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Movement skill and Emotion/Motivation：An Electroencephalographic Study on the Relationship between Performance of Movement Skills and Asymmetrical Frontal Brain Activity in Preschool Boys

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Abstract

Recently, asymmetrical frontal brain activity has been a critical topic in exploring the relationship between electroencephalography (EEG) and emotion or motivation. Research has proposed that left frontal brain activation is associated with positive emotions and approach behavior, whereas right frontal brain activation is associated with negative emotions and withdrawal behavior. In addition, physical education classes are proved to positively contribute to both cognitive and affective development of children. However, little evidence has been provided to support the relationship between EEG and children’s motor skills. The present study examined the differences among the different levels of movement skills on asymmetrical frontal activity in preschool boys. Twenty-eight boys aged between 53 and 74 months, with an average age of 64.50 months (SD = 6.90), were assigned to three groups (high, intermediate, and low) based on their movement skills assessed by the Movement Skills Assessment (Kovar, et al., 2003). All participants were recorded for their EEG activity, including six electrode sites (F3, F4, Cz, Pz, O1, O2) with linked earlobes as reference, with eyes closed for three minutes under a resting situation. After reprocessing the raw data, the frontal asymmetry ratios were calculated by (F4-F3) divided by (F4+F3), in terms of power values, in two frequency bands respectively (i. e., slow-α, 7.5-9Hz; fast-α, 9.5-12.5Hz). One-way ANOVAs indicated that there was a significant difference among three groups in fast-α power (F (2, 25) = 4.47, p = .022). Specifically, participants with a higher level of movement skills demonstrated more fast-α power in the right frontal lobe relative to the left than those with a lower level of movement skills (p = .025, η^2= .54). Since α power is conceived to be inversely related to brain activation, higher α power in the right frontal lobe represents higher approach behavior and positive emotions in boys with higher movement skills. The association between frontal asymmetry and mental health signifies the importance of the findings in this study.

Key Words:asymmetrical frontal brain activity, motivation, emotion

動作技能與情緒/動機：學前男童動作技能表現與腦前額不對稱性之關係研究

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摘　要

近年來腦前額不對稱性的研究指出左前額區活化與正向情緒及趨近行為有關；而右前額區活化則與負向情緒及退縮行為有關；亦即正/負向情緒與趨近/退縮動機在腦前額活化上有不對稱現象。兒童發展理論也提出身體的動作發展可刺激腦皮質區的發展；因此本研究以學齡前男童動作技能與腦前額皮質活動，來探討技能表現與前額不對稱性的關係。本研究以平均年齡為64.5個月 (SD = 6.90) 之男童28名為對象，依據Kovar等 (2003) 的動作技能評估方法 (Movement Skills Assessment)，將表現的得分以33.3%比例分為高、中、低三組；並收集其閉眼休息狀態之腦波，以slow-α (7.5-9Hz)、fast-α (9.5-12.5Hz) 二個頻率之右前額減左前額的比值，即(F4-F3)/(F4+F3)，探討表現水準高低與前額區不對稱性之關係；結果發現，不同動作技能表現水準在fast-α前額區不對稱比值有顯著差異 (F (2, 25) = 4.47, p = .022)。經事後比較結果顯示，動作技能表現高者比動作技能表現低者其右前額區的fast-α相對較高 (p = .025, η^2=.54)，依據α功率在一側較高時，另一側的腦活動較為活化的理論，顯示動作技能表現較優者其左前額腦波功率相對於其右前額較為活化，代表其動機趨近積極，情緒狀態也趨近正向。

關鍵詞：腦前額不對稱性活動、動機、情緒

Introduction

The nature of the perceptual process and its impact on movement and cognition has been topics of considerable interest to researchers and educators for years. The learning-through-movement aim of physical education is based on the realization that physical education program can make positive contributions to both cognitive and affective development of children. To date, there has been little scientific support for the hypothesis that certain movement activities will have a direct effect on the cognitive functioning of children. However, development of perceptual-motor abilities is a process with reference to both maturation and experience, in which the establishment and refinement of kinesthetic sensitivity to the real world may be achieved through movement. It is clear that the quality of movement performance depends on the accuracy of perceptions and the ability to interpret these perceptions into a series of coordinated movement.

With regard to the relationship between movement skills and brain maturation, Gallahue (1987) indicated that about 75 percent of brain growth was completed by age 3 and nearly 90 percent by age 6, and that neural myelination was mostly ripe by the end of the early childhood period (2-6 years). Therefore, increased complexity in children’s movement skills may occur following neural myelination. As the cortex matures and becomes progressively more organized, children are able to perform motor skills at higher level, both motorically and cognitively. The evidence of neural maturation with age was substantiated by Matousek and Petersen (1973). These authors conducted the initial research on age-related EEG changes, indicating that δ and θ (slow frequencies) activity were dominant until the age of four years and gradually decreased with age, while α and β (fast frequencies) activity increased throughout childhood. Matthis and his colleagues (1980) also found, with increasing age, slow frequencies brain waves appeared to be replaced by faster frequencies ones (Matthis, Scheffner, Benninger, Lipinski, & Stolzis, 1980). According to their findings, changes in EEG frequency can be used as an index of the neural maturation of a child’s brain. Moreover, several studies focusing on preschool children revealed that δ activity was negatively correlated with physical activity (Shih, 2004), and fast-α power was positively correlated with movement skill performance in boys, especially in mid-frontal regions (F3, F4), central region (Cz), parietal region (Pz), and occipital regions (O1, O2) (Lin, Chen, Ke, & Hung, 2005). Obviously, physical activity seems to associate with activation of children’ brain cortices.

Further, functional neuroimaging studies on human subjects revealed that motor skill learning was associated with activation of many brain areas in the frontoparietal cortices. For example, learning-related transition of activation from frontal to parietal areas was found that both the dorsolateral prefrontal cortex and the preSMA (pre-supplementary motor area) were activated during the early stages of learning, whereas more parietal areas were activated at the later stages (Sakai, et al., 1998). In addition, another two studies also reported dynamic changes in human cortical activation during motor learning (Petersen, Van Mier, Fiez, & Raichle, 1998; Toni, Krams, Turner, & Passingham, 1998).

Since the different brain areas dominated the different aspects of motor learning, with practice, the accuracy of performance was acquired earlier than the speed of performance. The motor skill, once established, was maintained for a long time, mainly in the form of speed (Hikosaka, Rand, Miyachi, &, Miyashita, 1995).

As the findings mentioned above, the relationship apparently exists between the patterns of brain development and motor skill learning. Besides, the asymmetry in frontal brain activity has been a critical topic while investigating emotion or motivation. It is widely accepted that relatively high left frontal brain activity is more psychologically and physically healthy than relatively less left frontal brain activity (Davidson, 1998; Fox, Henderson, Rubins, Calkins, & Schmidt, 2001). Research has suggested that approach-related positive emotions are associated with greater left frontal brain activity, and that withdrawal-related negative emotions are associated with greater right frontal brain activity (Davidson, 1995). In fact, several explanations have been proposed. One posits that frontal asymmetry is due to emotional valence (positivity/negativity); another posits that frontal asymmetry is associated with motivational direction (approach/withdrawal), and the other posits that frontal asymmetry is due to a combination of emotional valence and motivational direction (positive-approach/negative-withdrawal).

However, Harmon-Jones (2004) has doubted that increased left frontal activity is always beneficial. Although several studies have found left frontal activity to be associated with positive emotions, these findings resulted because the past research confounded approach motivation with positive emotional valence. Appetitive motivations are not always associated with positive affects. Anger, greed, lust, and mania are some examples of approach motivations that may have deleterious consequences. For instance, Harmon-Jones’ research revealed that anger and cognitive dissonance, emotions with negative valence and approach motivational tendencies, were related to relatively greater left frontal activity. Therefore, strongly supporting the fact that frontal asymmetry is due to the motivational direction model.

Besides, Gray’s theory of brain functions and behavior holds that two dimensions of personality (anxiety and impulsivity) represent individual differences in the sensitivity of two neurological systems: behavioral inhibition system (BIS) and behavioral approach/activation system (BAS) (Gray, 1982). Greater BIS sensitivity reflects greater proneness to anxiety and withdrawal behavior, whereas greater BAS sensitivity reflects a greater liability to engage goal-directed efforts and to experience positive feelings. BIS activity resulting in withdrawal behavior and the creation of negative affect would inhibit a person from exerting effort toward goals. Conversely, activity in BAS resulting in approach behavior and the creation of positive affect would motivate a person to increase ones endeavor toward goals (Gray, 1994). Some research has found that trait behavioral activation sensitivity relates to greater left than right frontal brain activity (Coan & Allen, 2003; Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997). However, these studies have produced inconsistent results, with one finding a significant relationship between BIS and greater right than left frontal activity (Sutton & Davidson) and the two others finding a non-significant relationship (Coan & Allen; Harmon-Jones & Allen). It is possible that BIS is not equivalent to withdrawal motivation (Harmon-Jones & Allen). Practically, BAS was measured by Carver and White’s BIS/BAS questionnaire in these studies. After all, self-report measures in the long run will prove to be inadequate to capture the core characteristics of affective style that are governed by brain neural affective circuits (Davidson, 1998).

In neuroscience, it has been proposed that motivation can be conceptualized as brain activity that processes “input” information about the internal state of the individual and external environment and determines behavioral “output”, and motivation can be restricted to the operations of appetitive “go” processes that ordinarily result in behavior which carries forward an action (Pribram, 2003). Davidson (1995) found that, by testing 356 children aged 31 months in a peer play session, behaviorally inhibited children showed right frontal activation, while behaviorally uninhibited children showed the opposite pattern. Evidence from brain imaging similarly revealed that an increase in motivation activated the left prefrontal regions, left thalamus, and left midbrain (Thut et al., 1997). Various lines of evidence suggest that the medial prefrontal cortex might be involved in the interpretation of emotional and motivational factors and the use of these to guide behavior (Elliott, Dolan, & Frith, 2000).

Additionally, past studies have suggested that resting anterior EEG asymmetry in α (8-13Hz) frequency band (serving as an indicator of cortical deactivation) may be a biological marker of emotional predispositions or traits. In serving as a proxy for trait-like asymmetries of cortical activity, a number of recent studies have examined the temporal stability of resting anterior α asymmetry (Tomarken, Davidson, Wheeler, & Kinney, 1992), indicating that the resting anterior α asymmetry shows excellent internal consistency and adequate test-retest stability (Reid, Duke, & Allen, 1998).

Summing up, children’s movement skills might get involved in motivation and brain development, and motivational factors might guide children’s behavior, but self-report questionnaire measures might be inadequate to capture the core characteristics of brain neural affective circuits. Accordingly, the current study attempted to test the movement skills practically, and examine the relationship between resting EEG frontal asymmetry and movement skills in preschool boys. Our hypothesis was that, boys with higher level of movement skills would show relatively greater left frontal activity compared to the right, than those with a lower level of movement skills.

Methods

Participants

Twenty-eight right-handed boys were recruited in this study, with an average age of 64.50 months (SD = 6.90). All of the subjects were prescreened via both a survey and an interview with parents in order to ascertain their health history without neuropsychiatric and physical diseases, a history of convulsions, loss of consciousness, and past severe head trauma. Then, the parents of identified subjects signed an informed consent form to agree on the subject’s participation in this study.

Instrument

Participants’ movement skills were assessed by the Movement Skills Assessment (Chou, 2004; revised from Kovar, Combs, Campbell, Napper-Owen, & Worrell, 2003), including walking, running, hopping, skipping, galloping, jumping, rolling, throwing, catching, kicking, and striking abilities (11 items). The Cronbach’s α coefficient of internal consistency was .87 with the samples in this study.

Procedure

According to the movement performance, participants were classified into three groups with different levels of movement skills (i.e., high, intermediate, and low). All participants were recorded for their EEG activity, including six electrode sites (i.e., F3, F4, Cz, Pz, O1, O2) with linked earlobes as reference, with eyes closed for three minutes under a resting situation. EEG was collected from the NeuroScan Synamps system with Ag/AgCl electrodes applied referring to the International 10/20-system. The amplifier gain was set up at 10,000, and the bandwidth was between 0.5 and 30 Hz. The fast Fourier transformation was implemented to reprocess the cleaned EEG epochs of two seconds so as to provide estimates for absolute power in two frequency bands (i.e., slow-α: 7.5-9Hz; fast-α: 9.5-12.5Hz).

Data Analysis

The frontal asymmetry ratios were calculated from (F4-F3) / (F4+F3) respectively in two frequency bands (Tomarken et al., 1992). Two one-way ANOVAs were employed to analyze the differences between the movement performance levels (high, intermediate, and low) in the frontal asymmetry ratios of fast-α and slow-α power.

Results

The descriptive statistics for F3 and F4 EEG powers in slow-α and fast-α bands among three levels of movement skills were presented in Table 1. Additionally, as shown in Table 2, the frontal asymmetry ratios in slow-α and fast-α bands among high, intermediate and low groups were calculated further. The results of one-way ANOVAs indicated that there was significant difference in fast-α band among these three different movement skills groups ($F(2, 25) = 4.47$, $p = .022$), but no difference in slow-α band ($F(2, 25) = 3.37$, $p = .05$). The Scheffe’s post-hoc tests revealed that the frontal asymmetry ratios of the high movement skills group in fast-α band was higher than that of the low group ($p = .025$, effect size $\eta^2 = .54$) (see Table 3). With respect to this finding, previous research also found that α power was inversely related to regional brain activity while using hemodynamic measures (Cook, O’Hara, Uijtdehaage, Mandelkern, & Leuchter, 1998) or behavioral tasks (Davidson, Chapman, Chapman, & Henriques, 1990).

Therefore, the individuals with high movement skills showed a greater left frontal activity relative to the right than those with low movement skills, which can be seen in Figure 1.

Table 1 Descriptive Statistics for F3, F4 EEG Power in the Different Movement Skills Groups

Group/Band	N	Slow-α F3	Slow-α F4	Fast-α F3	Fast-α F4
High	10	2.79 (0.49)	2.90 (0.50)	1.72 (0.43)	1.82 (0.34)
Intermediate	9	3.13 (0.30)	3.11 (0.41)	2.74 (0.56)	2.73 (0.66)
Low	9	2.90 (0.41)	2.82 (0.47)	2.03 (0.57)	1.94 (0.62)

Note: LN transformed

Table 2 Descriptive Statistics for (F4-F3)/(F4+F3) Ratios in the Different Movement Skills Groups

Group/Band	N	Slow-α	Fast-α
High	10	0.11 (0.17)	0.10 (0.17)
Intermediate	9	-0.02 (0.18)	-0.01 (0.18)
Low	9	-0.08 (0.15)	-0.09 (0.17)

Table 3 ANOVA Summary for the Comparisons of (F4-F3)/(F4+F3) Ratios Among the Different Movement Skills Groups

Band	Source	Sum of Squares	df	Mean Square	F	Sig.	Post -hoc Test
Slow-α	Between Groups	0.006	2	0.003	3.37	.050	
	Within Groups	0.022	25	0.001			
Fast-α	Between Groups	0.018	2	0.009	4.47*	.022	High group> Low group
	Within Groups	0.051	25	0.002			

Note: * p < .05

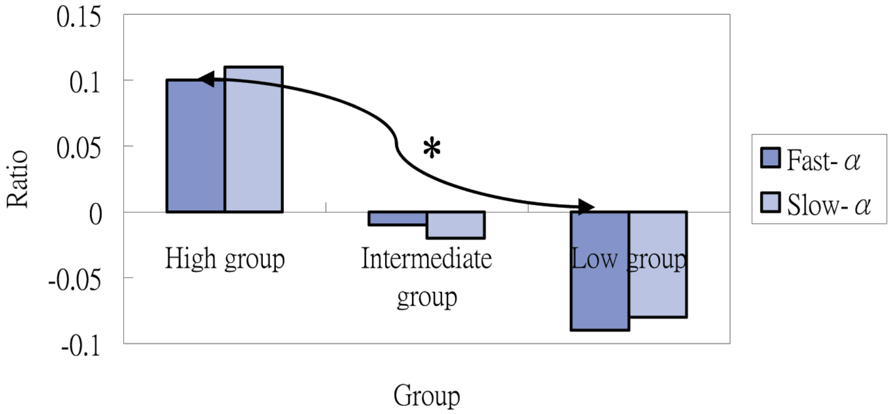

Figure 1- Comparisons of (F4-F3)/(F4+F3) ratios in slow- α and fast- α band among different movement skills groups (Note: * p < .05)

Discussion

The aim of this study was to explore the relationship between the resting EEG frontal asymmetry and movement skills in preschool boys. The results showed that a high level of movement skills had a greater left frontal activity compared to the right than those with a low level of movement skills. Several explanations might relate to the findings of this study.

First, neurologically, the growth of brain is complete nearly 90 percent by the age of six years. Myelination may probably enhance the development of the complexity for movement skills in children. As the cortex matures and becomes progressively more organized, children are able to perform more complicated motor skills motorically and cognitively (Gallahue, 1987). From the moment of birth, children start learning how to interact with their environment, which is involved in perceptual and motor processes. Thus, the development of children’s perceptual ability is dependent, in part, on motor activity. Perceptual abilities are learned abilities and, as such, use movement as an important medium for this learning to occur. Further, the reciprocal relationship between sensory input and motor output enables both perceptual and motor abilities to develop in harmony.

Second, as a child growing, child’s self-concept is following formed. A positive self-concept includes belonging, competence, worthwhileness, acceptance of self and limits, and uniqueness. Children need to see themselves as competent. Previous study has indicated that quality instruction in their attainment of movement skills and physical abilities contributes greatly to a sense of competence in children. Competence leads to confidence which in turn promotes an improved self-concept (Bressan & Weiss, 1982). Indeed, development of movement is not the only one influence on self-concept, but it is an important one. If movement skills are poorly developed, chances are that this will have a negative effect on self-concept development. If children begin to feel they are not able to do things, they become less willing to participate. On the other hand, Gallahue (1987) emphasized that movement experience played a very important role in motor skills acquisition. To develop and refine the movement ability in children, more practice, encouragement, and positive instruction are needed in the process of learning. Conversely, negative self-consciousness, embarrassment, and fear may hamper their development on movement skills. In fact, fear of being injured, or fear of peer ridicule are more likely to cause anxious emotion that makes learning in movement skills more difficult. It is obvious that children who have withdrawal behavior, negative self-concept or emotion (e.g., fear) would hardly develop proficient motor skills.

Third, in light of competence motivation theory, children who are successful in achieving movement skills will be intrinsically motivated in the motor domain. By contrast, intrinsic motivation of those who repeatedly fail in motor skills performance is likely to be diminished. Rose, Larkin and Berger (1998) examined the motivational orientations of children who differed in motor ability, and found that participants with poor coordinated movement were less motivated by challenge than those with well-coordinated movement. Consistent with this study, Skinner and Piek (2001) identified the influences of perceived competence and social support on self-worth and anxiety in children with developmental coordination disorder (DCD) underlying Harter’s theory of competence motivation. For the group of children with movement coordination problems, it appeared lower competence in several domains and less social support, compared to the control group with normal movement coordination. Briefly, children with DCD or poor coordination tended to show lower competence, self-worth, and motivation under the challenging circumstances. Thus, overall, these findings provided support for the relationship between poor movement skills and withdrawal behavior in children.

Fourth, previous research has indicated that preschoolers exhibit noticeable inter-individual differences in frontal brain activation. Children, aged four years, who demonstrated inhibited behavior and social withdrawal during a play session showed greater relative right frontal activation, whereas children with a high degree of social initiative and positive affect displayed greater relative left frontal activation (Fox et al., 1995). Similar to the findings mentioned above, Schmidt and his colleagues pointed out that adults with lower sociability or higher shyness evidenced relatively greater right frontal activation; namely, shyness was positively associated with relatively greater right frontal activation, while sociability was positively related to relatively greater left frontal activation. Therefore, it was determined that sociability and shyness were related to EEG asymmetry. Moreover, compared with shy individual who were less sociable, those shy individual who were more sociable possessed greater left frontal activation (Schmidt, 1999; Schmidt & Fox, 1994). For shy children, evidence revealed that those with greater relative right frontal activation were more likely to exhibit internalizing problem than those who had greater relative left frontal activation (Fox, Schmidt, Calkins, Rubin, & Coplan, 1996).

Practically, no direct evidence was found to identify the relationship between the resting EEG frontal asymmetry and movement skills in preschool boys. However, from the hypotheses this study induced herein before, indirect evidences could be derived to support the relationship between EEG asymmetry and movement skills. While learning movement skills, proficiency in skills, enhancement in self-concept, improvement in competence and motivation, and better sociability are probably beneficial to positive emotions and approach motivation.

This study concludes that the development of movement skills indicates a positive association with left frontal activation which represents positive emotions and approach motivation. It supports both theories of Harmon-Jones’ motivational direction model and Gray’s brain functions and behavior theory. Thus, physical activity may be warranted to conduce to mental health; herein, parents may encourage their children doing more exercise. With regard to the findings of this study, further research is needed to confirm the relationship between EEG asymmetry and movement skills in preschool children.

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