Dynamic visual perception and reading development in Chinese school children

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Abstract The development of reading skills may depend to a certain extent on the development of basic visual perception. The magnocellular theory of developmental dyslexia assumes that deficits in the magnocellular pathway, indicated by less sensitivity in perceiving dynamic sensory stimuli, are responsible for a proportion of reading difficulties experienced by dyslexics. Using a task that measures coherent motion detection threshold, this study examined the relationship between dynamic visual perception and reading development in Chinese children. Experiment 1 compared the performance of 27 dyslexics and their age- and IQ-matched controls in the coherent motion detection task and in a static pattern perception task. Results showed that only in the former task did the dyslexics have a significantly higher threshold than the controls, suggesting that Chinese dyslexics, like some of their Western counterparts, may have deficits in magnocellular pathway. Experiment 2 examined whether dynamic visual processing affects specific cognitive processes in reading. One hundred fifth-grade children were tested on visual perception and reading-related tasks. Regression analyses found that the motion detection threshold accounted for 11% and 12%, respectively, variance in the speed of orthographic similarity judgment and in the accuracy of picture naming after IQ and vocabulary size were

Keywords Chinese · Developmental dyslexia · Dynamic visual perception · Magnocellular pathway · Orthographic processing

Introduction

Reading development requires that children link language's spoken form and meaning with its written symbols. Studies have shown that phonological and orthographic skills are highly important to reading acquisition and development (Wagner, Torgesen, & Rashotte, 1994). Longitudinal and training studies demonstrate that phonological ability can predict and may play a causal role in children's literacy development (Bradley & Bryant, 1978, 1983, 1985; Lundberg, Frost, & Peterson, 1988), as do orthographic skills (see McBride-Chang, 2004 for a review). Substantial evidence also demonstrates that deficits in phonological and orthographic processing play a direct role in reading failure (e.g. Bruck, 1992; Manis, Custodio, & Szeszulski, 1993; Stanovich, Siegel, Gottardo, Chiappe, & Sidhu, 1997). Dyslexic children, for example, may have problems with phonological manipulation, phonological encoding, and phonological memory (Bradley & Bryant, 1978; Frith, 1981).

A large number of studies on developmental dyslexia suggest that, besides linguistic spatial attention (Casco & Prunetti, 1996; Facoetti, Paganoni, Turatto, Marzola, & Mascetti, 2000; Facoetti, Trussardi, Ruffino, et al., 2010; Hari, Valta, & Uutela, 1999; Bosse, Tainturier, & Valdois, 2007). In the lexical decision task, adult readers with good motion detection skills respond significantly faster than individuals with poor motion detection skills (Levy, Walsh, & Lavidor, 2010). Moreover, several longitudinal studies and training studies implicated the dorsal magnocellular pathway in reading development (Kevan & Pammer, 2008, 2009; Boets, Wouters, van Wieringen et al., 2006; Hood & Conlon, 2004; Fischer & Hartnegg, 2000).

However, evidence contradicting the magnocellular pathway theory of dyslexia has also been collected. For example, measures that are supposed to be sensitive to the functions of the magnocellular pathway, including contrast sensitivity (Williams, Stuart, Castles, & McAnally, 2003) and global motion sensitivity (Edwards, Giaschi, Dougherty, Edgell, Bjornson, Lyons, et al., 2004; Huslander, Talcott, Witton, DeFries, Pennington, Wadsworth, Willcut, & Olson, 2004; Reid, Szczerbinski, Iskierka-Kasperek, & Hansen, 2007), did not show significant differences between the dyslexics and their controls in some of the studies. Moreover, since visual deficits, when present, are only identified in a small subgroup of also shown that phonological skill is an important factor in Chinese reading development and dyslexia (Shu, Chen, Anderson, Wu, & Xuan, 2003; Siok & Fletcher, 2001; McBride-Chang & Ho, 2000; Ho & Bryant, 1997). Findings concerning general visual skills in the development of Chinese reading, however, are less consistent, with some studies observing positive associations between visual skills and Chinese character recognition (Huang & Hanley, 1995; McBride-Chang & Chang, 1995; Siok & Fletcher, 2001; Meng, Zhou, Zeng, Kong, & Zhuang, 2002; Ho et al., 2004; Chung, McBride-Chang, Wong, Cheung, Penney, & Ho, 2008) and other studies finding no such association (Ho, 1997; Hu & Catts, 1998; Huang & Hanley, 1997; McBride-Chang & Ho, 2000). A possible reason for this discrepancy is that tasks used to measure visual skills in the aforementioned studies involve mostly higher level cognitive processing and are not sensitive enough to lower level visual processes that rely on the magnocellular pathway.

In this study, we employed coherent motion detection, a task that has been proven to be sensitive to the functions of magnocellular pathway (Hansen, 2001; Conlon et al., 2009). Two patches of randomly moving white dots are presented on the left and right sides of screen, with one patch having a certain percentage of dots moving coherently. Participants have to judge which patch has such coherently moving dots. The percentage of these dots is varied adaptively to determine the participants' detection threshold. Using this task, Talcott et al. (2000) found that English children's sensitivity to dynamic visual stimuli is related to their literacy skills. Visual motion sensitivity can explain independent variance in orthographic skill, but not in phonological ability. Witton et al. (1998) found that dyslexic individuals are less sensitive to dynamic stimuli, with higher threshold in detecting the coherent motion. We also obtained evidence in a preliminary study showing that dynamic visual perception may be related to orthographic processing in Chinese (Meng et al., 2002). In this study, we more systematically investigated the relations between dynamic visual perception and reading development in Chinese. Experiment 1 was conducted to examine whether Chinese dyslexics have the same deficits in detecting coherent motion as their English counterparts. If Chinese dyslexics have deficits in the functions of magnocellular pathway, they will show reduced sensitivity to dynamic coherent motion compared with controls. Experiment 2 was designed to examine more specifically what aspects of cognitive processes in reading Chinese might be related to dynamic visual processing. To achieve this, we tested 100 randomly selected normal school children with both the visual perception tasks and a number of reading-related tasks and conducted regression analyses to determine possible predictive contributions of the coherent motion detection task to the reading-related measures.

Experiment 1

Method

Participants

Twenty-seven dyslexic children and 27 controls participated in the study. These two groups of children were matched on chronological age and nonverbal IQ (see Table 1). The 27 dyslexics were screened from a pool of 420 school children, with the percentage of incidence at 6.43%. The psychometric screening tests, which were administered in groups, are described below. This study was approved by the Academic Committee of the Department of Psychology, Peking University.

Psychometric tests

Raven's Standard Progressive Matrices were used to measure children's nonverbal IQ. There were five sets of 12 items each in the test. Each item consisted of a target matrix with one missing part. Children were asked to select, from six to eight alternatives, the part that best completed the matrix. Scoring procedures were based on the Chinese norm (Zhang & Wang, 1985).

A number of reading tests were administered, with three of them modeled after the Hong Kong test of specific learning difficulties in reading and writing (Ho, Chan, Tsang, & Lee, 2000). In the Chinese word reading test, children were asked to read aloud 150 Chinese two-character words in order of increasing difficulty. The test was discontinued when the child failed consecutively to read 15 words. The 1-min reading test consisted of 90 two-

The reading fluency test was a reading comprehension test which had 95 sentences, each sentence paired with five picture choices. Participants were asked to read each sentence and select from the five pictures the one that best reflected the meaning of the sentence. Children were encouraged to complete as many paragraphs as possible within a 10-min time period. The performance was measured by the total number of sentences the participants could understand. Rapid retrieval and retention of lexical information and construction of sentential representation are needed to complete the task.

The phonological awareness test used the oddball paradigm (Bradley & Bryant, 1978) in which participants were asked to pick out a phonologically odd item from four items. Three blocks of stimuli were tested, each having 20 quartets of items, with the oddity on either onset, rime, or lexical tone. Items were presented orally, and participants indicated on the

Experiment 2

Experiment 1 suggested that there is apparent relationship between poor performance in reading Chinese and deficits in dynamic visual perception and possibly its neural substrates. The purpose of Experiment 2 was to investigate whether the impact of dynamic visual perception on reading Chinese can be related to certain cognitive processes in reading Chinese. Specifically, we wanted to examine whether perception of dynamic visual information has specific impact upon orthographic processing in reading Chinese, as suggested by Meng et al. (2002).

Method

Participants

One hundred fifth-grade children from a primary school in Beijing were tested on a number of linguistic and visual perception tasks. These (Method)Tj8-325793r8431ges2Dssiblte,ibland

Previous studies have shown that orthographic, phonological, and semantic information is

Table 2 Correlation matrix between various measures in Experiment 2

	1	2	3	4	5	6	7	8	9	10	11	12
RAV		0.24*	0.21*	0.27**	0.04	−0.35**	0.12	−0.18	0.02	−0.20*	−0.00	−0.09
VOC			0.36**	0.50**	−0.18	−0.05	−0.23*	−0.13	−0.34**	−0.35**	0.02	−0.16
FLU				0.25*	−0.28**	0.04	−0.28**	−0.02	−0.40**	−0.16	−0.07	0.04
PHO					−0.20*	−0.26**	−0.11	−0.29**	−0.13	−0.30**	−0.16	−0.29*
ORT_RT						0.07	0.26**	0.19	0.37**	0.00	0.03	0.36**
ORT_ER							−0.15	0.36**	0.04	0.12	−0.00	0.21*
PIC_RT								−0.03	0.67**	−0.10	−0.02	−0.16
PIC_ER									0.00	0.52**	0.11	0.36**
CHA_RT										0.07	−0.10	−0.00
CHA_ER											−0.11	0.17
STA												0.28**
MOT												

RAV Raven Standard Progressive Matrices, VOC vocabulary, FLU reading fluency, PHO phonological awareness, ORT_RT orthographic similarity judgment latency, ORT_ER orthographic similarity judgment error rate, PIC_RT picture-naming latency, PIC_ER picture-naming error rate, CHA_RT character-naming latency, CHA_ER character-naming error rate, STASTSTTD(pi)TJpi

perception and its neural substrates. Experiment 1 found that the Chinese dyslexic group had a higher threshold in detecting coherent motion than normal controls did. Further deviance analysis showed that about 52% of the dyslexic children, as opposed to only 13%

underlying causes of development dyslexia across different cultures and different writing systems, and deficits in the magnocellular pathway is one of them.

Stein and Talcott (1999) suggested that accurate visual coding is needed to identify a word and to retrieve the correct pronunciation of that word. Eden, Van Meter, Rumsey, and Zeffiro (1996) also suggested that one way in which the visual deficiency could influence reading processes would be through interfering with the uptake of crucial visual information required for the formation of spelling-to-sound correspondences. In the present study, both orthographic similarity judgment and picture naming need accurate analyses and extraction of stimuli's configural information, and the ability to do this may depend on the more basic functions of magnocellular pathway. In contrast, the present study did not find correlation between coherent motion detection threshold and vocabulary size or reading fluency, although Meng et al. (2002) did find that the dynamic visual detection threshold accounted for 7% (4% in this study) of variance in reading fluency. The absence of stable correlations for these tasks may be due to the fact that these tasks tap into more complex cognitive processes rather than the simple visual–orthographic processing. It has been suggested that the possible effect of dynamic visual perception is not on the whole processes of reading or vocabulary development, but on a specific aspect of orthographic processing (Talcott et al., 2000).

The present study observed a significant correlation between coherent motion detection threshold and the measurement of phonological awareness (see also Conlon et al., 2009; Ben-Shachar, Dougherty, Deutsch, & Wandell, 2007; Borsting, Ridder, Dideck, Kelley, Matsui, & Motoyama, 1996; Johnson, Bruno, Watanabe, Quansah, Patel, Daskin, et al., 2008; Meng et al., 2002; Ridder, Borsting, & Banton, 2001; Slaghuis & Lovegrove, 1985; Slaghuis & Ryan, 1999; Talcott et al., 1998, 2000; Witton et al., 1998), which was taken by Vidyassagar and Pammer, (2009) as evidence that phonological problems experienced by dyslexics arise from impairment of the dorsal visual stream, which is responsible for visual processing of graphemes, their translation into phonemes, and the development of phonemic awareness. However, given that this correlation did not survive in the regression analysis after general cognitive ability and reading skills were removed (see also Talcott et al., 2000), further studies are needed to explore to what extent the deficit in dynamic visual perception contributes to the deficit in phonological skills.

It is noted that in the present study the coherent motion detection threshold correlated with both the speed and the error rate in orthographic similarity judgment, but correlated with only the error rate in picture naming. This difference might come from the difference in the processes underlying the two tasks. Orthographic similarity judgment is a task tapping mostly into the visual–orthographic process in visual word recognition. This process may be intrinsically related to dynamic visual perception. Picture naming, on the other hand, involves more complex processes including visual analysis of configural information, activating a specific concept, and mapping the concept onto a specific

To summarize, by using a coherent motion detection task that taps into the functions of the magnocellular pathway, the present study demonstrates that a large proportion (over 50%) of Chinese dyslexic children have deficits in dynamic visual perception and that this deficit affects specific cognitive processes in reading. Thus, reading development in

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