人文及管理學報　第三期
2006年11月　頁089~102
宜蘭大學人文及管理學院

# Does Sex Differences Moderate the Relationship between Basic Motor Ability and Preschooler's Brain Development? —An EEG Study

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## Abstract

Many past studies have found age-related maturation EEG changes in the early stages of childhood. Matousek and Petersen (1973) conducted the first major research of age-related EEG changes. The results indicated that δ and θ activity were dominant until the age of four years and gradually decreased with age, while α and β activity increased throughout childhood. Matthis, Scheffner, Benninger, Lipinski, and Stolzis (1980) also found, with increasing age, slow wave activity appeared to be replaced by faster frequencies. According to their findings and suggestions, changes in EEG frequency can be used as an index of the neural maturation of a child's brain. Among factors that might exert influence on the brain's aging, physical activity has been found to have an effect on brains several cognitive and emotional functions of adults. In studying the effects of physical activity on preschool children's cognitive and emotional development, Shih (2004) found that δ activity was significantly negatively correlated with physical activity (r=-.693) in preschool children. However, past studies related to the brain's EEG development of the different sexes were inconsistent. With an attempt to clarify the relationships among physical activity, sex differences and children's brain EEG development, the current study intended to examine whether sex differences moderated the relationship between basic motor ability and EEG frequency in preschoolers. Sixteen boys and fifteen girls, between the aged of sixty and sixty-six months, participated in this study. Each of them was assessed by the Basic Motor Ability Tests-Revised (Armheim & Sinclair, 1978) to determine their basic motor ability. The EEG was recorded during an eyes-closed resting condition at six electrode sites (i.e., F3, F4, Cz, Pz, O1, O2). The cleaned EEG was fast Fourier transformed to provide estimates for absolute power in the six frequency bands (i.e., δ, 0.5-3.5Hz; θ, 4-7Hz; α-1, 7.5-9Hz; α-2, 9.5-12.5Hz; β-1, 13-19Hz; β-2, 20-30Hz). A sex differences × motor ability Multivariate Test was employed on each of the six electrodes for the six frequency bands. The results revealed that there was no significant interactive effect between sex differences and basic motor ability at six electrode sites in the six frequency bands. Also, there were no significant main effects in sex differences and basic motor ability.

**Key Words：sex differences, preschoolers, basic motor ability, EEG.**

# 學前兒童基本運動能力與性別差異在腦波功率之比較研究

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## 摘　要

根據研究，δ功率遞減與α功率遞增是學前兒童腦波發展的重要指標。Clarke等人研究兒童腦波發展與性別之關係，發現男童比女童有較高的α功率，較低的θ、δ 功率，顯示女童比男童在腦波的發展上較爲遲緩；但其他研究則未有定論。Gallahue 指出神經軸突的髓鞘化大多完成於前兒童期，而髓鞘化與兒童動作技能發展有絕大的關係；在大腦皮質逐漸成熟與組織化後，兒童的動作與認知才能達到更高的水平。石恒星也證實：學前兒童腦波δ功率與身體活動能力高低呈現負相關，α-2功率與身體活動能力高低呈現正相關趨勢。本研究以腦波發展探討學前兒童基本運動能力與性別的關係，以Armheim 與 Sinclair 的Basic Motor Ability Tests-Revised (BMAT-R) 爲工具，該測驗以1536位年齡4-12歲兒童爲樣本，項目11項，其內部一致性＝.93。本研究檢測學前男女童共31名（男16，女15），年齡爲60-66個月；依其運動能力分成高、中、低三組；並以多頻道腦波儀收集腦波，電極位置採用國際10-20系統之標準配置，腦波資料以兒童放鬆後，腦波呈現穩定狀態爲擷取時段，分四次收

錄，每次收錄45秒，中間休息1分鐘。資料經快速傅立葉（FFT）轉換後求得各頻率功率值，分析δ、θ、α-1、α-2、β-1、β-2 等六個頻率段(0.5-3.5 Hz 、4-7 Hz 、7.5-9Hz、9.5-12.5Hz、13-19Hz、20-30Hz)的絕對功率，並使用LN轉換使功率值接近常態分配。本研究自變項為性別(男、女)與基本運動能力(高、中、低水準)；依變項為腦波活動功率(電極位置：F3、F4、Cz、Pz、O1、O2)。探討學前兒童六個區域六個頻率的功率在基本運動能力高低與性別的交互情形；使用二因子多變量分析進行檢定。本研究顯著水準設定為.05。所得結果顯示：學前兒童之性別與基本運動能力在腦波上並無交互作用。

關鍵詞：性別差異、學前兒童、基本運動能力、腦波

## Introduction

The myelination of children's brain neurons is largely complete by the end of the early childhood period (2-6 years old). It was suggested that increased complexity in children's motor skills had relation to the degree of neural myelination. As the cortex matures, children are able to perform at higher levels, both motorically and cognitively (Gallahue, 1987). EEG broad band frequency analysis has shown a stable correlation with age, with its changes corresponding to central nervous system (CNS) maturation. Studies have found that neuroanatomical development in the first year of life is reflected in the rhythmic EEG activity. The three to four month old infant's EEG is of low voltage (less than 50 $\mu$V) and not well organized. At around three months of age, some dramatic changes take place in which an occipital rhythm of 3-4 Hz of more than 50 $\mu$V amplitude appears. Since this is during the time that grasp reflexes disappear, these EEG changes have been interpreted as CNS development. By the end of the first year, the occipital EEG rhythm is in the 6-7 Hz range. The dendrites and myelinization development changes of brain neurons that appear first in the sensory and then in the motor areas are found to be parallel with EEG development. It was also found that EEG development during the next twelve years of childhood was less rapid. By twelve, the modal occipital EEG frequency is between 10 and 11 Hz, mirroring that of an adult (Marsh & Thompson, 1977). It is generally accepted that EEG developmental velocity is greater in childhood than in adulthood. As a child becomes older, activity in the lower frequency bands decreases and faster frequency bands increases (Katada & Koike, 1990; Matthis, Scheffner, Benninger, Lipinski, & Stolzis, 1980). In the absolute power measures, only the $\delta$ band showed a significant main effect of age. Absolute $\delta$ activity decreased with age (Clarke, Barry, McCarthy, & Selikowitz, 2001).

Studies of mentally retarded children (Gasser, Mocks & Bacher, 1983), learning disabled children (Lubar, et al., 1985), and children with attention-deficit /hyperactivity disorder (Clarke, Barry, McCarthy, & Selikowitz, 1998) have reported elevated levels of slow wave activity in the EEG compared with peer normal children. Katada, Ozarki, Suzuk, and Suchara (1981) found that the occipital region was the earliest growth area of a child's brain, followed by the central and frontal regions.

Thatcher, Walker, and Gludice (1987) used coherence and phase relation's measurements from 577 subjects ranging from two months to twenty-six years of age to map underlying hemispheric changes. They concluded that the left hemisphere develops at a faster rate than the right in terms of the EEG phase relationship between frontal and occipital areas. Researchers suggested five dominant growth periods in terms of intrahemispheric cortical coupling across the life span. The first, from birth to three years of age, can be described as a decrease in coherence and phase. The second, from age four to six years, involved more synchronized patterns, mainly in terms of left hemispheric coupling. The third period, from age eight to ten, involved right hemispheric connections between the temporal and frontal areas. The final two periods, from age eleven to fourteen and fifteen to adulthood, mainly involved bilateral connections within the frontal areas. Thatcher et al. point out that these periods are consistent with the Piagetian stages of cognitive development.

Many researchers have studied the relationship between exercise and brain function. Meta-analytical reviews have revealed that a moderate relationship exists between exercise and cognitive functioning in older adults (Thomas, Landers, Salazar, & Etnier, 1994). Data indicated exercise especially has a delaying effect on the brain's functional aging on the tasks that involve executive control, processes such as planning, scheduling, coordination, inhibition, and working memory (Churchill, et al., 2002). As to the relation between physical activity and children's brain development, Shih, et al. (2004) found that $\delta$ activity was significantly negatively correlated with motor ability in preschool children.

Reports of the sex differencess in normal maturation of the EEG have been mixed. Petersen and Eeg-Olofsson (1971) and Motousek and Petersen (1973) found EEG differences between boys and girls that are suggestive of earlier maturation in girls. However, Cohn, Kircher, Emmerson, and Dustman, (1985) and Gasser, Verleger, Bacher, and Sroka (1988a) failed to find EEG differences between males and females. In contrast to this, Mattis et al. (1980) found that at the age of six, girls have more relative $\theta$ and less relative $\alpha$. By the age of eleven, girls have surpassed boys for relative slow $\alpha$ in occipital areas, but still have deficiencies of $\alpha$ in frontal regions. These general findings have been supported by a number of studies (Benninger, Mattis, Scheffner, 1984; Diaz de Leon, Harmony, Marosi, Becker, 1998). The majority of these studies have thus found that girls have a maturational lag in the EEG compared with boys. This lag appears to disappear about the time of adolescence, with changes occurring faster in girls. It was usually suggested that there was a maturational lag in girls in EEG development (Harmony, Marosi, Leon, Becker, & Fernandez, 1990).

With an attempt to clarify the relationships among physical activity, sex differences and children's brain EEG development, and based on the above discussion, we have the following propositions. First, the better motor ability a child has, the better brain EEG developed a child will be, which would be shown in the decrease of EEG slow-frequency activity. Second, girls would have a maturation lag in EEG compared with boys. Thus, the aim of this study was to investigate maturational changes and the effect of different sexes and motor ability in the EEG of preschoolers.

# Method

## Participants

Thirty-one children were included in this study, with 16 boys and 15 girls between the ages of 60 and 66 month. Using results of a questionnaire and an interview by children's parents regarding each participant's present status and past history, we excluded those who had neuropsychiatry and physical diseases and those who had a past history of convulsions, loss of consciousness, or severe head trauma.

## Measures

Participants were assessed by the Basic Motor Ability Test-Revised (BMAT-R) (Armheim & Sinclair, 1979) to evaluate their basic motor ability. With eyes-closed, three minutes resting EEG of each participant was recorded at six electrode sites (i.e., F3, F4, Cz, Pz, O1, O2) with linked earlobes as reference. The amplifier gain was set up at 10,000; the bandwidth between 0.5 and 30 Hz. Cleaned EEG epochs of two seconds each were fast Fourier transformed to provide estimates for absolute power in the six frequency bands (i.e., $\delta$, 0.5-3.5Hz; $\theta$, 4-7Hz; low-$\alpha$, 7.5-9Hz; high-$\alpha$, 9.5-12.5Hz; low-$\beta$ 13-19Hz; high-$\beta$, 20-30Hz).

# Results

A two-factor (sex differences × motor ability) Multivariate Test was performed examining the effects of motor ability, sex differences and sites for each band in absolute power.

As table1 shows, the results reveal there was no significant interactive effect between sex differences and motor ability at six electrode sites in six frequency bands ($p > .05$). Also, no significant main effect in sex differences and motor ability (p> .05) were found.

Table1. Summary of Multivariate Tests ( Wilks' Λ) to sex differences and basic motor ability at six electrode sites in six frequency bands.

| Band | Effect | Wilks' Λ value | F value | Sig. |
|---|---|---|---|---|
| | Sex differences | .786 | 0.997 | .452 |
| $\delta$ | Motor ability | .614 | 2.303 | .071 |
| | Sex differences × Motor ability | .861 | 0.591 | .734 |
| | Sex differences | .603 | 2.417 | .060 |
| $\theta$ | Motor ability | .768 | 1.108 | .389 |
| | Sex differences × Motor ability | .768 | 1.107 | .390 |
| | Sex differences | .597 | 2.475 | .055 |
| $\alpha$-1 | Motor ability | .707 | 1.518 | .219 |
| | Sex differences × Motor ability | .763 | 1.137 | .374 |
| | Sex differences | .723 | 1.404 | .257 |
| $\alpha$-2 | Motor ability | .751 | 1.217 | .335 |
| | Sex differences × Motor ability | .774 | 1.070 | .410 |
| | Sex differences | .655 | 1.932 | .120 |
| $\beta$-1 | Motor ability | .870 | 0.548 | .766 |
| | Sex differences × Motor ability | .836 | 0.719 | .639 |
| | Sex differences | .698 | 1.583 | .199 |
| $\beta$-2 | Motor ability | .907 | 0.376 | .886 |
| | Sex differences × Motor ability | .859 | 0.603 | .725 |

*p<.05

## Discussion

The results were not in agreement with our predictions. There were no significant interaction among sex differences, motor ability, and EEG power. Additionally, no main effect in the different sexes and motor ability were found. We speculated that the main reason for this conflicting result came from the non-significant difference in motor ability between the boys and the girls in our study. We employed a t-test to examine the difference between the two groups (boys: mean = 50.90, SD = 12.79; girls: mean = 49.65, SD =9.92, t = .306, $p > .05$), the results showed no significant difference. Shih, et al. (2004) found that $\delta$ activity was significantly negatively correlated with motor ability in preschool children. Since no significant motor ability difference was found between boys and girls in this study, we inferred that this might have resulted in the conflicting results. In order to solve this problem, we suggested future related studies to choose participant children who are significantly different in motor ability.

Past studies had proved that the early care-giving environment had an influence on the subsequent development of the children. Harmony, et al. (1990) studied the effect of sex differences and psychosocial disadvantages on EEG maturation. They found that children from a low socioeconomic status (SES, very low income and/or illiterate mother) had higher values of absolute power and a higher percentage of $\delta$ activity and a lower percentage of $\alpha$ activity than children from a higher SES. This indicated that low SES children's maturation lagged behind high SES children.

Van Praag, Kempermann, and Gage (1999) placed mice in groups facing a learning stimulus, voluntary running wheel exercise, an enriched environment, and standard housing conditions separately. They found that the mice in both groups of voluntary exercise in a running wheel and enriched environment increased the survival of newborn cells in the dentate gyrus and net neurogenesis. From the findings of Harmony, et al. (1990) and Van Praag, we believe that physical activity and environmental enrichment together facilitate human brain development, and the human brain would change structurally in response to environmental demands.

We took the environmental factors of children's brain neuron growth into account, all children in our study went through similar intellectual development courses. In Taiwan, almost all children receive kindergarten education and attend cram school. According to a survey on children's pain index administered by Zheng (2002), 76.2% of children attended both cram schools and talent classes. In this situation, boys and girls receive similar amounts of stimulation during their childhood. We thought the similar growing environment among our participants might be another reason for the contradictory results of this study. We suggested that the influence of environmental growth experience on children's brain development should be taken into consideration in future related studies.

With regards to the sex differences between brains EEG of boys and girls, this study was not inconsistent with past studies. Previous studies concerning sex differences in EEG maturation were conflicting. Matousek and Petersen (1973) found girls, over sixteen years of age, showed significantly lower power in the $\theta$ frequencies but higher in the $\beta$ frequencies than boys. Petersen and Eeg-Olofsson (1971) found higher $\alpha$ frequencies in girls compared with boys up to eleven years of age. Matthis et al. (1980) suggested that the EEG maturation in girls up to eleven years of age seemed to be retarded compared with boys. Gasser, et al. (1988a) implied that there is little chance of finding sex differences in EEG developments from about six to seventeen years of age. In our study, participants were preschoolers of only five years of age, the similarities in EEG growth between boys and girls support the suggestion of Gasser et al. In addition, the number of participants in this study was rather small, which might have an influence on the statistical power; we recommend a larger number of participants would be needed in future studies.

The results revealed that there was no significant interactive effect between sex differences and basic motor ability at six electrode sites in six frequency bands. Also, there were no significant main effects in sex differences and basic motor ability. The implication of these results indicated that whether different sexes moderate the relationship between basic motor ability and preschool children's brain EEG development needed further investigation.

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