

Is the development of motor-reduced visual perceptual skill always prior to that of visual-motor integration skill?

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Abstract – In the assessment of general visual-perceptual abilities, there are two schools of thought. The first maintains that perceptual and motor abilities are interdependent and perceptual abilities are reflected in motor responses (Leonard, Foxcroft & Kroukamp, 1988). Another body of research argues that visual perception and motor development are autonomous systems in visual-perceptual abilities. (Bortner & Birch, 1960; Bortner & Birch, 1962; Rosenblith, 1965; Colarusso & Hammill, 1995). The study reported here investigated the possible relationship between motor-reduced visual perceptual abilities and visual-motor integration abilities in Chinese learning children and English learning children by employing the Developmental Test of Visual Perception, 2nd Edition (Hammill, Pearson & Voress, 1993), in which both abilities could be measured in a single test. A total of 41 mainstream native Chinese learning and 35 mainstream native English learning Australian children of age 5 participated in this study. The findings indicated that the Chinese learning children scored much higher marks in the visual-motor integration skills than the motor-reduced visual perceptual skills while English learning children performed comparably in both skills. The results of the Chinese learning children disproved a well established knowledge of the prior development of motor-reduced visual perceptual skills to that of visual-motor integration skills. The paper suggests that these findings can to some extend be accounted for by the psychogeometric theory of Chinese character-writing.

Introduction

In the assessment of general visual-perceptual abilities, there are two schools of thought. The first maintains that perceptual and motor abilities are interdependent and perceptual abilities are reflected in motor responses (Leonard, Foxcroft & Kroukamp, 1988). Scholars such as Bender (1938), Berko (1954), Ball (1962) and Kephart (1971) are strong advocates of this position. Another party of research supports the autonomous systems of visual perception and motor development (Bortner & Birch, 1960; Bortner & Birch, 1962; Rosenblith, 1965; Colarusso & Hammill, 1995). These researchers propose that visual perception and motor coordination are separate systems in visual-perceptual abilities.

Bender (1958) states that motor behaviour of a small child is adjusted to reflect the stimulus perceived in the optic field and therefore there is a constant interplay or integration between the motor and sensory features which cannot be separated. In Ball's (1962), studies the findings, did not prove the existence of a functional relationship between visual-perceptual and visual-motor development, and the fact that they paralleled each other developmentally was consistent with the claim that such a relationship existed. Kephart (1971) held a similar point of view and asserts that perceptual activities and motor activities should not be considered as two different items because a person cannot separate what part of his/her activities in any task, such as copying a figure, is motor and what part is perceptual. He claimed that perceptual data and motor data become related through the perceptual-motor match in the way that perceptual information is matched to motor information so that both come to have the same meaning. Therefore, one can be translated into the other, such that the eye can explore and the hand can duplicate; the hand can explore and the eye can visualize.

Alternatively, those who support the idea of autonomous systems of visual perception and motor development argue that young children always make perceptual discriminations well before they can match the perceived distinctions in their own copying behaviour (Maccoby & Bee, 1965). It has long been clear that there is a lag in reproducing discriminable visual form among most of children such that what is reproduced does not

reflect what is seen. Consequently, Bortner & Birch (1960) dispute an assumption that failure in block design reproduction reflects a perceptual inadequacy. They argue there are multi-demands required for the organization of sequential action patterns in a block design reproduction task and postulate that failure may stem not only from perceptual inadequacies but also from a disorganization of cerebral functioning that operates to make ineffective the determination of a voluntary action pattern even when appropriately organized perception exists. Bortner & Birch (1962) also stated that inadequacies in the performance of perceptual-motor reconstruction cannot in itself demonstrate the absence of perception. Perceptual recognition, perceptual analytic and perceptual synthetic capacities may still be present even when perceptual-motor reconstructive integration is seriously disturbed. The studies of Bortner & Birch (1960, 62) showed that brain-injured patients, despite the inability to reproduce designs, discriminated accurately and without equivocation. Thus, the ability to discriminate block designs may be in tact even though the ability to reproduce these same designs is impaired. Bortner & Birch concluded that it is not appropriate to equate the inability to reproduce these designs with the inability to perceive them accurately at a recognition level. They proposed that the discrepancy between the ability to discriminate perceptually and the ability to reproduce that which is perceived may be a reflection of different stages of ontogenetic development. Some scholars (Bortner & Birch, 1960; Piaget & Inhelder, 1956) even suggested the prior development of visual-perceptual form to that of visual-motor form.

The relationship of the independence between visual-perceptual and visual-motor abilities is made complicated on the one hand and on the other hand, clarified by the study of Leonard, Foxcroft & Kroukamp (1988). Their findings showed a small but significant association for the motor-free test scores with the visual-motor integration scores and the Copying Test scores indicated that the motor-free test assessed a component of behaviour tapped by each of the other tests. Furthermore, the lack of correlation between the motor-free test and the general motor abilities supported the idea that visual perception and general motor skills were relatively separate abilities for children. They claimed that their results gave little support to the notion that errors in visual-motor reproduction tasks were largely attributable to impaired visual perception. However, the question of whether perceptual discrimination test is necessarily associated with, and reflected in, a copying test is not resolved. Consequently, Leonard, Foxcroft & Kroukamp (1988) insisted that to infer perceptual deficits from an inaccurate copy of a model may be inappropriate and required careful consideration of the perceptual and motor loadings when selecting a test for a specific purpose. Many writers caution examiners to be careful when using tests of visual-motor integration to evaluate visual perceptual status (Hammill, Pearson & Voress, 1993) and suggest the value of measuring visual perception independently of all motor involvement.

Nevertheless, the discussions of the two schools of thought are based on evidence from western cultures and languages which are phonemic in nature. However, will a similar result be obtained with Chinese research participants, who learn Chinese which is logographic in nature? In order to have thorough understanding and develop a more complete picture of this issue, both western and Chinese learners should be included in a single study. The purpose of the study reported here was to investigate the possible relationship between motor-reduced visual perceptual abilities and visual-motor integration abilities to Chinese learning children and English learning children by employing the Developmental Test of Visual Perception, 2nd Edition (Hammill, Pearson & Voress, 1993), in which both the motor-reduced visual perceptual abilities and visual-motor integration abilities could be measured in a single test. The study attempted to interrogate the two schools of thought and to explore whether there was another explanation which had yet to be achieved.

Justification for using DTVP-2

Since the early 20th century, clinicians and researchers have developed many assessment devices for measuring children's visual perceptual abilities. Some tests were

widely used to study the nature of perception or to diagnose disturbances in individuals. These tests include: Visual Gestalt Test (Bender, 1938), Frostig's Developmental Test of Visual Perception (Frostig et al, 1961), the Chicago Test of Visual Discrimination (Weiner, Wepman, & Morency, 1965), the Developmental Test of Visual-Motor Integration (Berry, 1982), the Motor-Free Perception test (Colarusso & Hammill, 1972), The Bender Gestalt Test for Young Children (Kopitz, 1975), the Test of Visual-Perceptual Skills (Gardner, 1982), and the Test of Visual-Motor Skills (Gardner, 1986). However, most of the tests were criticized for, firstly, measuring either the motor-free visual perceptual abilities or visual-motor integration abilities but not both; and secondly, the inadequacy of their normative data, low reliability coefficients and unacceptable validity (Hammill, Brown & Bryant, 1992).

Researchers and psychologists (Hammill et al., 1993) state that a comprehensive evaluation of a child's visual perception should include assessment tasks that are exclusively visual perceptual (requiring little or no motor abilities) and tasks that involve visual-motor integration. It appears that DTVP-2 was the only test available with assessment tasks that could measure both abilities in a single test. Hammill et al. (1993) further claimed that the availability of quotients for both motor-reduced visual perceptual skills and visual-motor skills allowed a comparison to be made between the two abilities, which contribute greatly to understanding of any weakness a child might have.

Another reason for selecting the DTVP-2 is its improved normative data, reliability and validity as claimed by Hammill et al. (1993, p.vii): "Reliability for the subtests was increased to acceptable levels. Ample evidence of content, criterion-related, and construct validity was provided. Factorial validity analysis was undertaken to strengthen the test's validity. Studies showing an absence of racial, gender and handedness bias were performed. Normative data are now based on a large, stratified sample whose characteristics are demographically similar to those of the 1990 census school-aged population. Two new composite scores (motor-reduced visual perception and visual-motor integration) were developed to facilitate diagnosis. The ages at which the test can be administered were extended to include 10-year-olds.

Thus, it is believed that the DTVP-2 measures the quality that it is purported to measure and its test results indicate appropriately a child's visual perceptual abilities regarding both the motor-reduced visual perceptual and visual-motor integration skills.

Method

Sample

A total of 41 mainstream Chinese learning children (22 males, 19 females) who were born and resided in Hong Kong, and 35 mainstream English learning Australian children (19 males, 16 females) who were born in Australia and resided in Melbourne, all age 5 were invited to participate in this study. One-third of the Chinese participants belonged to middle to high socio-economic class and two-third of them belonged to middle to low socio-economic class while the majority of the Australian participants belonged to middle to high socio-economic class. All the participants were attending kindergarten regularly.

Test

The Developmental Test of Visual Perception, (DTVP-2) (Hammill, Pearson and Voress, 1993) was administered to participants to measure their visual perceptual abilities. This test contains a battery of eight subtests which measure different but interrelated motor-reduced visual perceptual and visual-motor perceptual abilities. The eight subtests that make up the developmental tests are: (a) eye-hand coordination, copying, spatial relations and visual-motor speed, all of which measure visual-motor integration abilities; (b) position in space, figure-ground, visual closure and form constancy, all of which measure motor-reduced visual perceptual abilities. Participants' performance was assessed according to the scoring key provided in the test manual of DTVP-2 (Hammill, Pearson and Voress, 1993). The score for each subtest was assigned to either the motor-reduced visual perception or the visual-motor integration composite. The general visual perception composite was

comprised of scores from all the subtests.

Test procedure

The DTVP-2 was administered to Chinese learning participants by a Chinese researcher “native” to Hong Kong and to the English learning Australian participants by an Australian research assistant in Melbourne, Australia. The Chinese researcher was the chief investigator and enrolled in a PhD. program in mathematics education at the University of Hong Kong while the Australian research helper was hired for this study and worked in the field of childcare at the Swinburne University of Technology, Melbourne, Australia. The research assistant was trained to administer the test. The DTVP-2 was administered individually to the participants in their respective kindergarten setting. The time required for the entire test was about 45 minutes. To maintain the energy level of participants, the test was administered in two to three sessions and asked each participant to finish three to four subtests in each session, allowing the participant to go back to their normal class in between sessions.

Results

Table 1 shows the mean quotients and standard deviations of each composite for each language group and the T-test results for equality of means between the two language groups.

Table 1 : Mean quotient and standard deviation for General Visual Perception (GVP), Motor-Reduced Visual Perception (MRV) and Visual-Motor Integration Perception (VMI) of the Australian group and Chinese group and T-test results between groups

| | Origin of language group | | | | T-test | |
|-------------|--------------------------|--------|-------------------|--------|---------|---------|
| | Australia, N = 35 | | Hong Kong, N = 41 | | | |
| | \bar{x} | SD | \bar{x} | SD | t value | p value |
| GVPQ | 105.97 | 14.220 | 121.75 | 9.467 | -6.819 | 0.000** |
| MRVQ | 106.741 | 16.411 | 108.14 | 11.426 | -0.522 | 0.603 |
| VMIQ | 104.71 | 12.780 | 133.21 | 10.570 | -12.202 | 0.000** |

Remarks: for \bar{x} , the minimum is 37 and maximum is 156 ($37 \leq \bar{x} \leq 156$)

*Significant at $p < 0.05$

**Significant at $p < 0.01$

Table 2 : T-test results between MRVQ and VMIQ

| | Language group | Mean difference | SD | Standard Error Mean | t value | p value |
|--------------------|-------------------|-----------------|--------|---------------------|---------|---------|
| MRVPQ - MIQ | Australian | 2 | 10.976 | 1.855 | 1.078 | 0.289 |
| | Hong Kong | -22.5 | 12.305 | 1.922 | -12.261 | 0.000 |

The main findings can be summarized as follows:

1. The Chinese children scored higher marks in visual-motor integration skills than motor-reduced visual perceptual skills and the difference of the two skills were

statistically significant ($p<0.000$) while the Australian children performed similarly in both types of tasks.

2. The Chinese children's performance in general visual perceptual abilities is significantly better ($p<0.01$) than that of the Australian children in the way that the Chinese outperformed the Australian in the visual-motor integration skills but scored similarly to that of the Australian children in the motor-reduced visual perception skills.

There is an assumption stated in the manual of the DTVP-2 that theoretically, one should never expect to find a case in which the Visual-motor Integration Quotient is greater than the Motor-reduced Visual Perception Quotient because presumably people must be able to perceive stimuli before they can duplicate or manipulate them. The authors of DTVP-2 agree with the view of autonomous systems of visual perception and motor development, and that visual-perceptual form develops prior to that of visual-motor form.

In this study, a total of 38 out of 41 Chinese learning children obtained a higher Visual-motor Integration Quotient than Motor-reduced Visual Perception Quotient. It is also stated in the manual that a difference between the Motor-reduced Visual Perception Quotient and Visual-motor Integration Quotient of 9.3 points is required to be significant. In this current study, the differences of the two quotients obtained from 38 Chinese participants were statistically significant and the mean difference was about 22.5, which was far higher than 9.3. Among the 35 English learning Australian participants, only six of them had higher VMIQ than MRPQ with significance. The mean difference of the two quotients for the 35 Australian children is two with the Motor-reduced Visual Perception Quotient being the higher. The following section will discuss the findings.

Discussion

Validity and reliability

Before finding a plausible explanation for the findings it is important to make one point first. The authors of the DTVP-2 mentioned in the examiner's manual that if the VMIQ is higher than the MRPQ, they are best considered examples of test error, situational error (i.e. distractions to child or examiner, noise level, room temperature), or subject error (i.e. inattention, low energy level, attitude, motivation). For this reason, one would argue that the results of the current study might be due to the above errors and therefore, the higher score of VMIQ does not truly reflect reality. However, factors that were considered as having an influence on the children were well controlled during the test in this current study. For example, the test was conducted with both language groups with the same procedures and instructions. The entire test was divided into sessions and the children were asked to finish three to four subtests in each session. Hence, the children's energy level and motivation could be maintained. Thus, it is unlikely that all the Chinese children were distracted in the test or had low energy and motivation. Accordingly, test error, situational error and subject error could not be reasons for the high score and outstanding performance in the VMIQ of the Chinese students.

To account for Chinese learning students' advanced position of visual-motor integration skills over motor-reduced visual perceptual skills, the researchers have considered Chinese learning participants access to visual-spatial properties of Chinese writing characters, in tandem with motor control and psychogeometric theory of Chinese character-writing as the basis for plausible answers.

The visual-spatial properties of the Chinese language

Some researchers (Halliday, 1978; Hoosian, 1991) believe that each language has its unique features for mathematics. Chinese characters, for example, put emphasis on the spatial layout of strokes, and the orthography of Chinese is based on the spatial organization of the components of characters (Hoosain, 1991; Kao, 2000). In contrast to Chinese words, the configurations of alphabetic words are more or less tied to their pronunciation. Kao (2002) points out that alphabetic words are composed of left-to-right letters and follow a

unidirectional scanning path while Chinese characters occupy an imaginary space of identical-size squares. He posits that Chinese characters should be treated as a formation contained in a rigid square of uniform size, occupying 2-D space in height and width. Kao (2002) compares the general principle of Gestalt psychology with the spatial properties of a square and finds that the square incorporates most of the visual properties strongly suggested by Gestalt principles such as symmetry, closure, continuity and balance, all of which contribute to the matter of simplicity. According to Gestalt principles, the above visual properties are easier to be captured and altered by vision. Also, the strokes in Chinese characters can be in different sizes, positions and orientations. Though there is a great variety of ways to form Chinese characters from different combinations of strokes, each character's formation must be restricted to a square and the strokes in one character are compatible and holistic in a certain configuration.

Because of the visual-spatial properties of Chinese characters, it has been proposed that the logographic nature of the Chinese script makes the concept represented by each character relatively transparent to the reader (Smith, 1985; Wang, 1973; cited in Chee et al., 2000). Advocates of this view suggest that there is greater predictability in the mapping of the surface form of a Chinese character to its meaning than is the case for English words. This result suggests that there may be relatively greater overlap between the cognitive processes that are engaged during Chinese character identification and picture identification than is the case for word identification in English (Chee et al., 2000). Consequently, some researchers posit this as an explanation for the fact that Chinese learners appear to outperform non-Chinese learners in visual skills.

Motor control theory

Applying the motor control theory to the writing action itself, attempts to explain how an individual's mental signals are transformed into actual writing motions. According to the theory, the major difference between writing Chinese and phonetic words is: when writing Chinese, one has to first retrieve the visual spatial characteristics of that word; in contrast, for a phonetic word, its linguistically-defined entity (e.g. the letter corresponding to the sound "h") is more important (Van Galen & Teulings, 1984). Thus, visual skills are essential to writing Chinese words while phonological awareness is vital to writing English words. Accordingly, it is reasonable to relate the difference encountered in writing phonetic words and Chinese, and the outstanding performance of the Chinese learning participants in general visual perceptual abilities. However, such difference does not enable a ready explanation of the more advanced performance in visual-motor integration skills but average performance in motor-reduced visual perceptual skills of the Chinese learning children. To account for that, researchers explored the Psychogeometric Theory of Chinese character-writing (Kao, 2000).

The psychogeometric theory of Chinese character-writing

Kao (1999) claimed that Chinese writing is a dynamic integration of the perceptual-cognitive-motor activities of a writer. He pointed out that Chinese writing can be conceptualized as an act involving the whole body of the writer in which visual perception, visual-spatial cognition and motor coordination take place. Therefore, the motor control of Chinese children who have acquired their Chinese writing skill assists them to follow the geometric pattern of the Chinese characters.

Kao (1999) stated that the activity of Chinese handwriting is essentially an external projection and execution of the writer's internal cognitive images of the Chinese character. He posits that the dynamic writing process is an integration of mind, body and Chinese character. Within the writing process??, Kao indicates that body movement is controlled by the brain; "brain" here refers to the writer's recognition and perception towards objective visual-spatial characteristics of Chinese characters. The Psychogeometric Theory of Chinese-character writing refers to the involvement of the geometric characteristics of Chinese characters in relation to the writer's perception, cognitive and motion power. Such close relationship foresees a mutual coordination between the writer and his writing action,

as well as between his perception and spatial organization skill.

Kao (2000) further points out that since the writer's perception, cognitive power and action are combined into one dynamic writing task, the visual spatial characteristics of Chinese characters will naturally affect the cognitive activity within the writing process. The basis of writing is formed from the writer's reflection on the visual-spatial characteristics of Chinese characters. Kao also indicated in relation to the writing motion, the writer's body movement originates from the geometricity of Chinese characters. Consequently, the results reported from this current suggest that a certain mode of action can induce the training and sharpening of an individual's relevant visual-spatial perception. As Kao indicated, his emphasis on the influence of writing Chinese on visual perception is a result of the visual-spatial characteristics of Chinese characters themselves: certain elements that are preserved in the Chinese language system such as closure, parallelism and symmetry all match with the most primitive and natural visual perception of human beings. Therefore, the study reported here suggests that writing Chinese is at the same time a process of training and strengthening the visual-spatial capacity of the writer. This study posits that when the writer becomes familiar with this mode of writing, she/he will subconsciously initiate the training and refinement of relevant visual-spatial perception whenever she/he writes.

This study makes a contribution to the research by verifying that Chinese writers do possess higher visual perceptual abilities than the non-Chinese writers. However, such performance must be considered in tandem with motor coordination in the format of writing. A possible explanation of such a phenomenon is that a Chinese writer's better visual perceptual abilities actually originated from motor activity occurring during writing, such that the control of motion which follows the visual spatial properties of Chinese characters may be an inducing facilitator of the refinement of one's visual perceptual abilities. When motor-reduced visual activity is carried out in isolation, the recognition and categorization of images cannot be carried out by stimulation of the brain due to a lack of motor coordination. This explains the Chinese learning children's outstanding performance in the visual-motor integration skills while their performance was average in the motor-reduced visual perception.

Conclusion

In the past twenty years, the belief in the prior development of motor-reduced visual perceptual skills to that of visual-motor integration skills has been widely accepted because of the phenomenon of lag in reproducing discriminable visual forms is frequently presented by most children. Consequently scholars deduced that a child's depressed performance on a test of visual-motor integration may represent only a problem in motor coordination but not in visual perception. On the contrary, if a person is weak in perceiving visual stimuli, definitely, he/she is unable to duplicate or manipulate them as they are unable to perceive figures and shapes. Therefore, Bortner & Birch (1960) and Piaget & Inhelder (1956) suggested the prior development of visual-perceptual form to that of visual-motor form. However, the results revealed in this present study refute this well established belief. On the basis of the motor control theory and psychogeometric theory of Chinese character-writing, this study provides evidence of the functional relationship between motor-reduced visual perceptual skills and visual-motor integration skills and hence, suggests the *interdependent* development of both skills such that the development of either skill may enhance the other.

In conclusion, this study challenges the existing knowledge of the prior development of motor-reduced visual perceptual skills to that of visual-motor integration skills, and identifies a possible functional relationship between both skills in such a way that their development is mutually dependent.

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