting, knotting shoelace, drawing and so on (Cools, De Martelaer, Samaey, Andries, 2009).

Gross motor skills are necessary at an early age in order to move, stabilise and control the body and objects while exploring the surroundings (Cools et al., 2009). Well-developed gross motor skills help children at a later age to execute motor movements smoothly (Cools et al., 2009). Throughout teaching, FMS should be divided into key components to help children learn and understand and to ensure that they develop their FMS normally in a sequential fashion (Victoria Department of Education, 1996).

Therefore, teaching FMS to children plays an essential role in preparing them to participate in physical or sport-specific activities on a daily-basis in the future since proficient FMS is not a naturally occurring process (Clark, 2007). It requires time, instruction and reinforcement from teachers, parents and health professionals (Stodden et al., 2008). Children who did not have the opportunity to develop FMS at a proficient level are more prone to experience frustration and difficulties in learning more advanced sports skills, which reduces their enjoyment of sports and other physical activities (Howe & Richard, 2011). Besides, it may affect the normal development of emotion, cognition and social relationships. The following section includes the importance of FMS on the overall development of children.

2.1.2 Importance of FMS

Lubans, Morgan, Cliff, Barnett and Okely (2010) and Hands (2012) proposed that FMS are a crucial aspect of children's physiological, psychological and cognitive development. Children with low skills face a major barrier to participating in sports (Booth et al., 1997; Ulrich, 1987) and exhibit low physical activity levels (Bouffard, Watkinson, Thompson, Dunn, & Romanow, 1996; Butcher & Eaton, 1989). FMS can enhance children's physical fitness and interpersonal, emotional, social and cognitive development (Piek, Dawson, Smith, & Gasson, 2008; Payne & Isaacs, 2007). The importance of FMS was discussed from the physiological, psychological and cognitive perspectives.

Children with good FMS competency are more likely to have higher physical activity level, greater cardiorespiratory fitness, healthier body weight, stronger muscles and bones and better neuromuscular coordination (Hands, 2012; Pang & Fong, 2009). Pang and Fong (2009) posited that FMS help children in learning complex and advanced sport skills to promote a higher level of physical activity and to develop better cardiorespiratory endurance. Other researchers identified the inverse relationship between body composition and FMS (Hardy, Barnett, Espinel, & Okely, 2013; Hume et al., 2008). Based on these findings, Foweather (2010) investigated the effects of FMS on physical activity and body fatness. The study found that eight FMS significantly ($p<0.01$) explained 11% and 9.2% of the variance in physical activity and total body fat respectively. Locomotor skills significantly ($p<0.01$) predicted

7.7% of unique variance in moderate-to-vigorous physical activity, 5.6% of total physical activity, 13.4% of cardiorespiratory fitness and 23.7% of the variance in percent body fat. Comparatively, object control skill weakly predicted 2% of the variance in total body fat ($p=0.04$). The predictive power of FMS on physical activity and obesity is not only found in childhood but also in adulthood (Stodden et al., 2008). These figures reflected the importance of FMS, especially locomotor skills, to children's health. Hardy et al. (2013) obtained a similar result about good FMS leading to a higher level of physical activity, better cardiorespiratory endurance and lower level of overweight.

From a psychological perspective, children with good FMS are more likely to have higher self-esteem, self-confidence and athletic competence and are more motivated to participate in sport-related games and activities (Hands, 2012; Henderson, May, & Umney, 1989; Hardy et al., 2013). Okely and Booth (2004) proposed that children who lack FMS are more likely to experience frustration and difficulty in learning more advanced skills. Barnett, van Beurden, Morgan, Brooks and Beard (2010) also found the relation between object control skill competency in childhood and perceived physical competence in adolescence. Hands (2012) added that children with better FMS would be more popular among peers and have higher chances of being involved in a lifelong physical activity.

FMS may also facilitate the cognitive development of children (Bushnell & Boudreau, 1993; Lin & Yang, 2015; Payne & Issacs, 2007). Piaget and Inhelder (1966) posited that cognitive processes and the motor process could not be separated because cognitive development relies on motor functioning. Piaget (1952, 1954) had explained this association between motor and cognitive skills by his developmental theory. The theory stated that self-produced locomotion could provide infants with an opportunity of actively exploring the environment around them, which would enable them to develop their knowledge and experience. As infants grow with developing motor and cognitive functions, sensorimotor functions (such as grasping and visual perception) become less important, while higher cognitive functions (such as planning and behaviour regulation) become more important (Churchland, 1986). Diamond (2000) proposed that both cognitive and motor developments become more complex when an infant grows from childhood to early adulthood. Cognitive skills related to action planning and executive functioning develop in accordance with motor skills in children of 5 to 10 years (Anderson, 2002; Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001).

2.1.3 Sequential development of FMS

As stated in section 2.1.1, children develop their FMS in a sequential order which is predictable and that can be explored, discovered, re-confirmed and celebrated (Gerber, Wilks, & Erdie-Lalena, 2010; Lipsitt, 1998). These FMS sequences can be differentiated into various key FMS milestones. Typical-developing children meet their key FMS milestones in a timely manner; however, they will not be able to perform these skills autonomously (Gallahue et al., 2012). The children must practise their skills until they reach the key FMS milestone and become proficiency, which is called the ‘proficiency barrier’ (Seefeldt & Nadeau, 1980). After overcoming the proficiency barrier, children will proceed to achieve other key FMS milestones such as performing sporting skills and participating in more complicated motor tasks in their later life (Seefeldt & Nadeau, 1980; Stodden, True, Langendorfer, & Gao, 2013). Children showing a different sequential pattern of FMS development can affect the patterns of cognitive, social and emotional development (Payne & Isaacs, 2007; Piek et al., 2008).

A typical sequence of FMS development can be studied in up to six-year-old children (Glascoe & Robertshaw, 2009). Children at infant age can raise their hands and point at pictures in books. At toddler age, children can walk with legs stiffed. At around three years old, children should be able to walk, begin to run, jump and hop, kick, throw and develop a dominant hand. At around four to five years old, children can walk up and down steps using alternate feet. At up to six years old, children can demonstrate adult-like skills, replicate sport-specific actions more smoothly, make more controlled movements, run faster and play an organised sport (Gallahue et al., 2012). The development of FMS would go beyond six years old and continue until adolescence (Piek et al., 2008). At adolescence, the focus of FMS development shifts from gaining new skills towards maintaining and/or losing proficiency (Piek et al., 2008). As a person becomes old, the functioning of his/her body's physiological, psychological and cognitive systems start to decline, which in turn affects the FMS proficiency.

2.1.4 Assessments of FMS

To evaluate the development of FMS, six assessments are commonly-used for children: Motoriktest für Vier-bis Sechsjärige Kinder (MOT 4-6) (Zimmer & Volkamer, 1987), Movement Assessment Battery for Children - Second Edition (Movement-ABC-2) (Henderson, Sugden, & Barnett, 2007), Peabody Developmental Scales - Second Edition (PDMS-2) (Folio & Fewell, 2000), Test of Gross Motor Development - Second Edition (TGMD-2) (Ulrich, 2000), the Maastrichtse Motoriek Test (MMT) (Vles, Kroes, & Feron, 2004) and the Bruininks-Oseretsky Test of Motor Proficiency - Second Edition (BOT-2) (Bruininks & Bruininks, 2005).

Motoriktest für Vier-bis Sechsjärige Kinder (MOT 4-6) (Zimmer & Volkamer, 1987) originates from Germany and has been developed to assess the development of FMS in children as well as to create an opportunity for early identification of motor delays or deficiency. The tool is suitable for assessing children aged from four to six years old. The test consists of 18 different items in seven different task divisions including Physical Dexterity and Coordination Skills (five items), Fine Motor Skills (three items), Equilibrium (three items), Responsiveness (two items), Bounce (two items), Moving Speed (three items) and Motion Control (two items). Some items measure more than one division.

The Movement Assessment Battery for Children - Second Edition (MABC-2) (Henderson et al., 2007) assesses the developmental status of fundamental movement skills, with a focus on the detection of delay or deficiency in a child's movement skill development (Vallaey & Vandroemme, 1999). The tool is used to evaluate the competence of fundamental movement skills of children aged from three to sixteen years. The 24-item test is subdivided into three categories for three different age ranges of children. The first category is for children aged from zero to six years and eleven months old. The second category is for children aged from seven years to ten years and eleven months old. The last category is for children aged from eleven years to sixteen years and eleven months old. Each category includes eight items measuring three types of tasks. The tasks are Manual Dexterity (three items), Throwing and Catching (two items) and Balance (three items).

Peabody Developmental Scales - Second Edition (PDMS-2) (Folio & Fewell, 2000) focuses on assessing and providing intervention or treatment to children with disabilities. The tool is applicable for assessing the FMS competency of children aged from birth to six years. This scale is composed of six subtests to assess the gross and fine motor skills in children. The subtests are 'Reflexes (eight items)', 'Stationary (thirty items)', 'Locomotion (eighty-nine items)', 'Object Manipulation (twenty-four items)', 'Grasping (twenty-six items)' and 'Visual-Motor Integration (seventy-two items)'.

The Maastrichtse Motoriek Test (MMT) (Vles et al., 2004) is a tool used to objectively assess the qualitative and quantitative aspects of FMS patterns and performance. The test is suitable for assessing the children aged from five to six years old with or without normal FMS behaviour. The scale covers the areas of manual dexterity (twenty-eight items), dynamic balance (twenty items), static balance (fourteen items) and ball skills (eight items).

The Bruininks-Oseretsky test of Motor Proficiency - Second Edition (BOT-2) (Bruininks & Bruininks, 2005) is a tool used to assess gross and fine motor skills of people. The test is suitable for people with motor deficit aged from four to twenty-one years. The scale consists of 53 items and is divided into 8 subscales: balance (nine items), fine motor integration (eight items), bilateral coordination (seven items), fine motor precision (seven items) , upper limb coordination (seven items), manual dexterity (five items), running speed and agility (five items) and strength (five items).

Finally, the Test of Gross Motor Development - Second Edition (TGMD-2) (Ulrich, 2000) assesses the qualitative measures of gross motor skills. It is suitable for evaluating the gross motor skills of children aged from three to ten years old. The test contains two subtests for the object control skills and locomotor skills. The locomotor subtest consists of six consecutive items: running, leaping, galloping, hopping, horizontal jumping and sliding, and the object control subtest also consists of six items: catching, striking a stationary ball, underhand rolling, overhand throwing, stationary dribbling and kicking. The test has been reported to be significantly reliable with Cronbach's alpha reliability coefficients for locomotor (0.85) and object control (0.88) scores (Ulrich, 2000). Wong and Cheung (2010) re-affirmed the two-factor structure of TGMD-2, based on confirmatory factor analysis, by testing 614 young Chinese children aged 6-10 years.

2.1.5 Motor program theory

Inside the human neuromusculoskeletal system, there are many independently controllable variables called degrees of freedom (DOFs), which are manifested at different levels – joints, muscles, motor neuron and so on (Park, 2003). The neuromusculoskeletal system deals with the lowest level of DOFs, that is, "*a myriad of neural motor commands to muscle fibres to execute a movement*" (Park, 2003, p. 17). The Russian neurophysiologist, Bernstein (1967), claimed that the central nervous system cannot control all the low-level DOFs separately because even planning and controlling a simple movement would be too complicated and attention-demanding. The individual only focuses on the movement goal (that is, the external focus of attention) or the movement technique (that is, the internal focus of attention) before movement execution (Park, 2003).

Therefore, Schmidt and Lee (2013b) claimed that the DOFs are centrally organised and controlled by an abstract representation of movement called 'motor program'. With motor programs, the response programming is simplified because the central nervous system only needs to select and execute an appropriate motor program rather than controlling tens of thousands of DOFs simultaneously and independently (Rosenbaum, 1991; Schmidt & Lee, 2013b). According to Schmidt (2013a), the motor program should be able to specify the muscles involved in the movement, select the order of muscle involvement, determine the forces of muscle contraction, specify the relative timing and sequences of contractions and determine the duration of contractions.

However, there are hundreds of muscles and joints in the body. If each muscle and joint had to be controlled separately each time a movement is executed, the movement would be unmanageable. Over time, the movement becomes automatic with practice (Schmidt & Wrisberg, 2008), and the motor control is progressively passed down to lower level until all the particular decisions about which motor units to fire are defined at the muscle level (Greene, 1972). Then, the concept of coordinative structures emerges. Coordinative structures are defined as a collection of muscles, often spanning over several joints that are constrained to act together to produce a human movement (Easton, 1972; Kugler, Kelso, & Turvey, 1982; Turvey, 1977). It internally regulates many skill relevant DOFs but is itself regarded as a single DOF. Coordinative structures could reduce the number of DOFs in a system; the fewer decisions required to operate it, the easier is its management (Mechner, 1995). In other words, the response programming needs fewer attentional resources to control a fewer number of DOFs (Whiting, Vogt, & Vereijken, 1992). It results in a faster reaction.

Schmidt and Lee (2013a) and Reason (1990) suggested that the motor program is running in either open-loop or closed-loop fashion. The motor program with open-loop control is automatic and fast (Reason, 1990). Attention is required only for action initiation, but the motor program can then be left to continue without feedback (Reason, 1990). Decisions are made in the central nervous system before the movement execution and are sent in a single message to the working muscles. The movement under closed-loop control is conscious and slow, which requires more attentional resources to start and monitor the movement (Lund, 2002). Only the information about the movement initiation is sent. Constant feedback from the brain or muscle provides a basis for altering the movement during execution (Adams, 1971; Reason, 1990).

To summarise, the motor program that is pre-determined before the movement execution is automatic and controlled in open-loop fashion, using fewer attentional resources to control the coordinative structures. The motor program that initiates and monitors the movement during execution is controlled in a closed-loop fashion, using more attentional resources to control the coordinative structures. For the execution of a new movement that has no stored motor program, much more attentional resources are required to control a large number of DOFs in a closed-loop fashion to perform the movement.

2.2 Executive Functioning (EF)

Executive functioning (EF) is a general collective term that encompasses a collection of inter-related complex cognitive processes required for performing purposeful, goal-directed tasks (Gioia, Isquith, & Guy, 2001; Hughes & Graham, 2002). EF develops throughout childhood and adolescence (Anderson, 2002). While there are many theories and descriptions of skill comprising EF, Anderson (2002) outlined four distinct domains: attentional control, information processing, cognitive flexibility and goal setting.

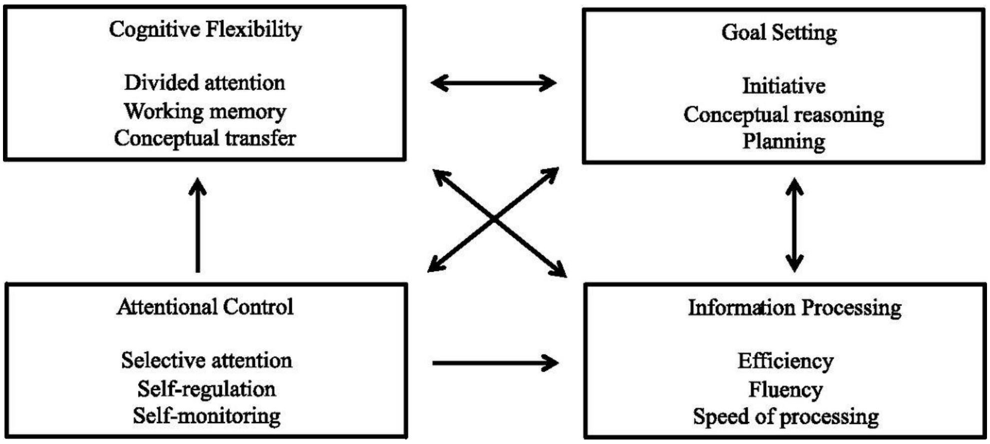

Figure 1: Executive Control System (Adapted from Anderson, 2002)

These domains work together as an Executive Control System to synthesise the external stimuli, to form goals and strategies, to prepare for action and to verify that plans and actions have been appropriately implemented (Luria, 1973). An individual with normal EF should be able to delay or inhibit a particular response, to plan the action sequences and to hold a mental representation of the task through working memory (Welsh & Pennington, 1988). Anderson (2002) claimed that attentional control significantly affects the functioning of other executive domains and is influenced by the goal setting, while other executive domains are related and dependent with each other. Burnett et al. (2015) think attentional control and information processing should act as foundations for cognitive flexibility and goal setting. In other words, cognitive flexibility and goal setting become a higher level of cognitive functions, with more efficient information processing and attention allocation that facilitate cognitive flexibility and problem-solving.

Attentional control is the capability of selective attention to specific stimuli to inhibit prepotent responses and regulate, monitor and execute actions in a correct order while identifying and correcting errors to achieve task goals (Anderson, 2002). Children aged under nine months have trouble in inhibiting previously learned responses, while children at 12-month-old are able to inhibit certain behaviours and employ new responses (Diamond, 1985; Diamond & Doar, 1989; Diamond & Goldman-Rakic, 1989). Until three years of age, children can inhibit intuitive behaviours well, sometimes leaving occasional mistakes (Diamond & Taylor, 1996; Espy, 1997). At up to six years old, children show improvements in the speed and accuracy employed in impulse control tasks (Diamond & Taylor, 1996; Espy, Kaufmann, McDiarmid, & Glisky, 1999). Children at nine years of age or older tend to keep track of and adjust their actions well, but some impulsive actions may occur for a short period around 11 years old (Anderson, Anderson, & Lajoie, 1996; Anderson, Anderson, Northam, & Taylor, 2000).

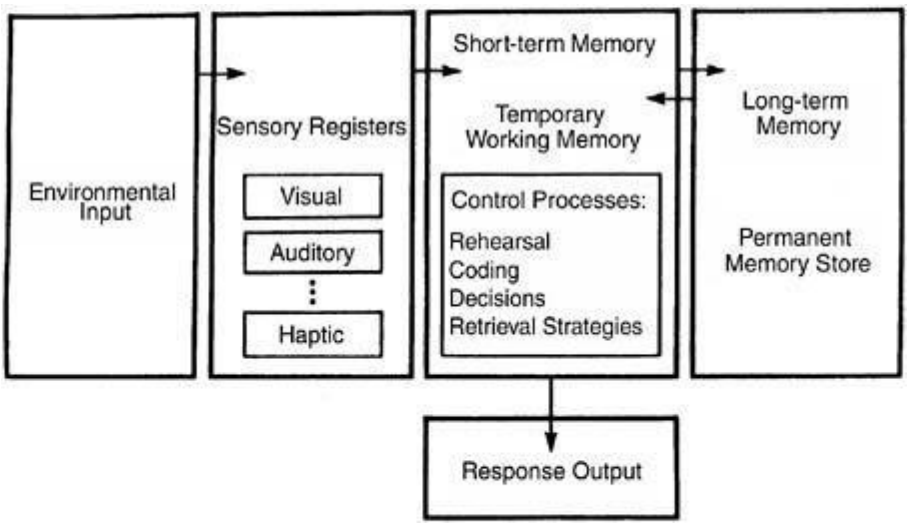

Figure 2: Information Processing Model (Adapted from Shiffren & Atkinson, 1969)

Information processing refers to the fluency, efficiency and speed of an individual's to analyse the stimuli, process the perceived information and output an appropriate response to a stimulus. It reflects the integrity of neural connections and the functional integration of frontal lobe brain systems that can be evaluated using measures of reaction time, output quality and output quantity (Anderson, 2002). The increase in response speed and fluency are observed in children between three and five years old (Espy, 1997; Gerstadt, Hong, & Diamond, 1994; Welsh, Pennington, & Groisser, 1991). When children reach middle childhood, their processing speed and fluency keep on improving (Anderson et al., 2000; Hale, 1990; Welsh et al., 1991). For children between nine and twelve years old, the processing speed significantly increases (Kail, 1986). Until adolescence, the improvement in efficiency (*the appropriateness of the skill execution*) and fluency (*the time needed for executing the skill*) would be observed (Anderson et al., 2001; Kail, 1986; Levin et al., 1991).

Cognitive flexibility refers to the ability of shifting between response sets, learning from mistakes, devising alternative strategies, dividing attention and processing multiple sources of information concurrently (Diamond, 2013; Miyake & Friedman, 2012). Working memory and divided attention are also elements of this domain. Children below three years old mostly have preservative behaviour (Chelune & Baer, 1986; Levin et al., 1991; Welsh et al., 1991). When they reach three to four years old, children can rapidly switch between two simple responses but have difficulty in switching when rules become more complicated (Espy, 1997). Children at seven to nine years old have significantly improved to cope with multi-dimensional switching tasks (Anderson et al., 2000). The capability to learn from mistakes and to devise alternative strategies emerges from early childhood, which keeps on improving alongside the switching fluency throughout middle childhood until adolescence (Anderson et al., 2000).

Goal setting refers to the ability of developing new initiatives and concepts, planning actions in advance and approaching tasks in an efficient and strategic manner (Anderson, 2002). Children at four years of age can generate new concepts (Jacques & Zelazo, 2001) and planning skills (Welsh et al., 1991), but they tend to plan and organise actions in advance (Welsh et al., 1991). At between seven and 10 years of age, children develop their planning and organisational skills rapidly (Anderson et al., 1996). Their reasoning abilities and strategic behaviour become more efficient and organised (Anderson, Anderson, & Garth, 2001; Levin et al., 1991).

The whole executive control system provided comprehensive explanations about the learning process and execution of FMS, the variability of movements and the FMS developments for children. The following sections explain how the attention, reaction time and reactive stress tolerance affect FMS in children.

2.2.1 Attention. At any given moment, the environment presents so much perceptual information that can hardly be handled in an effective manner by individuals (Chun, Golomb, & Turk-Browne, 2011). There is a need for selection due to the limited attentional resources. Selection is the primary goal of attention. Selective attention is an important area that allows a person to hold attention and to filter out irrelevant information from a complex, dynamic and highly variable environment (Hahn et al., 2008). Attention is the ability to generate, select, manage and maintain an adequate level of stimulation to process the relevant and irrelevant information. It involves suppression and inhibition from distracting stimuli that help a person to guide adaptive behaviour and is essential for encoding and attending to new information (Nobre, 2018). It also refers to the ability to select and focus on one particular part of our environment among several simultaneous competing stimuli, based on the cognitive skills, past learning experience and knowledge available to the individual (DeGangi, 2012; Moriarty, 2015).

Attention has a list of characteristics that shows implicitly in its definition: breadth, intensity, focus, direction and control. The breadth of attention refers to the number and range of stimuli attended to at any time (Kasof, 1997). A person who has a narrow range of attention focuses on a relatively small range of stimuli at any time and filter irrelevant stimuli from awareness (Mehrabian, 1995). In contrast, a person who has a wide range of attention focuses on a larger range of stimuli at any time and tend to be more arousable to irrelevant stimuli (Mehrabian, 1995).

The second characteristic of attention is the intensity which reflects the amount of attentional resources being paid to a given stimulus. There are two types of mental activities that need a different amount of attentional resources while performing a task. Automatic processes are mental activities running in open-loop fashion, that take place unconsciously and need a lower level of attentional resources (that is, working memory) (Abernethy, Maxwell, Masters, Van Der Kamp, & Jackson, 2007; Walczyk, 2000). They develop with the extensive practice for activities that are routinised or when a response is consistently bonded to a particular stimulus. Automated responses to stimuli or tasks are associated with fluent movement production and are hard to control or inhibit (Abernethy et al., 2007; Benjafield, 1997). Comparatively, control process refers to the activities running in closed-loop fashion, that demands high attentional resources. It is slow, error-prone and serial (Schneider, Dumais, & Shiffrin, 1984). New learning tasks and difficult tasks require a tremendous amount of attention during the control process.

The third characteristic of attention is focus. External attention is described as ‘where the individual’s attention is directed to the effects of the movements on the environment’. In contrast, internal attention is described as ‘where the individual’s attention is directed to the body’s movements or to a specific body part’ (Wulf, 2007). Typically, children who are learning a new motor skill are instructed with the correct movement pattern (internal focus of attention). However, some research found that the internal focus of attention on one’s movement can disrupt the performance of well-practised skills (Bliss, 1982-1983; Boder, 1935; Kimble & Perlmuter, 1970; Klatzky, 1984; Masters, 1992; Schmidt & Lee, 2013b). Rather, the external focus of attention may be more beneficial to a learner for learning new motor skills or an experienced athlete for better performance (Marchant, 2005; Singer, Lidor, & Cauraugh, 1993; Wulf, Höß, & Prinz, 1998; Wulf & Weigelt, 1997).

The fourth characteristic of attention is direction. External attention is about the selection and modulation of sensory information from stimuli coming from the external environment (Chun et al., 2011; Nobre, 2018). Internal attention refers to the selection and modulation of internally generated information (trains of thought) such as the information inside a working memory, long-term memory, task sets or response selection (Chun et al., 2011; Nobre, 2018).

The fifth characteristic of attention is control. An attentional shift occurs when directing attention to increase the efficiency of the skill-relevant focus processing and includes inhibition to devote attentional resources to unwanted or skill-irrelevant focuses (Johnson & Proactor, 2004). Shifting of attention is required to allocate attentional resources to more efficiently process skill-relevant information. Voluntary attention switching occurs when an individual's attention is voluntarily directed to optimally allocate sensory inputs towards a task outcome (Prinzmetal, McCool, & Park, 2005). For example, the long-distance runner stays alerted on running pace, running posture and proprioceptive feedbacks from joints, muscles and tendons until the race is finished. Reflexive attention switching occurs when an individual's attention is unintentionally but instinctively directed by certain external events (Eimer, Nattkemper, Schröger, & Prinz, 1996). For example, the sprinter starts 100-meters running involuntarily when the starter's gun is fired.

The attention of an individual has a significant effect on the motor skill performance (Bliss, 1892-1893; Boder, 1935; Gallwey, 1982; Schneider & Fisk, 1983). The quality of learning and the accuracy of motor skill execution are significantly influenced by how an individual initiate, select, shift and control his or her attention to a task when learning and executing motor skills (Wulf, 2007). Attention can prime the motor program with relevant somatosensory input and feedback while ignoring irrelevant information (Peters, Handy, Lakhani, Boyd, & Garland, 2015). It is reasonable to undertake the investigation about the effect of attention on motor response programming during the learning and execution of locomotor skills under the situations of stress and non-stress.

2.2.2 Reaction time. Reaction time is a measure of the quickness with which an individual responds to some sort of stimulus. Reaction time is defined as the time elapses from the presentation of the stimulus to the completion of motor movement and measures the capacity and speed of the cognitive system to process information (Jensen, 2006; Kuang, 2017). It consists of three parts: (1) sensory transmission of input; (2) central processing and (3) motor execution time, in which central processing makes up 80% of the total reaction time (Cech & Martin, 2012). The first two parts of reaction time are called pre-motor reaction time which represents the time from the presentation of a stimulus to initial changes in electrical activity in a muscle (Carlsen, Chua, Inglis, Sanderson, & Franks, 2004; Duke-Elder, 1959). The third part of reaction time is called motor reaction time. It is the interval between the first change in electromyographic activity in a muscle and the completion of a voluntary muscle movement (Kent & Kent, 2006).

Klapp (1995) claimed that response programming is a component of reaction time, which varies as a function of the nature of the response (that is, simple response and choice response) (Henry & Rogers, 1960; Klapp & Rodriguez, 1982; Sternberg, Monsell, Knoll, & Wright, 1978). The reaction time of simple response (that is, simple reaction time) is defined as the interval time between the appearance of a stimulus, its detection and the given simple response (Jayaswal, 2016). The individual starts the response programming of a simple response before the reaction time interval begins because the required simple response is specified in advance (pre-determined motor program). The reaction time of choice response (that is, choice reaction time) involves the identification and selection of a response to various stimuli (Boisgontier, Wittenberg, Fujiyama, Levin, & Swinnen, 2014). The individual undertakes the response programming of a choice response in choice reaction time task after the start of the reaction time interval because no advance cue concerning which response is required (Zelaznik, 1996). Therefore, the reaction time can reflect motor programs for movements (Schmidt & Lee, 2013b).

The influence of cognitive process is described as components that determine the reaction time (Deary & Der, 2005; Leckie et al., 2014). The reaction time requires attention because attention is a prerequisite for sensory information to enter the working memory (Cech & Martins, 2012; Jehu, Desponts, Paquet, & Lajoie, 2015; Prinzmetal et al., 2005; Vaportzis, Georgiou-Karistianis, & Stout, 2013). When people are taking a simple reaction time task, they are required to shift internal attention reflexively to provide a simple response to a presented stimulus in a pre-programmed fashion. Such a task operates in an open-loop fashion without consideration of feedback provided by the surroundings, muscles and/or brain between stimulus presentation and response onset (Kent & Kent, 2006; Klapp, 1996). Therefore, simple reaction time is faster. When people take a choice reaction time task, they are required to voluntarily shift internal attention to provide relevant responses to multiple stimuli (Schmidt & Lee, 2013a; Zelaznik, 1996). Such a task operates in a closed-loop manner with continuous modification in accordance with feedback from the surroundings, muscles and/or the brain. Therefore, choice reaction time is slower than a simple reaction time.

As previously mentioned in section 2.2.1, a task processing in an automatic fashion does not require much attention to control the mental process. Thus, automatic processing can be done quickly (that is, fast reaction time) and carried out at once. A task processing in a controlled manner requires much more attention to control the process of information. Hence, controlled processing is slower (that is, slow reaction time) and can only process one task at a time.

Based on the previous mentions about the relations among the concept of the motor program, reaction time and attention, the movement that has a motor program to control is expected to be faster and requires less attention to process the information. For those movements that require real-time, response programming is expected to be slower and requires much more attention to process the information.

2.2.3 Reactive stress tolerance (RST). Reactive stress tolerance (RST) is a measure of the capabilities of an individual to maintain attention and respond appropriately when placed in a stressful situation. RST is defined as the ability of an individual to react quickly and accurately to the continuously changing situation where the individual is overstretched (Neuwirth & Benesch, 2012, as cited in Schuhfried, 2016c).

The stress can affect cognitive and motor control performance (Bertilsson, 2019). Stress has both positive and negative effects on human motor performance (Jick & Payne, 1980; Keuss, Szalma & Hancock, 2011; Van Gemmert & Van Galen, 1997). Stress is formed from the interaction of the demands placed by the environment/task and the individual's resources to meet the demands (LeBlanc, 2009). If the individuals assessed their attentional resources or motor competence as being sufficient to meet the task demands, stress becomes a challenge and has a positive effect on the performance. If children assessed the task demands outweighing their attention resources, the stress becomes a threat and deteriorates the performance.

The effects of stress on locomotor performance can be explained by the neuromotor noise theory (Van Gemmert & Van Galen, 1997). The motor system is inherently noisy. The noise is responsible for motor variability (De Jong & Van Galen, 1997). Under this theory, stress activates and increases the neuromotor noise in the motor and information processing system. To resolve the increase in neuromotor noise, the system must filter out the noise by increasing information processing time before motor execution and by exploiting the mechanical properties of the limbs (Aiken, Odom, & Van Gemmert, 2015). Patmore (1986) suggested that the most crucial factor in sporting success is not only about the skill level and response speed of the athlete but also about how fast the correct decision is made under stress.

Based on *Figure 2*, a stimulus sensed by sensory organs is perceived as meaningful information by the athlete (Dogan, 2009). When the information arrives at the working memory, that is, in connection with long-term memory, the phase of decision making starts and matters the quality of RST. Working memory looks into the long-term memory to choose an action from a set of possible and appropriate attractor states stored there (that is, response programming) with speed applicable in the given situation and to execute it in the appropriate time.

Possible factors affected by stress

Factors affected by stress include attentional focus (Krohne & Hindel, 1988), motor coordination (Anshel, Kim, Kim, Chang, & Eom, 2001) and decision-making ability (Anshel, 1990). Attentional focus and decision-making ability are the matters that were explained in the Executive Control System. If the individual takes more time under the stressful situation than under the non-stress situation to pay attention, inhibit prepotent response and make correct decision/action to the stimuli, his/her attention to control the mental process and motor execution is considered to be affected by stress.

Motor coordination consists of motor skill selection and the quality of motor skill execution by the individual. As stated earlier, the motor program can either be operated in an open or closed-loop fashion. If the movement is controlled in open-loop fashion, the motor program is unable to remove the noise disturbance arising from stress due to the absence of feedback mechanism (Schmidt & Lee, 2013b). It might result in poor motor execution or even action slips (Reason, 1990). If the movement is controlled in closed-loop fashion, the increasing noise, perceptual traces, sensory feedbacks and large number of DOFs control might overload the attentional resources (that is, working memory) for motor control (Schmidt & Lee, 2013b). It might impair the quality of skill selection, extend the time of response programming and reduce the monitoring function of the movement (Che, Sun, Xiao, & Li, 2019).

Locomotor skills might benefit from a stress condition (Bertilsson, 2019). Under low to moderate level of the stress response, locomotor skills might become more effective when the heart rate increases to between 175 and 220 BPM (Siddle, 1995). The more effective motor skill execution is due to the increased adrenaline levels which increase the skeletal muscle tonus and strength (Bertilsson, 2019). However, a simple skill might also be less effective during a strong stress response due to the adrenal increased skeletal muscle strength and tension (Cairn & Borrani, 2015), thus resulting in poor motor execution.

<u>Factors affecting the stress effects on attention for motor control</u>

Other factors affect the stress effects on attention for motor control, such as gender and sport types (Ong, 2017). Males and females were found to have different capabilities in RST. Dogan (2009) found that female athletes had a higher number of inappropriate responses under stress than male athletes. Kaiseler, Polman and Nicholls (2012) found that female soccer players appraise stressors with lower levels of perceived control and higher levels of stress intensity. These findings may be caused by the coping methods adopted by female athletes. Besides, female athletes tend to use less approaches than male athletes (Anshel, Kang, & Miesner, 2010), in which problem-focused strategies, such as communication, planning and technique-oriented coping method, are mainly used by female athletes (Nicholls, Polman, Levy, Taylor, & Cobley, 2007). Contrarily, Ong (2017) provided that female athletes were found to have faster and more appropriate actions under stress than male athletes. These researches provide evidence of the effect of gender on RST, but the direction of the relationship is yet to be confirmed.

Sport type is another factor considered to be affecting the stress effect on the attention for motor control. Sports are mainly classified into open skill sports and closed skill sports. Open skill sports take place in an environment that is ever-changing, where decisions and movements must be made continuously in accordance with the situation that the athlete faces (Highlen & Bennett, 1983). Football, basketball and badminton are examples of open skill sports. Closed skill sports take place in an environment that is relatively more stable and predictable, where the performance depends on the consistency of the athlete's actions (Highlen & Bennett, 1983). Swimming and running are examples of closed skill sports. Craft, Magyar, Becker and Feltz (2003) found that anxiety and self-confidence were more strongly related to performance for open skill sports' athletes. The open skill sports' athletes have more difficulty in controlling the factors, such as situated environment or opponents, which increase the athletes' uncertainties about their quality of performance. Comparatively, the closed skill sports' athletes have more control over their quality of performance (Craft et al., 2003).

2.3 Neuropsychological Evidence of the Associations between FMS and EF

Major areas of human brain that associate with both cognitive and motor functions are prefrontal cortex and neocerebellum. The prefrontal cortex is the cerebral cortex that covers the anterior part of the frontal lobe (Fuster, 2015). The basic function of the prefrontal cortex is '*the representation and execution of new forms of organized goal-directed action*' (Fuster, 2015, p. 1). Several functional neuroimaging studies suggested that the prefrontal cortex is significantly activated when a person performs EF tests, such as attention, working memory, information processing and behavioural organisation (Bradshaw, 2001; Morris, Ahmed, Syed, & Toone, 1993; Pennington & Ozonoff, 1996; Rezai et al., 1993). If the prefrontal cortex is damaged or under-developed, it affects a person's ability to orientate and control his/her decision-making and behaviours.

This deficit can be observed in children with attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD). ADHD children were examined in order to obtain a significant size reduction in the prefrontal cortex by structural magnetic resonance imaging (MRI) scan (Casey et al., 1997; Castellanos et al., 1996; Filipek et al., 1997). The reduced prefrontal cortex activity has been found in both adults and children in a functional neuroimaging study (Amen, Paldi, & Thisted, 1993). Moreover, more than half of ADHD children were found to have poor motor coordination and were diagnosed with developmental coordination disorder (DCD) (Gillberg, 1995; Hartsough & Lambert, 1985; Hellgren, Gillberg, Gillberg, & Enerskog, 1993; Kadesjö & Gillberg, 1998; Piek, Pitcher, & Hay, 1999).

ASD children were more likely to be diagnosed with delayed maturation of the prefrontal cortex because insufficient blood flow was found in their prefrontal cortex according to Zilbovicius et al. (1995). Because of the immature prefrontal cortex, ASD children often show a significant level of motor impairment (Manjiviona & Prior, 1995), problems in executing goal-directed movements (Hughes, 1996), poor performance in gross motor skills (Page & Boucher, 1998). Hence, the prefrontal cortex is critical for the higher-order executive functions but also important for planning and executing motor movements.

Neocerebellum is a part of the cerebellum which is associated with the prefrontal cortex to coordinate the voluntary skilled limb movement and is involved in motor learning (Glickstein & Yeo, 1990; Houk, Buckingham, & Barto, 1996). It is important for both motor and cognitive functions. Most of the cognitive functions that need the prefrontal cortex also require the involvement of neocerebellum (Diamond, 2000). The neocerebellum becomes active when a task is new and challenging or when the condition of the task is changing, while the neocerebellum becomes less active when a task becomes more familiar (Flament, Ellermann, Kim, Uğurbil, & Ebner 1994; Friston, Frith, Passingham, Liddle, & Frackowiak, 1992). Courchesne et al. (1994) also proposed that the neocerebellum helps cognitive performance by predicting and improving sensitivity to the anticipated stimuli so that those stimuli can be perceived from the noisy environment. In other words, the neocerebellum is most needed by a person who must learn new cognitive or motor skills or who needs to pay attention to task from the environment selectively. Keele and Ivry (1990) also proposed the timing functions of neocerebellum for motor and cognitive tasks. The functions of neocerebellum contribute to the concepts of selective attention, sustained attention, divided attention and reaction time in EF.

The dysfunction of neocerebellum causes several motor problems. For example, ADHD children who have a smaller cerebellum (Berquin et al., 1998; Castellanos et al., 1996; Mostofsky, Reiss, Lockhart, & Denckla, 1998) have DCD (Gillberg, 1995; Hartsough & Lambert, 1985; Hellgren et al., 1993; Kadesjö & Gillberg, 1998; Piek et al., 1999) and have troubles with balance and rapid alternating movements (Diamonds, 2000). Likewise, ASD children are also found to have reduced size cerebellum (Courchesne, Hesselink, Jernigan, & Yeung-Courchesne, 1987; Murakami, Courchesne, Press, Yeung-Courchesne, & Hesselink, 1989), which leads to motor skills execution issues (Manjiviona & Prior, 1995; Page & Boucher, 1998).

A cognitive task or motor task also increases the activity of the prefrontal cortex and the neocerebellum. These two portions of the human brain play critical roles in a neural circuit when a task is difficult, new or changing or when a task needs a quick response or needs to be focused on.

2.4 Conclusion of the Review

Based on the literature review regarding the importance and motor control for locomotor skills and the attention and reactive stress tolerance of motor control, the correlation between FMS and attention can be asserted. However, the properties of attentional control and reactive stress tolerance of each locomotor skill is still uncertain. Therefore, in the following sections, the relationships between locomotor skills and attention properties are unveiled. The understanding of the attention properties and reactive stress tolerance of six selected locomotor skills become clear.

CHAPTER 3 METHODOLOGY

3.1 Sample

A convenient sample of children aged between six and nine-years-old was recruited from three local elementary schools. The participant inclusion criteria were: (a) studying in a local primary school, (b) exhibiting no significant sign of mental disorders such as Autistic Spectrum Disorder (ASD), Attention-deficit Hyperactivity Disorder (ADHD) and/or Dyslexia, (c) exhibiting no significant sign of physical disability and (d) attending regular PE classes at least twice a week.

Statistical power analysis for correlational study was performed for sample size estimation based on data from the research of Hartan, Houwen, Scherder and Visscher (2010) (N=61), comparing the locomotor skills to the decision time and execution time. The effect size (ES) in this study was 0.088 which is considered as medium ES by Cohen's (1988) criteria. With an alpha = 0.05 and power = 0.80, the projected sample size needed with this effect size (GPower 3.1 or other software) is approximately N = 66 for this correlational analysis. Thus, the proposed sample size of 100 is more than adequate for the main objective of this study, expected attrition and our additional objectives of controlling for possible covariates (that is, gender and age).

3.2 Instruments

Locomotor skill assessment

The locomotor subtest of Test of Gross Motor Development - Second Edition (TGMD-2) (Ulrich, 2000) was used to evaluate locomotor skills of running, galloping, horizontal jumping, leaping, hopping and sliding. Before the start of performance assessment, the videos of participants were orderly randomised. PE teachers evaluated each skill in two trials and rated participants' skill performance from three to five based on qualitative criteria, depending on the specific skills. They scored the presence or absence of skill components as one or zero. After the addition of all the scores of skill components, the maximum score of each trial ranged from three to five points.

Executive functions assessment

The Vienna Test System (VTS; Schuhfried GmbH, Austria) is a computerised test that was developed to analyse different sport psychology-related constructs. It is a valid and reliable tool for psychological assessment, which had been evaluated for reliability and validity in several studies (Gierczuk & Ljach, 2012; Whiteside, 2002; Whiteside, Parker, & Snodgrass, 2003). In this study, VTS was used to determine children's levels of selective attention, reactive stress tolerance and response time. Three VTS tests were selected to assess these psychological constructs of children and were presented in the following order: Cognitrone (COG), Determination Test (DT) and Reaction Test.

3.2.1 Cognitrone (choice reaction time task)

Cognitrone test implemented in the VTS (Schuhfried, 2016a) was used to assess attention and concentration of the participants by comparing figures for their congruence. In this test, participants were instructed to use a response panel as an input device and to compare an abstract figure with a reference figure to decide whether the two were identical. When the participant responded, the next figure followed automatically. Cognitrone test has eight test forms, and test form S11 (hereafter referred to as COG-S11) was used. It enabled a participant to attempt a choice reaction time task in a flexible working time. The participant maintained a constant level of accuracy while increasing the amount of energy required to ensure rapid and error-free processing (Reulecke, 1991 as cited in Schuhfried, 2016a).

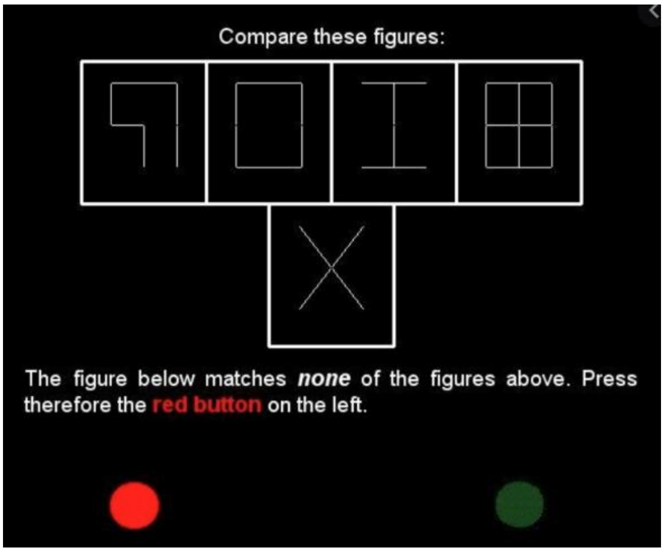

Figure 3: Screenshot of Cognitrone Test

The reliability of COG-S11 was previously reported to be >0.93 (Schuhfried, 2016a). In addition, the content, convergent and discriminant validity of COG-S11 were previously determined by Schuhfried (2016a), its construct validity was shown by Wagner (1999) as cited in Schuhfried (2016a) and its criterion validity was shown by Cale (1992) as cited in Schuhfried (2016a) and by Bukasa, Wenninger and Brandstatter (1990) as cited in Schuhfried (2016a).

3.2.2 Determination test (Stress tolerance task)

Determination test is a reaction task that measures reactive stress tolerance, attention and reaction speed of the participants in situations requiring continuous, speedy and varied responses to fast-changing visual and sound stimuli (Schuhfried, 2016c). Participants were presented with colour stimuli and sound signals. They were required to use their cognitive skills to react to different stimuli, including five coloured buttons, two acoustic tones (high and low) and two-foot pedals (left and right). The child should react as quickly and accurately as possible by pressing the appropriate buttons on the response panel or stepping on the pedals. Determination test has six test forms, and test form 1 (hereafter referred to as DT-S1) was used.

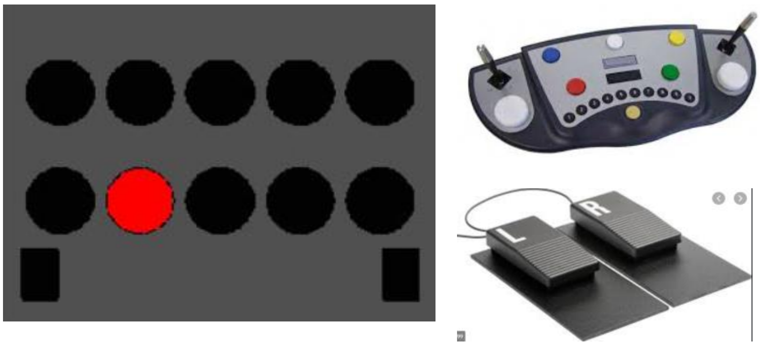

Figure 4: Screenshot and Equipment for Determination Test

The reported reliability of DT-S1 was previously reported to be as high as 0.98 (Schuhfried, 2016c). The DT-S1 construct validity was shown by Dorsch (1994) as cited in Schuhfried (2016c) and by Weinkirn (1996) as cited in Schuhfried (2016c). Its criterion validity was shown by Cale (1992) as cited in Schuhfried (2016c) and by Karner and Neuwirth (2000) as cited in Schuhfried (2016c).

3.2.3 Reaction test (simple reaction time task)

Figure 5: System Setup for Reaction Test

Reaction test is a simple reaction time task that typically measures pre-motor and motor reaction time in response to colour signals. In this test, participants are instructed to press the reaction key only when a colour stimulus appears and then, to return their finger immediately to a rest key (Schuhfried, 2016b). Reaction test has eight test forms, and test form S1 (hereafter referred to as RT-S1) was used. The reliability coefficients for RT-S1 for the pre-motor and motor reaction time were previously found to be 0.96 and 0.98 respectively (Schuhfried, 2016b). The RT-S1 construct validity was previously determined by Neubauer (1990) as cited in Schuhfried (2016b) and its criterion validity was shown by Cale (1992) as cited in Schuhfried (2016b), by Karner and Neuwirth (2000) as cited in Schuhfried (2016b) and by Sommer (2002) as cited in Schuhfried (2016b).

3.3 Procedures

The ethical review of human data collection was approved by the Human Research Ethics Committee (HREC), The Education University of Hong Kong. Participants, whose parents signed the consent form (*Appendix F*) before the study, reported to a particular room set up by their primary schools. The participants wore the school's sport uniform and sports shoes for the study. Before starting the test, they performed some warm-up exercises as per the instructions of the researchers. Participants in this study first performed the locomotor tests in the following order: running, galloping, horizontal jumping, leaping, hopping and sliding. Each participant was allocated time to practice each locomotor test twice and then officially execute each locomotor test twice. All executions were videotaped with a handheld camera.

After completing locomotor tests, each participant had a 3-5-minute break and then proceeded with VTS reaction time tests in the following order: COG-S11, DT-S1 and RT-S1. Before each VTS reaction time test, the researcher explained the test procedure in detail and allowed participants to practice before conducting tests for data gathering. Each participant had a 2-minute break between the VTS EF tests. When the participant finished all the tests, they left the test centre with their parents.

Following all on-site testing, two professional PE teachers who had six hours of video rating training exercises were recruited for rating all locomotor videos. Two duplicates (Set A and Set B) of locomotor performance videos with randomised order labelling were given to two raters. Rater A rates Set A videos first, while Rater B rates Set B videos first. After a month, Rater A rates Set B videos, while Rater B rates Set A videos. All scores rated by two teachers were constructed as score matrix to analyse their intra-rater and inter-rater reliabilities.

3.4 Data Analysis

3.4.1 Variables

Demography

Two independent demographic variables were included in this study: age and gender. *Age* is an independent continuous variable. The range of value of *Age* variable lies between 72 months and 120 months. *Gender* is an independent dichotomous variable. Its value lies between zero and one. Value '1' represents girls, while value '0' represents boys.

Locomotor skills

In this study, all variables of locomotor skills were dependent variables. Detailed descriptions of each variable of locomotor skills were presented in *Appendix A*. *Running* contained five continuous variables. The first four variables *(R1 to R4)* represent the performance criteria of *Running*, while the last variable *(Run_total)* represents the total score of *Running*. *Run_total* is the total sum of the four variables in two trials. The highest possible total score is eight, whereas the lowest possible total score is zero.

Galloping contained five continuous variables. The first four variables *(G1 to G4)* represent the performance criteria of *Galloping*, while the last variable *(Gallop_total)* represents the total score of *Galloping*. *Gallop_total* is the total sum of the four variables in two trials. The highest possible total score is eight, whereas the lowest possible total score is zero.

Horizontal jumping also contained five continuous variables. The first four variables *(HJ_1 to HJ_4)* represent the performance criteria of *Horizontal jumping*, while the last variable *(HJ_total)* represents the total score of *Horizontal jumping*. *HJ_total* is the total sum of the four variables in two trials. The highest possible total score is eight, whereas the lowest possible total score is zero.

Leaping contained four continuous variables. The first three variables *(L1 to L3)* represent the performance criteria of *Leaping*, while the last variable *(Leap_total)* represents the total score of *Leaping*. *Leap_total* is the total sum of the three variables in two trials. The highest possible total score is six, whereas the lowest possible total score is zero.

Hopping contained six continuous variables. The first five variables *(H1 to H5)* represent the performance criteria of *Hopping*, while the last variable *(Hop_total)* represents the total score of *Hopping*. *Hop_total* is the total sum of the five variables in two trials. The highest possible total score is ten, whereas the lowest possible total score is zero.

Sliding also contained five continuous variables. The first four variables *(S1 to S4)* represent the performance criteria of *Sliding*, while the last variable *(Slide_total)* represents the total score of *Sliding*. *Slide_total* is the total sum of the four variables in two trials. The highest possible total score is eight, whereas the lowest possible total score is zero.

Executive functioning

Variables of COG-S11 (Choice reaction time task)

COG-S11 contains six independent continuous variables. The descriptions of each variable were explained in the following paragraphs.

Mean time correct reactions represents the average time (in seconds) taken to provide the hits and correct rejections. This variable measures the internal attention in the form of the energy required to maintain a particular level of accuracy in providing the hits and correct rejections.

Mean time hits represent the average time (in seconds) taken to provide the correct answers. This variable measures the internal attention in the form of the energy required to maintain a particular level of accuracy in providing the correct answers.

Mean time correct rejections represents the average time (in seconds) taken to provide the correct rejections. This variable measures the internal attention in the form of the energy required to maintain a particular level of accuracy in giving the correct rejections.

To ensure that aspects of the internal attention are being measured, the correct decisions must be taken based on both the 85% of the true correct answers (hits) and 85% of the true incorrect answers (correct rejections). If the 85% criterion is met, the reaction time, as expressed by the variable *Mean time hits* and *Mean time correct rejections*, provide good indicators of the ability to control the internal attention to the correct decisions.

Therefore, the following variables represent the number of correct answers provided by the participants in the COG-S11. *Sum of correct reactions* represents the total of 60 items of hits and correct rejections. *Sum of hits* represents the total of 24 items of true correct answers, while *sum of correct rejections* represents the total of 36 items of true incorrect answers.

Variables of DT-S1 (Stress tolerance task)

DT-S1 contains nine independent continuous variables. The descriptions of each variable were explained in the following paragraphs.

Sum of omitted responses is an independent continuous variable that indicates whether the responses have been omitted by the participant under time pressure. If the participant omitted several reactions, he/she might have difficulties in paying attention to the choice reaction time task for a long period of time when under stress.

Sum of overall incorrect responses reflects a tendency of the participants to confuse different responses and react incorrectly under stress. The participant is unable to succeed in separating the correct response from the influence of irrelevant competing reactions. Thus, *DTS1_Incorrect* is closely linked to the ability of the participant to keep attention function during the test.

Median reaction time is an independent continuous variable that records the median of the reaction time of the participant to the stimuli in seconds. It reflects the ability of how fast the participant can react.

Sum of reactions is an independent continuous variable reflecting the total number of correct and incorrect responses. It is the sum of all reactions made by the participant. Since the participant may commit a correct reaction and several incorrect reactions to the same stimuli, all these reactions were counted into this variable. Therefore, there is no upper limit on the number of all reactions.

Number of stimuli is an independent continuous variable that provides information on the number of stimuli being presented during the task. Since test form S1 is an adaptive test, the number of stimuli depends on the working speed of the participant. The shorter the stimulus presentation time, the more the stimuli would be presented to the participant who works fast. This variable should be closely interpreted with other DT-S1 variables to investigate the underlying stress level of the participant during the test.

Sum of incorrect responses is a derived independent continuous variable from several DT variables. It is calculated by firstly subtracting the sum of omitted responses from the number of stimuli and further subtracting this number from the sum of reactions. This variable reflects the real sum of incorrect responses of the participant in the test without the redundant responses. It is assumed that the greater the number of incorrect responses, the higher the stress level of the participant during the test.

Sum of delayed correct responses describes the participant's normal functioning of attention to the stimuli but correct reaction to the stimuli that is slower than the system's adapted speed. It should be interpreted together with *sum of omitted responses* to reflect the attention level of the participant. If the participant has a small number in *delayed correct responses* and a large number in *omitted responses*, he/she probably has trouble in controlling attention under stress. Contrarily, if the participant has a large number in *delayed correct responses* and small number in *omitted responses*, he/she still has normal functioning in attention, but the attention to the tasks is dropping.

Sum of on-time correct responses describes the participant's success in constantly dealing with an adapted speed of stimuli presentation. If the participant can keep or even accelerate his or her correct reaction under an adapted speed, he/she has good reactive stress tolerance and can cope with the time pressure during the test.

Sum of overall correct responses is an independent continuous variable describing the number of correct reactions (including on-time and delayed correct responses). It measures the participant's ability to react quickly and accurately in a series of situations. If the number of *overall correct* responses is high, the stress tolerance of the participant is good.

Variables of RT-S1 (Simple reaction time task)

RT-S1 contains four independent continuous variables. The descriptions of each variable were explained in the following paragraphs.

Mean motor reaction time, *mean pre-motor reaction time*, *dispersion motor reaction time* and *dispersion pre-motor reaction time* are the variables being normalised by Box-Cox transformation (Box & Cox, 1964) because the distribution of raw motor time and reaction time are negatively skewed.

Mean motor reaction time is the average reaction time (in milliseconds) that elapses between the moment the finger leaves the rest button and the moment the reaction button is pressed in response to the stimuli. *Mean pre-motor reaction time* is the average reaction time (in milliseconds) that elapses between the moment the stimuli appeared and the moment the participant's finger leaves the rest button. These two variables reflect the speed of motor execution and response programming of the participant respectively. *Dispersion motor reaction time* is the standard deviation of the motor reaction time, while *dispersion pre-motor reaction time* is the standard deviation of the pre-motor reaction time. These two variables reflect the stability of motor execution and response programming of the participant respectively.

3.4.2 Statistical methods

Descriptive statistics

Descriptive characteristics of the children, including age and gender, were quantified using means, standard deviations and frequencies. The descriptive statistics (mean, standard deviation, minimum and maximum values, skewness and kurtosis) were reported. The data gathered was screened for normality of the data distribution to determine skewness and kurtosis of all locomotor variables and EF variables.

The values of skewness and kurtosis were further converted to z-score by dividing their standard error. According to Kim (2013) and Mayers (2013), when a sample size ranges from 50 to 300, data can be considered to be non-normal if z-scores of skewness (Zskew) and kurtosis (Zkurt) are greater than |3.29|.

Since the data was inspected with normal data distribution as well as the inter-rater and intra-rater reliability, correlation study can be performed because one of the assumptions of these tests had been met.

Inter-rater and intra-rater reliability study

Each trial of all six locomotor skills was assessed by two experienced PE teachers to obtain the inter-rater reliability in order to ensure the quality of performance ratings of children's locomotor skills. Each PE teacher had to rate each trial twice to obtain the intra-rater reliability. For skill components, Cohen's kappa coefficient (*K*) was used for the assessment of inter-rater and intra-rater agreement of the raters. Intra-class Correlation Coefficient (ICC) was used to assess the inter-rater and intra-rater reliabilities in each locomotor skill and the total locomotor skills.

A kappa statistic ranges from -1 to +1, where zero represents the amount of agreement that can be expected from random chance, and one represents perfect agreement between the raters. The kappa statistic can be interpreted as follows: values lower than zero indicate no agreement, values between 0.01 and 0.20 represent slight agreement, values between 0.21 and 0.40 represent fair agreement, values between 0.41 and 0.60 represent moderate agreement, values between 0.61 and 0.80 represent substantial agreement and values between 0.81 and 1.00 represent almost perfect agreement (Landis & Koch, 1977; McHugh, 2012).

ICC was used to determine the intra-rater reliability of each rater in the first and second rating and the inter-rater reliability between two raters in the first and second rating. For intra-rater reliability, a two-way mixed model with absolute agreement was used, while for inter-rater reliability, a two-way random-effect model with absolute agreement was used (Koo & Li, 2016; McGraw & Wong, 1996). ICC values generally range from zero to one, where one indicates perfect agreement and zero indicates no agreement. ICC can be interpreted as follows: values less than 0.50 indicate poor reliability, values between 0.50 and 0.75 indicate moderate reliability, values between 0.75 and 0.90 indicate good reliability and values greater than 0.90 indicate excellent reliability (Fleiss & Cohen, 1973; Koo & Li, 2016). The rating scores provided by the most reliable rater were used for the subsequent correlational studies.

Correlational study between age, gender, locomotor skills and variables of simple and choice reaction time tasks and stress tolerance task

The strengths of the relationships between the continuous variables of locomotor skills, simple and choice reaction time tasks and stress tolerance task, were tested by Spearman's correlation analysis because the variables of simple and choice reaction time tasks and stress tolerance task were not normally distributed. Zero-order correlational analyses were performed by using SPSS v.25 software (SPSS Inc., Chicago, IL, USA) and a significant level of $p \leq 0.05$ (two-tailed).

The correlations for boys and girls were transformed into z-scores using Fisher's r-to-z transformation and a significant level of $p \leq 0.05$ (two-tailed) to test the potential significant differences between the correlation coefficients for boys and girls. Based on the difference between two correlation values and the variance of the difference between two scores, a z-score was obtained.

Partial correlation analysis on age effect and the test of zero-order correlation being equal to partial correlation (two-tailed) were performed by using R 3.5.0 (R Core Team, 2018), the *zeroEQpart* (*v0.1.0*) package (Richard, 2018) and a significant level of $p \leq 0.05$ (two-tailed).

CHAPTER 4 RESULTS

4.1 Demographic Characteristics

A cross-sectional correlation study was conducted at three different local elementary schools. After receiving university ethical approval, this study included a convenient sample of 101 elementary school students (*mean age* = 7.62 years, *standard deviation (SD)* = 0.93) and comprised 55 (54.5%) boys and 46 (45.5%) girls. Among the students, 29 were aged six years (13 boys and 16 girls), 29 were aged seven years (13 boys and 16 girls) and 43 were aged 8–9 years old (29 boys and 14 girls) (Table 4.1).

Table 4.1

Frequencies and Percentage of Participants

Demographics	Frequency (%)
Boys	55 (54.5%)
6 years old	13 (12.9%)
7 years old	13 (12.9%)
8-9 years old	29 (28.7%)
Girls	46 (45.5%)
6 years old	16 (15.8%)
7 years old	16 (15.8%)
8-9 years old	14 (13.9%)

Note: N=101

4.2 Locomotor Performance of Participants

Sliding (*mean* = 6.8, *SD* = 1.1) and leaping (*mean* = 4.6, *SD* = 1.2) were the locomotor skills that were best performed by school children aged from six to nine years old.

Comparatively, horizontal jumping (*mean* = 3.71, *SD* = 1.92) and galloping (*mean* = 4.62, *SD* = 1.20) were the worst performed locomotor skills by school children (Table 4.2).

Based on the comparison of the locomotor performance between boys and girls, boys were better in horizontal jumping (*mean* = 3.9, *SD* = 1.9) and leaping (*mean* = 4.8, *SD* = 1.1), while girls were better in running (*mean* = 5.1, *SD* = 1.6) and sliding (*mean* = 7.1, *SD* = 0.9). The performance of galloping and hopping were approximately the same for the boys and girls aged six to nine years.

According to the comparison of the locomotor performance among different age groups, children aged eight years or above were better in horizontal jumping (*mean* = 4.1, *SD* = 1.9), leaping (*mean* = 4.7, *SD* = 1.2) and hopping (*mean* = 6.7, *SD* = 1.4). Children aged seven years were better in running (*mean* = 5.2, *SD* = 1.9). Children aged six were better in galloping (*mean* = 4.8, *SD* = 1.0). The performance of sliding was approximately the same for children of different ages.

4.3 Choice Reaction Time Performance of Participants

Cognitrone – test form 11 (COG-S11) is a choice reaction time task. The mean reaction times of hits and correct rejections were 3.40 s (*SD* = 1.00 s) and 4.04 s (*SD* = 1.29 s) respectively. The reaction time for hits was faster than that for correct rejections. The means of the sum of hits and correct rejections were 21.2 (*SD* = 2.2) and 33.2 (*SD* = 2.5) respectively.

According to the comparison of the choice reaction time performance between boys and girls, boys were faster in working time (*mean* = 223.47 s, *SD* = 69.03 s) and had more correct reactions (*mean* = 54.6, *SD* = 3.3) and hits (*mean* = 21.6, *SD* = 1.9). Girls were faster in correct reactions (*mean* = 3.77 s, *SD* = 1.10 s), hits (*mean* = 3.39 s, *SD* = 0.91 s) and correct rejections (*mean* = 4.02 s, *SD* = 1.31 s) and had more correct rejections (*mean* = 33.3, *SD* = 2.6).

According to the comparison of the choice reaction time performance among age groups, children aged eight years or above were faster in working time (*mean* = 198.33 s, *SD* = 52.56 s), correct reactions (*mean* = 3.38 s, *SD* = 0.93s), hits (*mean* = 3.04 s, *SD* = 0.84 s) and correct rejections (*mean* = 3.59 s, *SD* = 1.06 s) and had more correct rejections (*mean* = 33.4, *SD* = 1.6). Children aged six years were slower in working time (*mean* = 270.24 s, *SD* = 70.45s), correct reactions (*mean* = 4.52 s, *SD* = 1.21 s), hits (*mean* = 3.96 s, *SD* = 1.06 s) and correct rejections (*mean* = 4.91 s, *SD* = 1.37 s) but had more number of correct reactions (*mean* = 54.7, *SD* = 4.5) and hits (*mean* = 22.0, *SD* = 1.8).

Table 4.2

The Mean and Standard Deviation of Variables of Locomotor skills, simple reaction time task, choice reaction time task and stress tolerance task by overall participants, gender and age

		Gender		Age		
	Overall	Boys	Girls	6	7	8 or above
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Variables of Locomotor skills						
Running	5.0 (1.7)	5.0 (1.7)	5.1 (1.6)	4.8 (1.4)	5.2 (1.9)	5.1 (1.7)
Galloping	4.6 (1.2)	4.6 (1.3)	4.6 (1.0)	4.8 (1.0)	4.6 (0.9)	4.5 (1.5)
Horizontal Jumping	3.7 (1.9)	3.9 (2.0)	3.5 (1.8)	3.5 (2.1)	3.4 (1.8)	4.1 (1.9)
Leaping	4.6 (1.2)	4.8 (1.1)	4.3 (1.3)	4.5 (1.2)	4.5 (1.2)	4.7 (1.2)
Hopping	6.2 (1.7)	6.2 (1.8)	6.2 (1.6)	5.5 (1.6)	6.3 (1.9)	6.7 (1.4)
Sliding	6.8 (1.1)	6.6 (1.2)	7.1 (0.9)	6.8 (1.0)	6.8 (1.2)	6.8 (1.1)
Variables of Choice reaction time task						
MT Correct Reactions (*s*)	3.78 (1.13)	3.79 (1.17)	3.77 (1.10)	4.52 (1.21)	3.63 (1.01)	3.38 (0.93)
MT Hits (*s*)	3.40 (1.00)	3.41 (1.08)	3.39 (0.91)	3.96 (1.06)	3.36 (0.93)	3.04 (0.84)
MT Correct Rejections (*s*)	4.04 (1.29)	4.05 (1.29)	4.02 (1.31)	4.91 (1.37)	3.82 (1.13)	3.59 (1.06)
Sum of Correct Reactions	54.4 (3.7)	54.6 (3.3)	54.1 (4.2)	54.7 (4.5)	54.3 (4.1)	54.2 (2.8)
Sum of Hits	21.2 (2.2)	21.6 (1.9)	20.8 (2.5)	22.0 (1.8)	21.1 (2.5)	20.8 (2.2)
Sum of Correct Rejections	33.2 (2.5)	33.0 (2.4)	33.3 (2.6)	32.7 (3.7)	33.2 (2.2)	33.4 (1.6)

Table 4.2

The Mean ad Standard Deviation of Variables of Locomotor skills, simple reaction time task, choice reaction time task and stress tolerance task by overall participants, gender and age (Continue)

	Overall	Gender		Age		
		Boys	Girls	6	7	8 or above
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Variables of Stress tolerance task						
Sum of Omitted Responses	13.8 (6.0)	13.7 (5.2)	14.0 (6.8)	15.6 (7.5)	12.2 (4.2)	13.7 (5.6)
Sum of Overall Incorrect Responses	15.4 (19.8)	21.6 (24.4)	7.9 (6.9)	7.1 (5.8)	10.1 (6.5)	24.4 (27.0)
Median Reaction Time (*s*)	1.13 (0.15)	1.13 (0.16)	1.15 (0.14)	1.25 (0.12)	1.15 (0.09)	1.06 (0.15)
Sum of Reactions	175.9 (36.3)	183.2 (40.9)	167.2 (28.0)	147.0 (22.4)	175.5 (20.4)	195.6 (39.4)
Number of Stimuli	178.3 (27.8)	180.3 (30.2)	176.0 (24.6)	158.1 (18.4)	180.1 (17.7)	190.8 (30.9)
Sum of Incorrect Responses	3.9 (4.2)	5.0 (4.6)	2.6 (3.4)	2.6 (2.8)	2.5 (1.8)	5.8 (5.4)
Sum of Delayed Correct Responses	42.3 (14.6)	41.3 (14.9)	43.6 (14.2)	35.2 (13.4)	46.0 (10.6)	44.6 (16.2)
Sum of Ontime Correct Responses	118.2 (19.6)	120.3 (22.0)	115.8 (16.2)	104.7 (13.2)	119.4 (12.5)	126.6 (22.3)
Sum of Overall Correct Responses	160.6 (29.8)	161.6 (32.3)	159.3 (26.7)	139.9 (21.9)	165.4 (19.6)	171.2 (33.3)
Variables of Simple reaction time task						
Mean Motor reaction time (*ms*)	229.30 (53.17)	217.35 (58.35)	243.59 (42.58)	252.38 (53.88)	239.28 (51.84)	207.00 (45.37)
Mean Premotor reaction time (*ms*)	430.32 (81.00)	431.64 (93.98)	428.74 (63.06)	451.07 (53.22)	430.38 (58.66)	416.28 (104.59)
Dispersion Motor reaction time (*ms*)	45.32 (21.14)	44.42 (21.69)	46.39 (20.65)	47.83 (24.06)	46.97 (24.02)	42.51 (16.71)
Dispersion Premotor reaction time (*ms*)	87.26 (58.73)	97.05 (72.10)	75.54 (34.21)	97.48 (55.24)	81.45 (41.89)	84.28 (70.04)

4.4 Reactive Stress Tolerance Performance of Participants

DT-S1 is a stress tolerance task measuring reactive stress tolerance of the participants in situations requiring continuous, speedy and varied responses to fast-changing visual and sound stimuli. The median reaction time of participants in stress tolerance task was 1.13s (*SD* = 0.15 s). The participants were averagely presented with 178.3 stimuli (*SD* = 27.8) and made 175.9 reactions (*SD* = 36.3) in the task. The participants averagely made 13.8 omitted responses (*SD* = 6.0), 3.9 incorrect responses (*SD* = 4.2) and 15.4 overall incorrect responses (*SD* = 19.8) in the task. On the other hand, the participants averagely made 42.3 delayed correct responses (*SD* = 14.6), 118.2 on-time correct responses (*SD* = 19.6) and 160.6 overall correct responses (*SD* = 29.8) in the task.

According to the comparison of the reactive stress tolerance between boys and girls, boys had faster choice reaction time (mean = 1.13s, *SD* = 0.16 s), more reactions (mean = 183.2, *SD* = 40.9) and more stimuli being presented with (mean = 180.3, *SD* = 30.2). Boys also had more overall incorrect responses (mean = 21.6, *SD* = 24.4), incorrect responses (mean = 5.0, *SD* = 4.6), on-time correct responses (mean = 120.3, *SD* = 22.0) and overall correct responses (mean = 161.6, *SD* = 32.3) than girls. Girls had more omitted responses (mean = 14.0, *SD* = 6.8) and delayed correct responses (mean = 43.6, *SD* = 14.2) than boys.

According to the comparison of the reactive stress tolerance among age groups, children aged eight years or above had more overall incorrect responses (mean = 24.4, *SD* = 27.0), faster choice reaction time (mean = 1.06 s, *SD* = 0.15 s), more reactions (mean = 195.6, *SD* = 39.4), more stimuli being presented with (mean = 190.8, *SD* = 30.9), more incorrect responses (mean = 5.8, *SD* = 5.4), more on-time correct responses (mean = 126.6, *SD* = 22.3) and more overall correct responses (mean = 171.2, *SD* = 33.3). Children aged seven years had more delayed correct responses (mean = 46.0, *SD* = 10.6). Children aged six years had more omitted responses (mean = 15.6, *SD* = 7.5).

4.5 Simple Reaction Time Performance of Participants

RT-S1 is a simple reaction time task that requires a participant to press the reaction key only when a colour stimulus appears and then to immediately return his/her finger to a rest key. The premotor reaction time (*mean* = 430.32 ms, *SD* = 81.00 ms) was nearly two-fold slower than the motor reaction time (*mean* = 229.30 ms, *SD* = 53.17 ms). The premotor reaction time (*mean* = 87.26 ms, *SD* = 58.73 ms) was also more dispersed than the motor reaction time (*mean* = 45.32 ms, *SD* = 21.14 ms).

According to the comparison of the simple reaction time performance between boys and girls, boys had faster motor reaction time (*mean* = 217.35 ms, *SD* = 58.35 ms) and less dispersed motor reaction time (*mean* = 44.42 ms, *SD* = 21.69 ms) than girls in the simple reaction time task. Girls had faster premotor reaction time (*mean* = 428.74 ms, *SD* = 63.06 ms) and less dispersed premotor reaction time (*mean* = 75.54 ms, *SD* = 34.21 ms) than boys.

According to the comparison of the simple reaction time performance among age groups, children aged eight years or above had faster premotor reaction time (*mean* = 416.28 ms, *SD* = 104.59 ms) and motor reaction time (*mean* = 207.00 ms, *SD* = 45.37 ms) and less dispersed motor reaction time (*mean* = 42.51 ms, *SD* = 16.71 ms). Children aged seven years had less dispersed premotor reaction time (*mean* = 81.45 ms, *SD* = 41.89 ms).

4.6 Normality Test of Variables of Locomotor Skills, Simple Reaction Time, Choice Reaction Time and Stress Tolerance

The assumption of normality (that is, normal distribution) is a prerequisite for inferential statistical methods such as intraclass correlation analysis, correlation analysis, regression analysis and so on. Normal distribution describes the sample data in a symmetrical, bell-shaped curve which has the most significant frequency of scores in the middle, with smaller frequencies towards the extremes (Gravetter & Wallnau, 2000). Normality can be assessed by inspecting the z-scores of Skewness and Kurtosis.

Table 4.3 showed the standardised scores (z-scores) of Skewness (Zskew) and Kurtosis (Zkurt) of all variables used in this study. According to the critical values for z-scores defined by Kim (2013), all variables of locomotor skills were normally distributed. The Zskew for locomotor skill variables ranged from 0.35 to 2.03, while the Zkurt for locomotor skill variables ranged from 0.24 to 3.75, except the Zkurt of galloping which was slightly higher than |3.29|.

The variables of choice reaction time task were not normally distributed. Their Zskew ranged from 3.34 to 8.62, while their Zkurt ranged from 0.24 to 14.32. All z-scores were much greater than the critical values proposed by Kim (2013). Three of choice reaction time task variables were negatively skewed, including the sums of correct reactions, hits and correct rejections. Two of choice reaction time task variables had positive excess kurtosis, including the sums of correct reactions and correct rejections.

Table 4.3

The standardized score (z-score) of skewness and kurtosis of variables of locomotor skills, simple reaction time, choice reaction time and stress tolerance

Variables	skew	Zskew	kurt	Zkurt	Variables	skew	Zskew	kurt	Zkurt
Locomotor Skills					Stress Tolerance Task				
Running	-0.25	1.03	-0.12	0.24	Sum of Omitted Responses	1.13	4.70	2.73	5.74
Galloping	0.20	0.83	1.79	3.75	Sum of Overall Incorrect Responses	3.23	13.45	11.04	23.19
Horizontal Jumping	-0.09	0.35	-0.79	1.67	Median Reaction Time (*s*)	0.34	1.41	0.41	0.85
Leaping	-0.45	1.87	-0.70	1.48	Sum of Reactions	0.86	3.56	1.90	4.00
Hopping	-0.35	1.45	-0.35	0.73	Number of Stimuli	0.29	1.22	0.02	0.05
Sliding	-0.49	2.03	-0.39	0.82	Sum of Incorrect Responses	2.16	9.00	5.92	12.44
					Sum of Delayed Correct Responses	-0.07	0.28	-0.83	1.75
					Sum of Ontime Correct Responses	0.51	2.11	1.39	2.93
Choice Reaction Time Task					Sum of Overall Correct Responses	0.05	0.23	-0.58	1.22
MT Correct Reactions (*s*)	0.80	3.34	0.12	0.24					
MT Hits (*s*)	0.85	3.55	0.39	0.83	Simple Reaction Time Task				
MT Correct Rejections (*s*)	0.80	3.35	0.14	0.29	Mean Motor reaction time (*ms*)	0.00	0.01	-0.25	0.53
Sum of Correct Reactions	-1.24	5.15	2.58	5.41	Mean Premotor reaction time (*ms*)	1.05	4.38	2.35	4.93
Sum of Hits	-0.90	3.75	0.20	0.42	Dispersion Motor reaction time (*ms*)	1.85	7.69	5.05	10.61
Sum of Correct Rejections	-2.07	8.62	6.82	14.32	Dispersion Premotor reaction time (*ms*)	2.37	9.87	6.32	13.28

Skew: Skewness;
Zskew: standardized score of Skewness;
kurt: Kurtosis;
Zkurt: standardized score of Kurtosis

Regarding the variables of stress tolerance task, five were normally distributed, including the median of reaction time (Zskew: 1.41; Zkurt: 0.85), the number of stimuli (Zskew: 1.22; Zkurt: 0.05), the sums of delayed correct responses (Zskew: 0.28; Zkurt: 1.75), on-time correct responses (Zskew: 2.11; Zkurt: 2.93) and overall correct responses (Zskew: 0.23; Zkurt: 1.22). The Zskew for stress tolerance task variables ranged from 0.23 to 13.45, while their Zkurt ranged from 0.05 to 23.19. Four variables had positive excess kurtosis, including the sums of omitted responses, overall incorrect responses, reactions and incorrect responses.

Regarding the variables of simple reaction time task, only one was normally distributed, that is the mean of motor reaction time. The Zskew for simple reaction time task variables ranged from 0.01 to 10.59, while their Zkurt ranged from 0.53 to 18.34. Other simple reaction time variables were positively skewed. Four simple reaction time task variables had positive excess kurtosis.

4.7 Intra-rater reliability and Inter-rater reliability of Raters

The raw values of intra-rater kappa scores of the first rater for each skill component ranged from 0.80 to 1.00, which led to the intra-rater reliability of the first rater being considered as substantial to almost perfect agreement. The averaged intra-rater kappa for the first rater was 0.95. The ICC of the first rater for total locomotor skills was 0.97 (0.95-0.98), which indicated excellent reliability of ratings given by the first rater. The ICCs of the first rater for each locomotor skill ranged from 0.97 to 0.99, which also indicated excellent reliability of ratings provided by the first rater.

The raw values of intra-rater kappa scores of the second rater for each skill component ranged from 0.66 to 1.00, which led to the intra-rater reliability of the second-rater being considered as substantial to almost perfect agreement. The averaged intra-rater kappa for the second rater was 0.87. The ICC of the second rater for overall locomotor skills was 0.98 (0.97–0.99), which indicated excellent reliability of ratings provided by the second rater. The ICCs of the second rater for each locomotor skill ranged from 0.85 to 0.98, which indicated good to excellent reliability of ratings provided by the second rater.

Of the raw inter-rater kappa scores of each skill component in the first trial provided by two raters, 37.5% showed kappas 0.60–0.80, indicating substantial agreement, and the remaining 62.5% showed kappas 0.81–1.00, indicating almost perfect agreement. The averaged inter-rater kappa for the first trial between two raters was 0.82. The ICC of the first trials between two raters for overall locomotor skill was 0.93 (0.90-0.96), which indicated excellent reliability of the first trials' ratings provided by two raters. The ICCs of the first trials provided by two raters for each locomotor skill ranged from 0.82 to 0.94, which indicated well to excellent reliability of the first trials' ratings provided by two raters.

Of the raw inter-rater kappa scores of each skill component between the first rater's first trial and the second rater's second trial, 29.2% showed kappas 0.41-0.60, indicating moderate agreement, a further 41.7% showed kappas 0.61-0.80, indicating substantial agreement, and the remaining showed kappas 0.81-1.00, indicating almost excellent agreement. The averaged inter-rater kappa between the first rater's first trial and the second rater's second trial was 0.71. The ICC between the first rater's first trial and the second rater's second trial was 0.91 (0.86-0.94), which indicated well to excellent reliability between the first rater's first trial and the second rater's second trial. The ICCs for each locomotor skill ranged from 0.78 to 0.88, thus indicating good reliability between the first rater's first trial and the second rater's second trial.

Of the raw inter-rater kappa scores of each skill component between the first rater's second trial and the second rater's first trial, 8.3% showed kappas 0.41-0.60, indicating moderate agreement, a further 41.7% showed kappas 0.61-0.80, indicating substantial agreement, and the remaining showed kappas 0.81-1.00, indicating almost excellent agreement. The averaged inter-rater kappa between the first rater's second trial and the second rater's first trial was 0.78. The ICC between the first rater's second trial and the second rater's first trial was 0.90 (0.86-0.93), which indicated excellent reliability between the first rater's second trial and the second rater's first trial. The ICCs for each locomotor skill ranged from 0.82 to 0.91, thus indicating well to excellent reliability between the first rater's second trial and the second rater's first trial.

Of the raw inter-rater kappa scores of each skill component in the second trials provided by two raters, 4.2% showed kappas 0.21-0.40, indicating fair agreement, a further 29.2% showed kappas 0.41-0.60, indicating moderate agreement, a further 45.8% showed kappas 0.61-0.80, indicating substantial agreement, and the remaining showed kappas 0.81-1.00, indicating almost excellent agreement. The averaged inter-rater kappa for the second trials between two raters was 0.68. The ICC of the second trials between two raters for overall locomotor skill was 0.88 (0.83-0.92), which indicated well to excellent reliability of the second trials' ratings given by two raters. The ICCs of the second trials provided by two raters for each locomotor skill ranged from 0.76 to 0.87, thus indicating good reliability of the second trials' ratings given by two raters.

According to the comparison of all the intra-rater reliability and the inter-rater reliability results, the ratings of the first rater's first trial were the most reliable and were used for the correlational analysis. For more information on the values of the intra-rater and inter-rater reliabilities between two raters, please refer to *Appendix B*.

4.8 Correlation Analysis among Age, Gender and Variables of Locomotor Skills, Simple and Choice Reaction Time Tasks and Stress Tolerance Task

Spearman's rank correlation analysis was used to examine the correlations among demographic variables and variables of locomotor skills, simple and choice reaction time tasks and stress tolerance task. The correlations were summarised in *Table 4.4*. Results showed that the relationships between age and hopping were statistically significant (r = 0.283, p<0.01). Other variables of locomotor skills were not significantly correlated with age, with correlation coefficients ranging from -0.143 to 0.117. The relationships of gender with leaping (r = -0.207, p<0.05) and sliding (r = 0.252, p<0.05) were found to be statistically significant. Other locomotor variables were not significantly correlated with gender, with correlation coefficients ranging from -0.088 to -0.026.

With regard to the relationships between choice reaction time task variables and age, four variables were negatively correlated with age (Mean working time: r = -0.321, p<0.01; Mean reaction time of correct reaction: r = -0.297, p<0.01; Mean reaction time of hits: r = -0.294, p<0.01; Mean reaction time of correct rejection: r = -0.303, p<0.01). No choice reaction time task variables were found to be significantly correlated with gender, with correlation coefficients ranging from -0.172 to 0.125.

With regard to the relationships between stress tolerance task variables and age, seven variables were correlated with age. The median reaction time was negatively correlated with age (r = -0.507, p<0.01). The remaining six variables were positively correlated with age (Sum of overall incorrect responses: r = 0.49, p<0.01; Sum of reactions: r = 0.533, p<0.01; Number of stimuli: r = 0.444, p<0.01; Sum of incorrect responses: r = 0.359, p<0.01; Sum of on-time correct responses: r = 0.417, p<0.01; Sum of overall correct responses: r = 0.367, p<0.01). Three variables were negatively correlated with gender (Sum of overall incorrect responses: r = -0.464, $p<0.01$; Sum of reactions: r = -0.216, $p<0.05$; Sum of incorrect responses: r = -0.362, $p<0.01$).

With regard to the relationships between simple reaction time task variables and age, three variables were significantly negatively correlated with age (Mean motor reaction time: r = -0.364, $p<0.01$; Mean premotor reaction time: r = -0.293, $p<0.01$; Dispersion premotor reaction time: r = -0.273, $p<0.01$). The positive relationship was found significant between Mean motor reaction time (r = 0.239, $p<0.05$) and gender.

The following section discusses the relationships between variables of locomotor skills, simple and choice reaction time tasks and stress tolerance task with or without controlling for the age and discusses the differences of these relationships for boys and girls.

4.9 Correlation Analysis among Locomotor Skills, Simple Reaction Time, Choice Reaction Time and Reactive Stress Tolerance

According to the results of the normality tests, the assumptions of normality, which hypothesised that the data distributions of variables were non-normal, for all variables of locomotor skills, simple reaction time task, choice reaction time task and stress tolerance task could not be rejected. Correlational analysis was performed by non-parametric Spearman's rank correlation analysis.

Table 4.4

Correlation coefficients among age, gender, and variables of locomotor skills, simple reaction time task, choice reaction time task and stress tolerance task

Variables	Age	Gender	Variables	Age	Gender
Locomotor Skills			Stress tolerance task		
Running	0.038	0.037	Sum of Omitted Responses	-0.041	-0.017
Galloping	-0.143	-0.03	Sum of Overall Incorrect Responses	0.49**	-0.464**
Horizontal Jumping	0.117	-0.088	Median Reaction Time (*s*)	-0.507**	0.087
Leaping	0.098	-0.207*	Sum of Reactions	0.533**	-0.216*
Hopping	0.283**	-0.029	Number of Stimuli	0.444**	-0.08
Sliding	-0.013	0.252*	Sum of Incorrect Responses	0.359**	-0.362**
			Sum of Delayed Correct Responses	0.191	0.078
			Sum of Ontime Correct Responses	0.417**	-0.097
Choice reaction time task			Sum of Overall Correct Responses	0.367**	-0.041
MT Correct Reaction (*s*)	-0.297**	0.003			
MT Hits (*s*)	-0.294**	0.017	Simple reaction time task		
MT Correct Rejection (*s*)	-0.303**	-0.016	Mean Motor reaction time (*ms*)	-0.364**	0.239*
Sum of Correct Reactions	-0.118	-0.046	Mean Premotor reaction time (*ms*)	-0.293**	0.037
Sum of Hits	-0.189	-0.172	Dispersion Motor reaction time (*ms*)	-0.112	0.116
Sum of Correct Rejections	-0.008	0.125	Dispersion Premotor reaction time (*ms*)	-0.273**	-0.044

*. *Correlation is significant at the 0.05 level (2-tailed)*

**. *Correlation is significant at the 0.01 level (2-tailed)*

4.9.1 Correlational analysis between variables of locomotor skills and simple reaction time task

Referring to the simple reaction time task, correlational analyses were used to examine the associations between locomotor skills, and the mean and dispersion of pre-motor reaction time for 101 children. The results are summarized in Appendix V. Running was found to be the only locomotor skill that was significantly and negatively correlated with the mean (r = -0.354, p<0.01) and the dispersion (r = -0.28, p<0.01) of pre-motor reaction time. The associations of running remained significant with the mean ($r(98)$ = -0.359, p<0.01) and the dispersion ($r(98)$ = -0.281, p<0.01) of pre-motor reaction time after controlling for the age. For running, the correlation coefficients for boys and girls were not statistically different (p>0.05). The remaining locomotor skills were not significantly correlated with the mean and dispersion of pre-motor reaction time (p>0.05).

Running and hopping were found to be significantly and negatively correlated with the mean (Running: r = -0.36, p<0.01; Hopping: r = -0.354, p<0.01) and the dispersion of motor reaction time (Running: r = -0.324, p<0.01; Hopping: r = -0.218, p<0.05). The associations remained significant with the mean (Running: $r(98)$ = -0.372, p<0.01; Hopping: $r(98)$ = -0.281, p<0.01) and the dispersion (Running: $r(98)$ = -0.322, p<0.01; Hopping: $r(98)$ = -0.196, p<0.05) of motor reaction time after controlling for the age. The correlation coefficients for boys and girls in some of locomotor skills were statistically different. Some locomotor skills were still significantly correlated with the mean (Running: $r(53)$ = -0.558, p<0.01; Hopping: $r(53)$ = -0.497, p<0.01) and dispersion (Running: $r(53)$ = -0.475, p<0.01) of motor reaction time for boys. The remaining locomotor skills were not significantly correlated with the mean and dispersion of motor reaction time (p>0.05).

4.9.2 Correlational analysis between variables of locomotor skills and choice reaction time task

In regard to the choice reaction time task, the results of the correlational analyses are summarized in Appendix III. Some locomotor skills were significantly and negatively correlated with the mean reaction times of correct reactions (Running: r = -0.347, p<0.01; Hopping: r = -0.216, p<0.05), hits (Running: r = -0.294, p<0.01; Leaping: r = -0.203, p<0.05; Hopping: r = -0.195, p=0.051) and correct rejections (Running: r= -0.368, p<0.01; Hopping: r = -0.219, p<0.05). After controlling for the age, running remained significantly correlated with the mean reaction times of correct reactions ($r(98)$ = -0.352, p<0.01), hits ($r(98)$ = -0.297, p<0.01) and correct rejections ($r(98)$ = -0.374, p<0.01). Hopping and leaping became insignificantly correlated with the mean time of correct reactions (Hopping: $r(98)$ = -0.144, p>0.05), hits (Leaping: $r(98)$ = -0.184, p>0.05; Hopping: $r(98)$ = -0.122, p>0.05) and correct rejections (Hopping: $r(98)$ = -0.146, p>0.05). Some of correlation coefficients for boys and girls were statistically different. Hopping was still significantly and negatively correlated with the mean times of correct reactions ($r(53)$ = -0.421, p<0.01), hits ($r(53)$ = -0.376, p<0.01) and correct rejections ($r(53)$ = -0.46, p<0.01) for boys. Horizontal jumping became negatively correlated with the mean times of correct rejections ($r(53)$ = -0.279, p<0.05) for boys. The remaining locomotor skills were not significantly correlated with the mean time of correct reactions, hits and correct rejections (p>0.05).

Locomotor skills were not significantly correlated with the sums of correct reactions, hits and correct rejections whether the age effect was controlled or not (p>0.05). However, some of correlation coefficients for girls were found to be significant and statistically different from boys. Running, galloping and sliding were negatively correlated with the sum of hits for girls (Running: $r(44)$ = -0.365, p<0.05; Galloping: $r(44)$ = -0.354, p<0.05; Sliding:

r(44) = -0.296, *p*<0.05). Hopping was positively correlated with the sum of correct rejections for girls (*r(44)* = 0.412, *p*<0.01).

4.9.3 Correlational analysis between variables of locomotor skills and stress tolerance task

Regarding the stress tolerance task, the results of correlational analysis are summarized in Appendix IV. Some of the locomotor skills were negatively correlated with the overall incorrect responses (Sliding: *r* = -0.264, *p*<0.01) and the incorrect responses (Running: *r* = -0.241, *p*<0.05; Leaping: *r* = -0.212, *p*<0.05; Sliding: *r* = -0.374, *p*<0.01). After controlling for the age, these associations with the overall incorrect responses (Sliding: *r*(98) = -0.296, *p*<0.01) and the incorrect responses (Running: *r*(98) = -0.272, *p*<0.01; Leaping: *r*(98) = -0.266, *p*<0.01; Sliding: *r*(98) = -0.395, *p*<0.01) remained significant. Some correlation coefficients for boys and girls were significantly different. Horizontal jumping and sliding were positively correlated with the sum of omitted responses for girls (Horizontal jumping: *r*(44) = 0.293, *p*<0.05; Sliding: *r*(44) = 0.29, *p*<0.05). Sliding was negatively correlated with the sum of omitted responses for boys (*r*(53) = -0.282, *p*<0.05). The remaining locomotor skills were not correlated with the sums of omitted responses, overall incorrect responses and incorrect responses (*p*>0.05).

Some locomotor skills were also correlated with the median reaction time (Running: *r* = -0.358, *p*<0.01; Leaping: *r* = -0.246, *p*<0.05; Hopping: r = -0.304, *p*<0.01), the sum of reactions (Running: *r* = 0.441, *p*<0.01; Leaping: *r* = 0.222, *p*<0.05; Hopping: *r* = 0.338, *p*<0.01) and the number of stimuli (Running: *r* = 0.398, *p*<0.01; Leaping: *r* = 0.261, *p*<0.01; Hopping: r = 0.306, p<0.01; Sliding: *r* = 0.201, *p*<0.05). After controlling for the age, these associations with the median of reaction time (Running: *r*(98) = -0.393, *p*<0.01; Leaping: *r*(98) = -0.229, *p*<0.05; Hopping: *r*(98) = -0.193, *p*<0.05), the sum of reactions (Running:

r(98) = 0.497, *p*<0.01; Leaping: *r*(98) = 0.202, *p*<0.05; Hopping: *r*(98) = 0.231, *p*<0.05) and the number of stimuli (Running: *r*(98) = 0.426, *p*<0.01; Leaping: *r*(98) = 0.244, *p*<0.05; Hopping: *r*(98) = 0.21, *p*<0.05; Sliding: *r*(98) = 0.231, *p*<0.05) remained significant. With some exceptions that sliding became significantly and negatively correlated with the median of reaction time (*r*(98) = -0.196, *p*<0.05) and galloping became significantly and positively correlated with the sum of reactions (*r*(98) = 0.221, *p*<0.05) after controlling for the age. Some correlation coefficients for boys and girls were significantly different. Running, horizontal jumping and hopping were found to be significantly correlated with the sum of reactions for boys (Running: *r*(53) = 0.646, *p*<0.01; Horizontal jumping: *r*(53) = 0.278, *p*<0.05; Hopping: *r*(53) = 0.494, *p*<0.01). The remaining locomotor skills were not correlated with the median of reaction time, the sum of reactions and the number of stimuli (*p*>0.05).

Some of locomotor skills were significantly correlated with the sums of delayed correct responses (Running: *r* = 0.449, *p*<0.01; Galloping: *r* = 0.209, *p*<0.05; Hopping: *r* = 0.227, *p*<0.05; Sliding: *r* = 0.277, *p*<0.01), on-time correct responses (Running: *r* = 0.314, *p*<0.01; Leaping: *r* = 0.257, *p*<0.01; Hopping: *r* = 0.254, *p*<0.01) and overall correct responses (Running: *r* = 0.425, *p*<0.01; Leaping: *r* = 0.251, *p*<0.05; Hopping: *r* = 0.297, *p*<0.01; Sliding: *r* = 0.207, *p*<0.05). After controlling for the age, some associations with the sums of delayed correct responses (Running: *r(98)* = 0.45, *p*<0.01; Galloping: *r(98)* = 0.244, *p*<0.01; Sliding: *r(98)* = 0.285, *p*<0.01), on-time correct responses (Running: *r(98)* = 0.329, *p*<0.01; Leaping: *r(98)* = 0.239, *p*<0.05) and overall correct responses (Running: *r(98)* = 0.443, *p*<0.01; Leaping: *r(98)* = 0.233, *p*<0.05; Hopping: *r(98)* = 0.216, *p*<0.05; Sliding: *r(98)* = 0.228, *p*<0.05) remained significant. Hopping became insignificantly correlated with the sums of delayed correct responses (*r(98)* = 0.184, *p*>0.05) and on-time correct responses (*r(98)* = 0.156, *p*>0.05) after controlling for the age. Some correlation coefficients for boys and girls were statistically different. For boys, running was significantly and positively correlated with the sums of delayed correct responses (*r(53)* = 0.576, *p*<0.01) and overall correct responses (*r(53)* = 0.575, *p*<0.01). The remaining locomotor skills were not correlated with the sums of delayed correct responses, on-time correct responses and overall correct responses (*p*>0.05).

CHAPTER 5 DISCUSSION

This study is in attempt to investigate the correlations between locomotor skills, simple reaction time task, choice reaction time task and stress tolerance task. From the associations, the understanding of the properties of attention in motor control and stress tolerance for different locomotor skills would be clearer. The associations were further controlled by the age. The associations for boys and girls were investigated separately to see the differences.

5.1 Properties of Attention in Motor Control for Different Locomotor Skills

This part is based on the results of section 4.9, which regards the correlations between variables of locomotor skills, simple reaction time tasks and choice reaction time tasks.

The role of attention in motor control focuses on movement outcomes but not on the way through which attention changes the movement itself (Lohse, Jones, Healy, & Sherwood, 2014). The attention in motor control for various locomotor skills may be different. In the following section, the properties of attention in motor control for different locomotor skills are discussed in the perspective of attentional shift, attention allocation and attentional demand.

Based on the correlational results regarding pre-motor reaction time in simple reaction time task and mean reaction time of correct reactions in choice reaction time task, the way in which the attention shifted can be understood. Based on the correlational results relating to the means of choice reaction time in choice reaction time task, where the attention is shifted to can be understood. Based on the correlational results regarding motor reaction time in simple reaction time task, the demand of attention resources for locomotor skill execution can be understood.

5.1.1 Ways in which attention is shifted in different locomotor skills

As mentioned earlier in Chapter 2, there are two ways in which attention can be shifted: reflexive attention and voluntary attention (Posnet, 1980; Posnet, Snyder, & Davidson, 1980). Voluntary attention is deliberately applied and controlled by the individual (Prinzmetal et al., 2005) as opposed to reflexive attention that is spontaneously captured by a stimulus in the environment (Eimer et al., 1996). The simple reaction time task requires the respondent to shift attention reflexively to provoke a single response from a single external stimulus. The response in the simple reaction time task is pre-programmed with fewer mental processes between the stimulus presentation and the onset of the response (Kent & Kent, 2006; Klapp, 1996). The responses in the simple reaction time task are relatively consistent (Cech & Martin, 2012).

On the contrary, choice reaction time task requires central processing to select the optimal response to multiple stimuli. The response cannot be pre-programmed because the required response is not identified until the beginning of the response time interval (Zelaznik, 1996). The attention of participants is shifted voluntarily for response programming within the pre-motor choice reaction time interval (Zelaznik, 1996). Complex responses take a longer time and more attentional resources to program.

Based on the results of simple reaction time task regarding pre-motor reaction time, running was found to be significantly negatively correlated with the mean and dispersion of pre-motor reaction time. Children with better running proficiency tend to have faster pre-motor reaction time and have more stable pre-motor reaction time. As a result, running was associated with reflexive attentional shift. The internal focus of attention may be shifted reflexively to the skill-relevant focus points during running. When children are about to start fast running (sprinting), they may control their sprinting movement in an open-loop manner, without expending considerable voluntary attention (Schmidt & Lee, 2013b). Children seem to neglect or avoid addressing movement feedback and changes in their surroundings such that sprinting movements are not considerably modified. Therefore, children may plan their sprinting movement before they start.

Since the premotor reaction time for sprinting is less dispersed (that is, stable), a well-established pre-determined motor program for sprinting movements is imparted in the child's long-term memory. When a child is about to start sprinting, this pre-determined motor program may be initiated during the response programming stage and may shift internal attention involuntarily. The pre-programmed motor program controls decisions, such as the determination and the order of muscle to be contracted, initiation time and duration of these contractions, permitting sprinting to be executed with a high degree of automaticity.

Schmidt and Lee (2013b) reported that motor control might be dominated by either an open-loop or closed-loop control system, depending on the nature and duration of the task. Based on the results of choice reaction time task regarding the mean reaction time of correct reactions, running was also associated with voluntary attentional shift. Voluntary attention was also required by motor program to control slow or prolonged running movements in a closed-loop fashion but not for sprinting.

Hopping was not associated with pre-motor reaction time in the simple reaction time task, which indicates that it may not be associated with reflexive attentional shift. Hopping might not be associated with the development of a pre-determined motor program for motor control. Instead, hopping was associated with the mean reaction time of correct reactions in choice reaction time task. Therefore, hopping was associated with voluntary attentional shift. Hopping is associated with and help facilitate the development of motor program. The internal focus of attention is shifted voluntarily to control hopping movements in a closed-loop manner while taking movement feedback into account.

Leaping was not associated with pre-motor reaction time in simple reaction time task and the mean reaction time of correct reactions in choice reaction time task. Hence, leaping might not be completely facilitative to the development of pre-determined motor programs and motor programs for attentional shifts to control correct motor movement.

The pre-determined motor program and motor program for running may shift the internal focus of attention reflexively or voluntarily to control the running movement in either an open-loop or closed-loop system, depending on the speed and duration of running. The motor program for hopping may shift the internal focus of attention voluntarily to control the hopping movement in a closed-loop system. The rest of the locomotor skills was not associated with the mean and dispersion of premotor reaction time in simple reaction time task and mean reaction time of correct reactions in choice reaction time task; these skills might not be associated with the development of either pre-determined motor program and motor program for attentional shifts to control motor movement.

5.1.2 Where the attention is shifted in locomotor skills

The focus of internal attention of locomotor skills should also be understood. In choice reaction time task, the participant needs to pay attention to accept the existence of identical figures or to reject the absence of identical figures. It is the same concept as go/no-go procedure which programs correct response by accepting the skill-relevant focuses and inhibiting the skill-irrelevant focuses for correct locomotor movements.

In choice reaction time task, running, leaping and hopping were associated with the mean reaction time of hits. Children who have higher score in running, leaping and hopping tend to have faster hits. As a result, the motor programs of these locomotor skills should be associated with an attentional shift to skill-relevant focuses for correct running, hopping and leaping movement. Except for leaping, running and hopping were also associated with the mean reaction time of correct rejections. Children who obtain higher score in running or hopping tend to have faster correct rejections. Therefore, the motor programs of running and hopping should inhibit attentional shifts to skill-irrelevant focuses for correct running or hopping movement.

In addition, running and hopping were associated with the mean and dispersion of motor reaction time in the simple reaction time task. Highly functional coordinative structures (CSs) might have been developed for correct running and hopping movement. Various skill-relevant degrees of freedom (DOFs) are progressively integrated as CS, with the aim of reducing the control of individual DOFs, which can significantly decrease demands for limited attention capacity (Whiting et al., 1992). The motor programs of running and hopping can allocate the attention resources to control CSs rather than controlling numerous individual high-attention-demand DOFs for correct running and hopping movement. The highly functional CSs also exclude skill irrelevant DOFs that are not useful for correct locomotor movement. The motor programs of these locomotor skills can allocate fewer attentional resources for inhibiting skill irrelevant DOFs. With the existence of CSs, the development of automaticity accelerates and stabilises the running and hopping movement.

The difference between running and hopping lies in the fact that the motor program for running became a kind of instincts. The individual does not have to allocate much attention for response programming with optimal CSs for running movement. Instead, the attentional resources can be saved for external factors such as tactical choices. Although hopping has developed optimal CSs, it is yet to become an instinct and still needs the participant’s voluntary internal attention to program a response with CSs and continuously monitor the motor movement. This may be the reason why hopping was not significantly correlated with the mean and dispersion of pre-motor reaction time.

Leaping was associated with the mean reaction time of hits in choice reaction time task rather than the mean reaction time of correct rejection. It was also not associated with the mean and dispersion of motor reaction time. Hence, in leaping, voluntary attention was shifted towards control skill relevant DOFs or CSs that are temporary, stable and preferred but not optimal. To become optimal CSs, CSs should be progressively integrating more active DOFs, increasing the amplitude of articular movements and inhibiting skill irrelevant DOFs (Caillou, Nourrit, Deschamps, Lauriot, & Delignieres, 2002). The less-optimised CSs used for response programming might result in increased motor movement variability.

Based on the results of simple and choice reaction time tasks, other locomotor skills might not have developed any CSs and motor programs but only developed at the beginner level. Children mastering a motor skill at a beginner level may still need to allocate their voluntary attention to 'freeze' some joints, thus reducing the number of active DOFs (Vereijken & Bongaardt, 1999). Most of DOFs involved are potentially skill irrelevant and less functional to the correct movement (Caillou et al., 2002). Participants may require extensive attention resources for response programming and continuous control of motor movement. This may be the reason why other locomotor skills were not significantly correlated with the mean and dispersion of motor reaction time in the simple reaction time task.

The above finding may also be explained in the neurological perspective. There are two subcortical structures responsible for regulating and switching the attention to select and rectify DOFs or CSs for correct movement (van Schouwenburg, den Ouden, & Cools, 2013), namely the basal ganglia and the cerebellum. The basal ganglia are a group of structures located deep within the cerebral hemispheres, while the cerebellum is located behind the top part of the brain stem and is made of two hemispheres (Purves et al., 2012). Both structures receive inputs from the motor cortex. The output of the cerebellum to motor cortex is excitatory, while the basal ganglia are inhibitory. They direct their output, through the thalamus, back to the motor cortex. The cerebellum integrates the inputs from sensation, motor cortex and motor memory to correct the errors in each movement command, add skill to each movement and then impart motor skills (Fine, Ionita, & Lohr, 2002). The basal ganglia also integrate the inputs from sensation, motor cortex and motor memory to release appropriate movements from the motor cortex and inhibit unwanted and competing movements (Purves et al., 2012). The fine-tuned motor program initiated the signals via motor neurons and interneurons in the spinal cord to the selected specific muscles for smooth and coordinated motor execution.

In case of running and hopping, the basal ganglia and cerebellum operate together to select and trigger well-coordinated voluntary movements. In the case of leaping, basal ganglia do not function to inhibit unwanted movements due to the absence of relevant motor memory stored in the basal ganglia (Packard & Knowlton, 2002). With regard to other locomotor skills, basal ganglia and the cerebellum do not function properly to inhibit, correct and add skill to the movement due to the absence of relevant motor program stored inside (Attwell, Cooke, & Yeo, 2002; Yeo, 2004).

5.2 Stress Control on the Attention for Locomotor Skills

Based on the findings of the reactive stress tolerance test, different locomotor skills showed different reactive stress tolerance.

5.2.1 Reactive Stress Tolerance in Mature Locomotor Skills

Under stress, children with better running performance may process more stimuli and reactions, react faster and give more delayed and on-time correct responses. Incorrect responses were less likely to happen in good runners. This finding is consistent with the previous finding in simple and choice reaction time tasks, which claimed that children with better or prolonged running performance had separately established their corresponding pre-determined motor program or motor program with highly functional CSs. According to Fitts and Posner's (1967) stages of motor learning, running may be developed to the autonomous stage. Stress might have a positive and challenging effect on running performance. Children with better running ability perceived running as an easy task. The task demands of running need a lower proportion of attentional resources and largely controlled automatically. More attentional resources can be retained to filter out the increasing noise raised by the stressors.

Children with running ability at the autonomous level can be considered as skilled runners. According to Newell (1985) and Wilson, Simpson, van Emmerik and Hamill (2008), a skilled athlete who executes a closed-loop skill represented a flexible motor system that could adapt to perturbations. It provides the motor movement with more highly functional variability. Sternad and Abe (2010) claimed that motor performance with high functional variability might be prone to be affected by the system noise raised by the stress. More processing time is needed to filter out the increasing system noise in order to maintain a sufficient degree of accuracy. Therefore, delayed correct responses might be occasionally provided by the skilled slow/prolonged runner. In short, with well-developed running skills, children are more likely to have better reactive stress tolerance.

Under stress, children with better hopping performance had faster and more reactions, more stimuli being presented and more delayed and on-time correct responses. Hopping had also developed motor programs with highly functional CSs. Unlike running, hopping was not significantly correlated with the sum of incorrect responses. The reason for this is uncertain. It may be due to the problem of perception-action coupling. Under stressful environment, perception of the information and feedback from the surroundings may be affected and thus lead to problematic real-time motor programming. According to Reason (1990), this is called action slip in the automatic process. The inability to constrain incorrect reactions may be due to the choice of CSs in motor programming rather than the quality of motor execution. In other words, the motor program may occasionally shift the focus of attention wrongly to skill irrelevant CSs under stressful conditions. For example, children may use CSs of single leg jumping for hopping. Therefore, with well-developed hopping skills, children may have reasonably good reactive stress tolerance.

Children with better leaping proficiency might be capable of processing more stimuli, having more and faster reactions and providing more correct responses and fewer incorrect responses under stressful conditions. Leaping was not significantly correlated with the sum of delayed correct responses. As mentioned earlier in this chapter, the motor program for leaping was not fully optimised. Caillou et al. (2002) stated that improvements of motor skill are characterised by progressively involving a greater number of active DOFs. Since the motor program for leaping might consist of CSs that contained a reduced number of active DOFs, the attentional resources for leaping might be temporarily abundant. Increasing system noise cannot cause delayed responses under stress. Improved leaping with more number of active DOFs in the motor program might lead to some delayed correct responses (increasing reaction time), such as running and hopping under stress, due to the increasing volume of information (that is, more active DOFs as well as the system noise from stressors needed to be controlled). Therefore, the reactive stress tolerance of leaping is good but may vary if the performance of leaping improves with more active DOFs involved.

5.2.2 Reactive Stress Tolerance in Immature Locomotor Skills

Children might be capable of processing more stimuli and providing more delayed correct responses and fewer incorrect responses during sliding under stress. Sliding was not significantly correlated with the median of reaction time, the sums of reactions and on-time correct responses. As mentioned earlier, no motor programs and CSs were developed for sliding. Generally, children performing sliding may require a lot of attentional resources to control DOFs for correct sliding movement. The increasing stress noise may overload the attentional resources, which might extend the time of real-time response programming and result in delayed correct responses. According to Fitts and Posner's (1967) stages of motor learning, sliding may be developed to the late cognitive stage in which some essential DOFs for sliding start to appear but not yet ensembled as CSs. For minimisation of incorrect responses, some DOFs were frozen to reduce the number of active DOFs (Vereijken & Bongaardt, 1999). The motor performance of sliding for children under stress is slow, inconsistent and inefficient. This may explain why sliding was not be significantly correlated with the sum of on-time correct responses. Hence, the reactive stress tolerance of sliding is poor.

Children who perform galloping may provide more delayed correct responses under stress. However, galloping was not significantly correlated with the median of reaction time, the sums of reactions, on-time correct responses, overall incorrect responses and the number of stimuli. The real-time motor programming for galloping needs many attentional resources to control each DOF. Under a stressful condition, the stress noise and number of DOFs might overload the limited attentional resources. Children assessed the task demands of galloping as outweighing their resources. They considered stress as a threat which might, in turn, affect the motor programming and execution of galloping. Under stress, children might not be able to process more stimuli and provide more delayed correct responses and might have more low-to-non-functional motor variations during galloping. According to Fitts and Posner's (1967) stages of motor learning, galloping might be in the cognitive stage. The motor skill in this stage may exhibit high motor variability (Newell, 1985). It caused no correlations between galloping and stress tolerance task variables, except for delayed correct responses. As a result, galloping had poor reactive stress tolerance.

Under stressful conditions, horizontal jumping was not correlated with any variables of stress tolerance task. As mentioned earlier, horizontal jumping is far beyond the formation of CSs and motor program. The control of DOFs for horizontal jumping is spurious. Therefore, the stress effect on the execution of horizontal jumping is not fully understood.

5.2.3 Summary of Reactive Stress Tolerance in Locomotor Skills

The locomotor skills developed with highly-functional CSs and motor program might have better reactive stress tolerance, while the locomotor skills without CSs or motor program may have worse reactive stress tolerance because the real-time motor programming for these locomotor skills needs lots of attentional resources to deal with the stress noise and the control of DOFs. According to this study, the strengths of the stress effect depend on the availability of attentional resources, motor variability, perception-action coupling and perception of stress. Once the attentional resources are enough to process the stress noise, the negative stress effect on the motor performance might be minimised. Locomotor skills with a higher degree of motor variability are more susceptible to the stress effect. For locomotor skills with high functional motor variability, stress effect causes delayed responses but still with high accuracy. For locomotor skills with high non-functional motor variability, stress effect might worsen the locomotor performance. Stress may affect the perception of stimuli and feedbacks on the perception-action couplings that are not strongly bonded. Lastly, stress effect may have a different meaning to children with different capabilities in individual locomotor skills. If stress is perceived as eustress by children, it would have an encouraging effect on their performance. Otherwise, distress may have an adverse effect on the locomotor performance of children.

5.3 Attention for Motor Control in Locomotor Skills between Boys and Girls

In simple reaction time task, the correlation coefficients for boys and girls in the relationships between running and the mean and dispersion of motor reaction time, between hopping and the mean of motor reaction time and between sliding and the dispersion of motor reaction time were found significantly different. The correlation was stronger for boys than girls. In accordance to the study conducted by Hodgkins (1963), he claimed that the difference between boys and girls in motor reaction time was more significant than the gender difference in total reaction time. The boys were significantly faster in motor reaction time than girls. McGuinness (1976) and Åstrand and Rodahl (1970) explained that males are usually more muscular and possess greater muscular strength than girls from puberty onwards, implying that the significant correlations between running, hopping, sliding and motor reaction time may be due to the difference in physical fitness, that in turn affect the formation and execution of CSs.

Marta, Marinho, Barbosa, Izquierdo, & Marques (2012) found that boys had better aerobic fitness, strength, speed and agility. Other studies revealed the effect of better physical fitness on the decrease in reaction time during exercise (Brisswalter, Arcelin, Audiffren, & Delignieres, 1997; Brisswalter & Legros, 1995). According to research, when physical fitness is high, the physiological constraints for CS execution are minimal and the attentional demand associated with the control of movement decreases (Armstrong & Van Mechelen, 2017), and therefore, the performance of reaction time task can be optimised.

However, this conclusion cannot be generalised to all locomotor skills. The relationships of motor reaction time with sliding, leaping, horizontal jumping and galloping for boys and girl were found insignificant. This may be due to different fitness requirements of each locomotor skill. Moreover, the studies of Brisswalter and Legros (1995) and Brisswalter et al. (1997) had only examined the effect of cardiovascular endurance on reaction time and not the effects of other physical fitness components. Further studies on the effects of other fitness components, such as flexibility (Chatzopoulos, Galazoulas, Patikas, & Kotzamanidis, 2014), muscular endurance (Alan Stul & Kearney, 1978), physical exertion (Levitt & Gutin, 1971), on the gender difference in motor reaction time are needed.

In choice reaction time task, the relationships between horizontal jumping and the mean reaction times of hits and correct rejections, between hopping and the mean reaction times of correct responses, hits and correct rejections were found significantly different for boys and girls. Boys probably provide faster correct response than girls during horizontal jumping and hopping. This finding is consistent with the study of Fairweather and Hutt (1972), which claimed that adult men are found to be faster than women in performing choice reaction time tasks.

As the study revealed, boys were more likely to have faster motor reaction time in simple reaction time task than girls during running and hopping. Assuming that the motor reaction times for simple reaction time task and choice reaction time task are the same, boys would have faster choice reaction times in hits and correct rejections during running and hopping. Nevertheless, the correlation coefficients for boys and girls in the relationships with reaction times of hits and correct rejections during running were not significantly different.

According to a study, girls' premotor reaction time were significantly faster and motor reaction time were significantly slower than boys in choice reaction time task (Landauer, Armstrong, & Digwood, 1980). These findings can only be applied to running and hopping. Girls' shorter premotor reaction time cannot compensate for their longer motor reaction time during hopping, which results in faster overall choice reaction for boys in the choice reaction time task. However, girls' shorter premotor reaction time may compensate their longer motor reaction time during running, which results in no significant difference between boys and girls in the relationships with overall choice reaction time in choice reaction time tasks.

Based on these findings, girls may have better premotor reaction time, while boys may have better motor reaction time during running and hopping. When this finding is applied to motor control context, girls' motor program for running and hopping is better than boys' in shifting attention to skill relevant CSs and inhibiting shifting attention to skill irrelevant CSs. Boys are better in motor execution during running and hopping.

In the case of horizontal jumping, boys are more likely to have shorter choice reaction times in the correct rejections and correct reactions than girls, but not choice reaction time in hits. Since the correlation coefficients of the relationships between horizontal jumping and motor reaction time in simple reaction time task for boys and girls were not significantly different, it is assumed that the relationships between horizontal jumping and motor reaction time in choice reaction time task were the same for boys and girls. Therefore, boys might have shorter premotor reaction time in choice reaction time task, especially correct rejections. It seems to contradict the result of running and hopping, which claimed that girls have faster premotor reaction time in choice reaction time task than boys. This contradiction might be explained by the difference in attention allocation.

As mentioned earlier, no CSs or motor program have been developed for horizontal jumping. Children must control their focus of attention to perform real-time motor programming with individual DOFs. Comparatively, running and hopping have developed highly functional CSs and motor program. The motor program for running and hopping sets the focus of attention on controlling CSs. Based on the results of choice reaction time test, boys can be inferred to have better control of attention to motor programming with individual DOFs than girls when executing a new or immature locomotor skill like horizontal jumping. Girls have better control of attention to CSs when executing mature locomotor skills such as running and hopping. In other words, boys may have better attention in motor control for both matured and immature locomotor skills, while girls may be more attentive to the control of the motor movement of matured locomotor skills than immature locomotor skills.

5.4 Reactive Stress Tolerance in Locomotor Skills between Boys and Girls

In stress tolerance test, the correlations between the sum of omitted responses and three locomotor skills (horizontal jumping, leaping and sliding) were significantly different for boys and girls. As mentioned earlier, boys possess better attention for controlling individual DOFs of new or immature locomotor skills. Girls with poorer attention for controlling these immature locomotor skills are more susceptible to be affected by stressors. Under stress, girls may miss skill relevant DOFs that are important for correct locomotor movement. Comparatively, boys are more able to concentrate on the skill relevant DOFs for correct locomotor movement under stress.

The correlations between the sum of reactions and three locomotor skills (running, horizontal jumping and hopping) were also significantly different for boys and girls. Since boys generally have better physical fitness and CSs for locomotor movement, they are more likely to react more during running and hopping by increasing repetitions of CSs or involving higher functional CSs into motor program under stress. Since horizontal jumping is a one-off task, boys increase their reactions by involving more DOFs for horizontal jumping under stress because boys were found to have better attention for motor programming with individual DOFs than girls. Another correlation between the sum of delayed correct responses and running was also significantly different for boys and girls. Boys are more likely to produce more delayed responses during running under stress. The reason for this is not clear but may be due to physical fatigue or temporary attentional overload (Guo et al., 2018).

The significant differences in the correlation coefficients for boys and girls were observed in advanced locomotor skills (running and hopping) and immature locomotor skills (horizontal jumping). Boys are relatively better at controlling attention on real-time motor programming with DOFs for new and immature locomotor skills, while girls are relatively better at controlling attention to CSs of mastered locomotor skills. Since girls might not be good at controlling attention on individual DOFs, they are more prone to be affected by stress and to miss skill relevant DOFs for movement when they are learning or performing new or immature locomotor skills. Boys have a better ability to withstand the stress and react more but sometimes with delays when they are executing mastered locomotor skills.

5.5 Attention for Motor Control and Reactive Stress Tolerance after controlling for age

Based on the results of simple and choice reaction time tasks and stress tolerance test, the relationships between hopping and the means of motor reaction time, choice reaction time and median reaction time and the number of reactions under stress were weakened and even became insignificant after controlling for the age. According to Gabbard (2009), as children get older, motor skills improve with body maturation, growth of the cerebellum (responsible for balance and coordination) and the pruning of unused synapses. Since hopping might need extra better muscle strength, coordination and balance (Tveter, & Holm, 2010), it may improve the control of attention to response programming with CSs in a more considerable extent when the body size, cerebellum and myelination of cerebellum connections to the cortex are developed as children get older (Gabbard, 2009). The improvements in motor reaction time in simple reaction time task, reaction times of hits and rejections in choice reaction time task and reaction time, the sums of reactions, online correct reactions and stimuli under stressful conditions may become more significant in older children when executing hopping movement because of body maturation. Older children might have better attention for motor control and reactive stress tolerance during hopping.

According to the results of stress tolerance test, the relationships between galloping and the number of reactions became significant after controlling for the age. The result reflected that children should be able to react more during galloping under stress, except for the children aged six to nine years. It may be the result of insufficient training in galloping between the age of six and nine. Since galloping has not developed motor program or CSs, it may result in worse stress tolerance when controlling attention to the increasing number of individual DOFs and proprioceptive feedback during galloping. Hence, age might not be the factor affecting the attention for motor control and reactive stress tolerance in locomotor skills, except hopping.

5.6 Limitations of this study

Since this study is a cross-sectional correlational study, the results reflect the associations between locomotor skills, attention for motor control and stress tolerance do exist, but are unable to reflect the causal relationships. It is suggested that quasi-experimental design should be used for better understanding the effect of locomotor skill development on attentional control and stress control. Although some significant age effects were found in the partial correlation analysis and some correlation coefficients for boys and girls were found significantly different, the results are still unable to reflect the age and gender difference in the attention for motor control and stress tolerance. It is suggested that more participants should be recruited and divided into different groups according to age or gender, to see the groups differences in the attention for motor control and stress tolerance when performing different locomotor skills.

As mentioned earlier, Vienna Test System is a computerized testing procedure for assessing the cognitive functioning of people. But the testing environment of Vienna Test System is quite different from the actual locomotor testing environment. The cognitive functioning measured in Vienna Test System may be deviated from the cognitive functioning used in controlling locomotor movement. Adding that Vienna Test System is mainly finished by hands, while locomotor skills are mainly finished by legs, hand-eye coordination, foot-eye coordination and leg-eye coordination may make the study results different. It is suggested using some assessment tools finished by leg to measure the attention during the locomotion; for example, Trail Making Test (Schott, 2015).

CHAPTER 6 CONCLUSION

In the population of 6 to 9 years of age, locomotor skills which have developed a predetermined motor program were highly automatic and executed in an open-loop manner. The predetermined motor program may shift the internal focus of attention reflexively to stimulus-corresponding and skill relevant coordinative structure for correct movement. On the contrary, locomotor skills which have developed a motor program were operated in a closed-loop manner. The motor program may shift the internal focus of attention voluntarily to stimulus-corresponding and skill relevant coordinative structures and may inhibit shifting the internal focus of attention to skill irrelevant coordinative structures. For locomotor skills which may need real-time response programming draw a lot of attentional resources to shift the voluntary internal focus of attention to unoptimized coordinative structures and skill relevant degrees of freedom, and to adjust the temporary motor program in real-time for better motor execution.

Locomotor skills which have developed motor program show better reactive stress tolerance. The stress on these locomotor skills might have encouraging effect on performance. Under stress, these locomotor skills lead to more and faster reactions, more stimuli or feedbacks processing from the surroundings or inner body and more on-time correct reactions. Due to their high motor variability, these locomotor skills might occasionally have delayed correct responses and misperception of stimuli and feedbacks under stress.

Based on the findings of this study, locomotor skills at different developmental stages showed differences in the attention for motor control and stress tolerance. Children keep practicing and developing locomotor skills to matured and autonomous stage might show better attention and stress tolerance for motor control.

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APPENDIX I: Performance criteria of six locomotor skills in TGMD-2

Performance Criteria	
Running	R1-Arms move in opposition to legs, elbows bent
	R2-Brief period where both feet are off the ground
	R3-Narrow foot placement landing on heel or toe (i.e. not flat-footed)
	R4-Non-support leg bent approximately 90 degrees (i.e. close to buttocks)
Galloping	G1-Arms bent and lifted to waist level at takeoff
	G2-A step forward with the lead foot followed by a step with the trailing foot to a position adjacent to or behind the lead foot
	G3-Brief period when both feet are off the floor
	G4-Maintains a rhythmic pattern for four consecutive gallops
Horizontal Jumping	HJ1-Preparatory movement includes flexion of both knees with arms extended behind body
	HJ2-Arms extend forcefully forward and upward reaching full extension above the head
	HJ3-Take off and land on both feet simultaneously
	HJ4-Arms are thrust downward during landing
Leaping	L1-Take off on one foot and land on the opposite foot
	L2-A period where both feet are off the ground longer than running
	L3-Forward reach with the arm opposite the lead foot
Hopping	H1-Non-support leg swings forward in pendular fashion to produce force
	H2-Foot of nonsupport leg remains behind body
	H3-Arms flexed and swing forward to produce force
	H4-Takes off and lands three consecutive times on preferred foot
	H5-Takes off and lands three consecutive times on nonpreferred foot
Sliding	S1-Body turned sideways so shoulders are aligned with the line on the floor
	S2-A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot
	S3-A minimum of four continuous step-slide cycles to the right
	S4-A minimum of four continuous step-slide cycles to the left

APPENDIX II: Inter-rater and intra-rater reliabilities of the ratings of six locomotor skills between two raters

Performance Criteria		Intra-rater Reliability (Rater 1)		Intra-rater Reliability (Rater 2)		Inter-rater Reliability (R1T1-R2T1)	
		Kappa	ICC (LCl-UCl)	Kappa	ICC (LCl-UCl)	Kappa	ICC (LCl-UCl)
Running	R1	0.98		0.82		0.73	
	R2	0.92		0.90		0.87	
	R3	0.92		0.88		0.83	
	R4	0.98		0.92		0.88	
		Overall	0.97 (0.96-0.98)	Overall	0.96 (0.95-0.98)	Overall	0.92 (0.89-0.95)
Galloping	G1	0.82		0.67		0.68	
	G2	1.00		0.85		0.74	
	G3	0.91		0.71		0.82	
	G4	1.00		1.00		0.66	
		Overall	0.98 (0.97-0.99)	Overall	0.94 (0.91-0.96)	Overall	0.87 (0.81-0.91)
Horizontal Jumping	HJ1	0.98		0.90		0.94	
	HJ2	0.93		0.92		0.78	
	HJ3	0.88		0.89		0.88	
	HJ4	0.99		0.99		0.83	
		Overall	0.99 (0.98-0.99)	Overall	0.98 (0.97-0.99)	Overall	0.92 (0.85-0.95)

Note: R1T1-Rater 1 First Rating; R1T2-Rater 1 Second Rating; R2T1-Rater 2 First Rating; R2T2-Rater 2 Second Rating
ICC: Intraclass Correlation Coefficient; LCI: Lower Quartile of Confidence Interval; UCl: Upper Quartile of Confidence Interval

APPENDIX II: Inter-rater and intra-rater reliabilities of the ratings of six locomotor skills between two raters (Continue)

Performance Criteria		Inter-rater Reliability (R1T1-R2T2)		Inter-rater Reliability (R1T2-R2T1)		Inter-rater Reliability (R1T2-R2T2)	
		Kappa	ICC (LCl-UCl)	Kappa	ICC (LCl-UCl)	Kappa	ICC (LCl-UCl)
Running	R1	0.57		0.71		0.55	
	R2	0.78		0.86		0.76	
	R3	0.72		0.91		0.79	
	R4	0.83		0.86		0.81	
		Overall	0.88 (0.83-0.92)	Overall	0.90 (0.85-0.93)	Overall	0.86 (0.79-0.90)
Galloping	G1	0.46		0.63		0.47	
	G2	0.65		0.74		0.65	
	G3	0.52		0.71		0.37	
	G4	0.66		0.66		0.66	
		Overall	0.84 (0.77-0.89)	Overall	0.85 (0.79-0.90)	Overall	0.83 (0.76-0.88)
Horizontal Jumping	HJ1	0.84		0.92		0.82	
	HJ2	0.69		0.72		0.63	
	HJ3	0.78		0.78		0.71	
	HJ4	0.82		0.82		0.80	
		Overall	0.88 (0.77-0.93)	Overall	0.91 (0.85-0.94)	Overall	0.87 (0.79-0.92)

Note: R1T1-Rater 1 First Rating; R1T2-Rater 1 Second Rating; R2T1-Rater 2 First Rating; R2T2-Rater 2 Second Rating
ICC: Intraclass Correlation Coefficient; LCI: Lower Quartile of Confidence Interval; UCl: Upper Quartile of Confidence Interval

APPENDIX II: Inter-rater and intra-rater reliabilities of the ratings of six locomotor skills between two raters (Continue)

Performance Criteria		Intra-rater Reliability (Rater 1)		Intra-rater Reliability (Rater 2)		Inter-rater Reliability (R1T1-R2T1)	
		Kappa	ICC (LCl-UCl)	Kappa	ICC (LCl-UCl)	Kappa	ICC (LCl-UCl)
Leaping	L1	1.00		0.96		0.96	
	L2	0.95		0.88		0.88	
	L3	0.98		0.98		0.87	
		Overall	0.99 (0.98-0.99)	Overall	0.97 (0.95-0.98)	Overall	0.82 (0.73-0.87)
Hopping	H1	0.95		0.82		0.90	
	H2	1.00		0.71		0.75	
	H3	1.00		0.83		0.73	
	H4	1.00		1.00		0.60	
	H5	0.88		1.00		0.73	
		Overall	0.99 (0.99-0.99)	Overall	0.95 (0.93-0.97)	Overall	0.86 (0.79-0.90)
Sliding	S1	0.97		0.69		0.89	
	S2	1.00		0.66		0.90	
	S3	0.80		1.00		1.00	
	S4	-		-		-	
		Overall	0.99 (0.98-0.99)	Overall	0.85 (0.78-0.89)	Overall	0.94 (0.91-0.96)
		Total	0.97 (0.95-0.98)	Total	0.98 (0.97-0.99)	Total	0.93 (0.90-0.96)

Note: R1T1-Rater 1 First Rating; R1T2-Rater 1 Second Rating; R2T1-Rater 2 First Rating; R2T2-Rater 2 Second Rating
ICC: Intraclass Correlation Coefficient; LCI: Lower Quartile of Confidence Interval; UCl: Upper Quartile of Confidence Interval

APPENDIX II: Inter-rater and intra-rater reliabilities of the ratings of six locomotor skills between two raters (Continue)

Performance Criteria		Inter-rater Reliability (R1T1-R2T2)		Inter-rater Reliability (R1T2-R2T1)		Inter-rater Reliability (R1T2-R2T2)	
		Kappa	ICC (LCl-UCl)	Kappa	ICC (LCl-UCl)	Kappa	ICC (LCl-UCl)
Leaping	L1	0.93		0.96		0.93	
	L2	0.78		0.83		0.76	
	L3	0.85		0.89		0.87	
		Overall	0.78 (0.68-0.85)	Overall	0.82 (0.74-0.87)	Overall	0.78 (0.69-0.85)
Hopping	H1	0.76		0.88		0.74	
	H2	0.53		0.75		0.53	
	H3	0.63		0.73		0.63	
	H4	0.60		0.60		0.60	
	H5	0.73		0.55		0.55	
		Overall	0.82 (0.75-0.88)	Overall	0.85 (0.79-0.90)	Overall	0.82 (0.75-0.88)
Sliding	S1	0.58		0.87		0.56	
	S2	0.60		0.90		0.60	
	S3	1.00		0.80		0.80	
	S4	-		-		-	
		Overall	0.78 (0.69-0.85)	Overall	0.91 (0.88-0.94)	Overall	0.76 (0.67-0.83)
		Total	0.91 (0.86-0.94)	Total	0.90 (0.86-0.93)	Total	0.88 (0.83-0.92)

Note: R1T1-Rater 1 First Rating; R1T2-Rater 1 Second Rating; R2T1-Rater 2 First Rating; R2T2-Rater 2 Second Rating
ICC: Intraclass Correlation Coefficient; LCI: Lower Quartile of Confidence Interval; UCl: Upper Quartile of Confidence Interval

APPENDIX III: Correlation coefficients of the zero-order and age-controlled relationships between variables of locomotor skills and choice reaction time task

	Mean time Correct Reactions (s)				Mean time Hits (s)				Mean time Correct Rejections (s)			
	Zero-order	Age	Boys	Girls	Zero-order	Age	Boys	Girls	Zero-order	Age	Boys	Girls
Running	-0.347**	-0.352**	-0.405**	-0.251	-0.294**	-0.297**	-0.361**	-0.193	-0.368**	-0.374**	-0.453**	-0.245
	diff.	0.005	*z*	-0.84	*diff.*	0.002	*z*	-0.89	*diff.*	0.006	*z*	-1.16
Galloping	-0.025	-0.072	0.06	-0.145	0.053	0.011	0.11	0.015	-0.042	-0.09	0.047	-0.155
	diff.	0.047	*z*	1.00	*diff.*	0.042	*z*	0.46	*diff.*	0.049	*z*	0.99
Horizontal	-0.078	-0.045	-0.225	0.166	-0.018	0.018	-0.148	0.184	-0.114	-0.083	-0.279*	0.113
Jumping	*diff.*	-0.033	*z*	-1.92^{c}	*diff.*	-0.035	*z*	-1.63	*diff.*	-0.031	*z*	-1.94^{c}
Leaping	-0.133	-0.109	-0.214	-0.037	-0.203*	-0.184	-0.296*	-0.11	-0.107	-0.082	-0.174	-0.032
	diff.	-0.024	*z*	-0.87	*diff.*	-0.02	*z*	-0.94	*diff.*	-0.025	*z*	-0.7
Hopping	-0.216*	-0.144	-0.421**	0.072	-0.195	-0.122	-0.376**	0.056	-0.219*	-0.146	-0.46**	0.057
	diff.	-0.072^{b}	*z*	-2.53^{d}	*diff.*	-0.073^{b}	*z*	-2.19^{c}	*diff.*	-0.073^{b}	*z*	-2.69^{d}
Sliding	-0.137	-0.148	-0.128	-0.159	-0.069	-0.076	-0.056	-0.094	-0.178	-0.191	-0.182	-0.188
	diff.	-0.01	*z*	0.15	*diff.*	0.007	*z*	0.19	*diff.*	0.013	*z*	0.03

*. Correlation is significant at the 0.05 level (2-tailed) **. Correlation is significant at the 0.01 level (2-tailed)

diff. Correlation coefficient difference between zero-order relationship and age-controlled first-order relationship

^{a}. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.05 level (2-tailed)

^{b}. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.01 level (2-tailed)

z. difference between two correlation coefficients of boys and girl using the Fisher r-to-z transformation

^{c}. significance of the difference between two correlation coefficients of boys and girls at the 0.05 level (2-tailed)

^{d}. significance of the difference between two correlation coefficients of boys and girls at the 0.01 level (2-tailed)

APPENDIX III: Correlation coefficients of the zero-order and age-controlled relationships between variables of locomotor skills and choice reaction time task (Continue)

	Sum of Correct Reactions				Sum of Hits				Sum of Correct Rejections			
	Zero-order	Age	Boys	Girls	Zero-order	Age	Boys	Girls	Zero-order	Age	Boys	Girls
Running	-0.084	-0.08	0.028	-0.232	-0.155	-0.15	0.039	-0.365*	0.028	0.028	-0.002	0.088
	diff.	-0.004	*z*	1.28	*diff.*	-0.004	*z*	2.05[c]	*diff.*	-0.00	*z*	-0.44
Galloping	-0.041	-0.059	0.094	-0.208	-0.101	-0.132	0.083	-0.354*	0.082	0.082	0.115	0.085
	diff.	0.018	*z*	1.48	*diff.*	0.031	*z*	2.2 [c]	*diff.*	0.00	*z*	0.15
Horizontal	-0.041	-0.027	-0.034	-0.059	-0.151	-0.132	-0.158	-0.187	0.089	0.09	0.068	0.144
Jumping	*diff.*	-0.013	*z*	0.12	*diff.*	-0.019	*z*	0.15	*diff.*	-0.002	*z*	-0.37
Leaping	-0.054	-0.043	-0.095	-0.018	-0.005	0.013	0.044	-0.085	-0.084	-0.084	-0.179	0.012
	diff.	-0.011	*z*	-0.37	*diff.*	-0.019	*z*	0.63	*diff.*	-0.00	*z*	-0.94
Hopping	0.114	0.154	0.003	0.246	0.112	0.176	0.136	0.084	0.09	0.096	-0.122	0.412**
	diff.	-0.041	*z*	-1.2	*diff.*	-0.064[a]	*z*	0.26	*diff.*	-0.006	*z*	-2.72[d]
Sliding	-0.042	-0.044	0.123	-0.245	-0.126	-0.131	0.11	-0.296*	0.057	0.057	0.056	-0.051
	diff.	0.002	*z*	1.81	*diff.*	0.005	*z*	2.02[c]	*diff.*	0.00	*z*	0.52

**. Correlation is significant at the 0.05 level (2-tailed) **. Correlation is significant at the 0.01 level (2-tailed)*

diff. Correlation coefficient difference between zero-order relationship and age-controlled first-order relationship

[a]. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.05 level (2-tailed)

[b]. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.01 level (2-tailed)

z. difference between two correlation coefficients of boys and girl using the Fisher r-to-z transformation

[c]. significance of the difference between two correlation coefficients of boys and girls at the 0.05 level (2-tailed)

[d]. significance of the difference between two correlation coefficients of boys and girls at the 0.01 level (2-tailed)

APPENDIX IV: Correlation coefficients of the zero-order and age-controlled relationships between variables of locomotor skills and stress tolerance task

	Omitted Responses				Overall Incorrect Responses				Incorrect Responses			
	Zero-order	Age	Boys	Girls	Zero-order	Age	Boys	Girls	Zero-order	Age	Boys	Girls
Running	-0.183	-0.182	-0.351**	0.014	-0.009	-0.032	0.157	-0.183	-0.241*	-0.272**	-0.239	-0.26
	diff.	-0.001	*z*	-1.85	*diff.*	0.023	*z*	1.67	*diff.*	0.032	*z*	0.11
Galloping	-0.106	-0.113	-0.009	-0.213	-0.023	0.055	-0.078	0.119	-0.066	-0.015	-0.195	0.053
	diff.	0.007	*z*	1.01	*diff.*	-0.078	*z*	-0.96	*diff.*	-0.05	*z*	-1.22
Horizontal	0.038	0.044	-0.171	0.293*	-0.087	-0.167	-0.01	-0.25	-0.13	-0.186	-0.063	-0.339*
Jumping	*diff.*	-0.005	*z*	-2.3[c]	*diff.*	0.08	*z*	1.19	*diff.*	0.056	*z*	1.41
Leaping	-0.008	-0.008	-0.22	0.219	-0.064	-0.129	-0.225	-0.149	-0.212*	-0.266**	-0.221	-0.428**
	diff.	-0.004	*z*	-2.17[c]	*diff.*	0.065	*z*	-0.38	*diff.*	0.054	*z*	1.13
Hopping	-0.105	-0.097	-0.212	0.004	0.089	-0.058	0.254	-0.122	-0.014	-0.129	0.118	-0.247
	diff.	-0.008	*z*	-1.06	*diff.*	0.148[b]	*z*	1.85	*diff.*	0.115[b]	*z*	1.8
Sliding	-0.039	-0.039	-0.282*	0.29*	-0.264**	-0.296**	-0.139	-0.209	-0.374**	-0.395**	-0.325*	-0.306*
	diff.	0.001	*z*	-2.85[d]	*diff.*	0.031	*z*	0.35	*diff.*	0.021	*z*	-0.1

**. Correlation is significant at the 0.05 level (2-tailed)*

***. Correlation is significant at the 0.01 level (2-tailed)*

diff. Correlation coefficient difference between zero-order relationship and age-controlled first-order relationship

a. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.05 level (2-tailed)

b. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.01 level (2-tailed)

z. difference between two correlation coefficients of boys and girl using the Fisher r-to-z transformation

c. significance of the difference between two correlation coefficients of boys and girls at the 0.05 level (2-tailed)

d. significance of the difference between two correlation coefficients of boys and girls at the 0.01 level (2-tailed)

APPENDIX IV: Correlation coefficients of the zero-order and age-controlled relationships between variables of locomotor skills and stress tolerance task (Continue)

	Median reaction time (s)				Sum of Reactions				Number of Stimuli (Sum)			
	Zero-order	Age	Boys	Girls	Zero-order	Age	Boys	Girls	Zero-order	Age	Boys	Girls
Running	-0.358**	-0.393**	-0.495**	-0.16	0.441**	0.497**	0.646**	0.148	0.398**	0.426**	0.54**	0.207
	diff.	0.036	*z*	-1.85	*diff.*	-0.057	*z*	3.00[d]	*diff.*	-0.028	*z*	1.91
Galloping	-0.032	-0.122	0.068	-0.101	0.109	0.221*	-0.028	0.239	0.072	0.153	-0.062	0.208
	diff.	0.091	*z*	0.82	*diff.*	-0.112[a]	*z*	-1.32	*diff.*	-0.081[a]	*z*	-1.33
Horizontal	-0.163	-0.121	-0.235	-0.034	0.122	0.071	0.278*	-0.132	0.126	0.083	0.24	-0.053
Jumping	*diff.*	-0.042	*z*	-1	*diff.*	0.051	*z*	2.03[c]	*diff.*	0.043	*z*	1.44
Leaping	-0.246*	-0.229*	-0.286*	-0.192	0.222*	0.202*	0.225	0.105	0.261**	0.244*	0.33*	0.181
	diff.	-0.017	*z*	-0.48	*diff.*	0.02	*z*	0.6	*diff.*	0.017	*z*	0.78
Hopping	-0.304**	-0.193*	-0.429**	-0.149	0.338**	0.231*	0.494**	0.141	0.306**	0.21*	0.398**	0.18
	diff.	-0.11[b]	*z*	-1.5	*diff.*	0.107[b]	*z*	1.94[c]	*diff.*	0.096[b]	*z*	1.16
Sliding	-0.162	-0.196*	-0.16	-0.227	0.132	0.165	0.249	0.129	0.201*	0.231*	0.229	0.245
	diff.	0.034	*z*	0.34	*diff.*	-0.033	*z*	0.6	*diff.*	-0.03	*z*	-0.08

**. Correlation is significant at the 0.05 level (2-tailed)*
***. Correlation is significant at the 0.01 level (2-tailed)*
diff. Correlation coefficient difference between zero-order relationship and age-controlled first-order relationship
a. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.05 level (2-tailed)
b. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.01 level (2-tailed)
z. difference between two correlation coefficients of boys and girl using the Fisher r-to-z transformation
c. significance of the difference between two correlation coefficients of boys and girls at the 0.05 level (2-tailed)
d. significance of the difference between two correlation coefficients of boys and girls at the 0.01 level (2-tailed)

APPENDIX IV: Correlation coefficients of the zero-order and age-controlled relationships between variables of locomotor skills and stress tolerance task (Continue)

	Sum of Delayed Correct Responses				Sum of On-time Correct Responses				Sum of Overall Correct Responses			
	Zero-order	Age	Boys	Girls	Zero-order	Age	Boys	Girls	Zero-order	Age	Boys	Girls
Running	0.449^{**}	0.450^{**}	0.576^{**}	0.255	0.314^{**}	0.329^{**}	0.447^{**}	0.147	0.425^{**}	0.443^{**}	0.575^{**}	0.233
	diff.	-0.001	*z*	1.92^{c}	*diff.*	-0.015	*z*	1.61	*diff.*	-0.017	*z*	2.03^{c}
Galloping	0.209^{*}	0.244^{**}	0.125	0.322^{*}	0.024	0.093	-0.071	0.128	0.113	0.18	0.017	0.281
	diff.	-0.034	*z*	-1.01	*diff.*	-0.069	*z*	-0.97	*diff.*	-0.067	*z*	-1.32
Horizontal	0.151	0.132	0.31^{*}	-0.065	0.041	-0.009	0.125	-0.094	0.125	0.088	0.263	-0.103
Jumping	*diff.*	0.019	*z*	1.87	*diff.*	0.05	*z*	1.07	*diff.*	0.036	*z*	1.81
Leaping	0.166	0.151	0.268^{*}	0.119	0.257^{**}	0.239^{*}	0.311^{*}	0.165	0.251^{*}	0.233^{*}	0.318^{*}	0.148
	diff.	0.015	*z*	0.75	*diff.*	0.018	*z*	0.75	*diff.*	0.019	*z*	0.87
Hopping	0.227^{*}	0.184	0.279^{*}	0.126	0.254^{**}	0.156	0.326^{*}	0.151	0.297^{**}	0.216^{*}	0.383^{**}	0.148
	diff.	0.043	*z*	0.78	*diff.*	0.098^{b}	*z*	0.9	*diff.*	0.081^{b}	*z*	1.23
Sliding	0.277^{**}	0.285^{**}	0.401^{**}	0.087	0.129	0.148	0.152	0.188	0.207^{*}	0.228^{*}	0.255	0.184
	diff.	-0.008	*z*	1.64	*diff.*	-0.019	*z*	-0.18	*diff.*	-0.021	*z*	0.36

**. Correlation is significant at the 0.05 level (2-tailed)*

***. Correlation is significant at the 0.01 level (2-tailed)*

diff. Correlation coefficient difference between zero-order relationship and age-controlled first-order relationship

a. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.05 level (2-tailed)

b. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.01 level (2-tailed)

z. difference between two correlation coefficients of boys and girl using the Fisher r-to-z transformation

c. significance of the difference between two correlation coefficients of boys and girls at the 0.05 level (2-tailed)

d. significance of the difference between two correlation coefficients of boys and girls at the 0.01 level (2-tailed)

APPENDIX V: Correlation coefficients of the zero-order and age-controlled relationships between variables of locomotor skills and simple reaction time task

	Motor reaction time				Premotor reaction time			
	Zero-order	Age	Boys	Girls	Zero-order	Age	Boys	Girls
Running	-0.36**	-0.372**	-0.558**	-0.108	-0.354**	-0.359**	-0.41**	-0.285
	diff.	0.012	*z*	-2.53[d]	*diff.*	0.005	*z*	-0.69
Galloping	-0.056	-0.118	-0.014	-0.128	-0.044	-0.09	0.049	-0.17
	diff.	0.061	*z*	0.56	*diff.*	0.047	*z*	1.07
Horizontal Jumping	-0.114	-0.077	-0.184	0.044	-0.129	-0.099	-0.154	-0.068
	diff.	-0.037	*z*	-1.12	*diff.*	-0.029	*z*	-0.42
Leaping	0.003	0.042	0.063	0.043	-0.055	-0.027	-0.163	0.116
	diff.	-0.039	*z*	0.1	*diff.*	-0.027	*z*	-1.36
Hopping	-0.354**	-0.281**	-0.497**	-0.13	-0.178	-0.103	-0.302*	0.032
	diff.	-0.073[b]	*z*	-2.01[c]	*diff.*	-0.074[b]	*z*	-1.67
Sliding	-0.125	-0.139	-0.281*	-0.075	-0.107	-0.116	-0.104	-0.097
	diff.	0.014	*z*	-1.04	*diff.*	0.009	*z*	-0.03

**. Correlation is significant at the 0.05 level (2-tailed)*

***. Correlation is significant at the 0.01 level (2-tailed)*

diff. Correlation coefficient difference between zero-order relationship and age-controlled first-order relationship

a. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.05 level (2-tailed)

b. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.01 level (2-tailed)

z. difference between two correlation coefficients of boys and girl using the Fisher r-to-z transformation

c. significance of the difference between two correlation coefficients of boys and girls at the 0.05 level (2-tailed)

d. significance of the difference between two correlation coefficients of boys and girls at the 0.01 level (2-tailed)

APPENDIX V: Correlation coefficients of the zero-order and age-controlled relationships between variables of locomotor skills and simple reaction time task (Continue)

	Dispersion motor reaction time				Dispersion premotor reaction time			
	Zero-order	Age	Boys	Girls	Zero-order	Age	Boys	Girls
Running	-0.324**	-0.322**	-0.475**	-0.109	-0.28**	-0.281**	-0.393**	-0.1
	diff.	-0.002	*z*	-1.97[c]	*diff.*	0.001	*z*	-1.53
Galloping	-0.141	-0.159	-0.074	-0.239	0.067	0.029	0.213	-0.168
	diff.	0.019	*z*	0.82	*diff.*	0.037	*z*	1.87
Horizontal	-0.141	-0.129	-0.216	0.018	-0.038	-0.007	-0.137	0.156
Jumping	*diff.*	-0.011	*z*	-1.15	*diff.*	-0.032	*z*	-1.43
Leaping	-0.059	-0.049	-0.083	0.034	0.011	0.039	-0.174	0.18
	diff.	-0.01	*z*	-0.57	*diff.*	-0.028	*z*	-1.74
Hopping	-0.218*	-0.196*	-0.292*	-0.096	-0.168	-0.099	-0.262	0.006
	diff.	-0.023	*z*	-0.99	*diff.*	-0.07[b]	*z*	-1.33
Sliding	-0.016	-0.017	-0.244	0.197	-0.004	-0.008	-0.003	0.013
	diff.	0.002	*z*	-2.18[c]	*diff.*	0.004	*z*	-0.08

**. Correlation is significant at the 0.05 level (2-tailed)*

***. Correlation is significant at the 0.01 level (2-tailed)*

diff. Correlation coefficient difference between zero-order relationship and age-controlled first-order relationship

a. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.05 level (2-tailed)

b. significance of the difference between zero-order correlation and age-controlled first-order correlation at the 0.01 level (2-tailed)

z. difference between two correlation coefficients of boys and girl using the Fisher r-to-z transformation

c. significance of the difference between two correlation coefficients of boys and girls at the 0.05 level (2-tailed)

d. significance of the difference between two correlation coefficients of boys and girls at the 0.01 level (2-tailed)

APPENDIX VI: Sample consent form for child's parent

參與研究同意書

研究項目：初小學生基礎活動技能自動化評鑑系統（暫名）

本人乃學生 ________________________（姓名）之家長，茲同意敝子女參加由香港教育大學健康及體育學系系主任周鴻奇講座教授負責監督，黃凱偉老師執行的研究項目：「初小學生基礎活動技能自動化評鑑系統」（暫名）研究計劃。是次研究的內容包括：

1. 研究本港初小學生不同基礎活動技能的發展；
2. 建立初小學生各項基礎活動技能的數據庫；
3. 發展基礎活動技能自動化評鑑系統。

本人清楚明白此研所獲得的資料，有機會被用於日後的學術研究及發表；然而本人有權保護敝子女的個人隱私，其個人資料將不能洩漏。

本人理解本人及敝子女皆有權就此計劃的任何部分提出疑問，並有權隨時決定退出研究。

本研究計劃的研究人員黃凱偉先生已清楚向本人解釋研究計劃的詳情。如有任何問題，可與本研究計劃的研究人員聯絡。

本人同意參與上述的研究項目，並讓敝子女參與 2017 年 7 月 24 日上午 9 時至 10 時（地點：新界婦孺福利會梁省德學校）的基礎活動技能的測試。

________________	____________________	____________
監護人姓名	監護人簽署	日期
黃凱偉先生	____________________	____________
研究員姓名	研究員簽署	日期

APPENDIX VI: Sample consent form for child's parent (Continue)

有關資料

研究項目：初小學生基礎活動技能自動化評鑑系統（暫名）

誠邀閣下及 貴子女參加由香港教育大學健康及體育學系系主任周鴻奇講座教授負責監督，黃凱偉老師執行的研究計劃。他們都是香港教育大學健康及體育學系的教職員及研究生。

甲：研究計劃簡介：

A）是次研究的目的是希望透過研究，了解本港初小學童不同基礎活動技能（如跑步、立定跳遠、原地拍球等）的發展；從而在收集數據的過程中，建立屬於本港初小學生各項基礎活動技能的數據庫；進而發展基礎活動技能自動化評鑑系統，促進本港初小基礎活動的學與教效能。

B）由於 貴子女正就讀本港小學一至三年級，並正在參與校內的常規體育課。在隨機取樣的機制下，邀請 貴子女參加是次的研究計劃。

乙：研究方法：

A） 研究工作及步驟

1. 參與研究的學生將在學校的體育老師的指導下，進行適量的暖身活動；
2. 學生在體育老師及研究人員的指導下，試做測試項目；
3. 學生將會為每一個項目進行不多於三次的測試（包括短跑、立定跳遠、踏跳步、拼步、單足跳及跨跳）。測試過程中，研究人員將以攝錄機及微軟 Kinect for Xbox One 鏡頭作紀錄；
4. 完成測試後，學生在體育老師的指導下進行活動後伸展活動。

B） 對參與研究者的補償

是次研究並不會為閣下及 貴子女提供任何利益，但所搜集的數據將對研究學童的基礎活動技能發展提供寶貴的資料。

APPENDIX VI: Sample consent form for child's parent (Continue)

丙：研究所帶來的可能風險：

A） 進行研究的過程中，具急救資格的體育老師會在場監督，並會鋪設一些體操用軟墊，以防學生跌傷或撞傷。

B） 如果學生在研究過程中拉傷肌肉，會即時終止研究，並會作出適當的急救處理和通知學生的監護人。

丁：研究結果的發表：

A） 研究的結果將會用作研究人員的畢業論文，並會在本地和國際學術會議及期刊中發表。大學亦會將研究結果的副本交給　貴子女所屬學校作保存。

如閣下想獲得更多有關這項研究的資料，請與黃凱偉老師聯絡，電話[redacted]。