Neuropsychologia 47 (2009) 1193–1199

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Note

Reading does not depend on writing, even in Chinese

Yanchao Bi [a], Zaizhu Han [a,*], Yumei Zhang [b]

[a] State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing 100875, China
[b] Neurology Department, Beijing Tiantan Hospital, China

ARTICLE INFO

Article history:
Received 11 May 2008
Received in revised form 3 November 2008
Accepted 7 November 2008
Available online 13 November 2008

Keywords:
Reading
Writing
Chinese

ABSTRACT

A recent hypothesis proposes that reading depends on writing in a logographic language – Chinese. We present a Chinese individual (HLD) with brain damage whose profile challenges this hypothesis. HLD was severely impaired in the whole process of writing. He could not access orthographic knowledge, had poor orthographic awareness, and was poor at delayed- and direct-copying tasks. Nevertheless, he was perfect at visual word-picture matching and read aloud tasks, indicating his intact ability to access both the semantics and phonology in reading. He was also able to distinguish between fine visual features of characters. We conclude that reading does not depend on writing, even in Chinese.

1. Introduction

Reading is a learnt yet central cognitive process literate people employ everyday. Given that oral language is acquired far earlier than written language both on the species level and individual level, one of the foci of the past research on language processing mechanisms has been the role of phonology in processing written language. A new notion has been put forward recently that promotes the contribution of writing to reading in a logographic language, Chinese. Motivation and support for this hypothesis come from two perspectives, including reading development research and neuroimaging studies of normal adult subjects. First, Tan, Spinks, Eden, Perfetti, and Siok (2005) studied a group of dyslexic Chinese children and observed that handwriting skills were the most significant predictors of reading ability, and were more significant than phonological awareness, which is traditionally assumed to be the major explanatory factor for dyslexia in various languages (e.g., Ho, Law, & Ng, 2000; Vellutino, Fletcher, Snowling, & Scanlon, 2004). Two potential mechanisms underlying the involvement of writing in reading were identified by the authors: orthographic awareness (assessed by copying ability of pseudo-characters) and motor programming/motor memory skills (measured by picture copying ability). Both variables showed significant explanatory power of reading skills in beginning and intermediate Chinese readers. Such writing skill measurements were not found to explain the reading disabilities in their English-speaking counterparts (Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004; Vellutino, Steger, & Kandel, 1972; Vellutino, Smith, Steger, & Kaman, 1975).

Furthermore, a series of functional brain-imaging studies (e.g., Siok, Perfetti, Jin, & Tan, 2004; Tan et al., 2003) consistently found that the posterior portion of the left middle frontal gyrus (BA9) was activated when subjects made phonological judgment about Chinese written words. This same region was not observed to be responsive when native English speakers carried out similar tasks on English words (see He et al., 2003). Also significantly, structural and functional abnormalities (reduced grey matter volumes and reduced activation in language tasks) in this region was found in dyslexic readers of Chinese (Siok et al., 2004; Siok, Niu, Jin, Perfetti, & Tan, 2008). Given that this region is close to the premotor cortex, Siok et al. suggested that its activation in judging visual words reflects the potential involvement of writing in reading Chinese characters. Taken together, the contribution of writing experience to reading was indicated both by behavioural, anatomical and functional imaging measures in developmental study and by functional imaging of the mature brain.

Tan et al. (2005) offered a theoretical speculation about the role of writing in the reading process that is specific to speakers of Chinese. They argued that (1) learning strategies modulate the cognitive system and (2) for English children the learning-to-read strategy emphasizes the sound structure of speech, whereas Chinese children learn to read by repeatedly copying Chinese characters. This strategy is driven by the language-specific characteristics of Chinese words. As a logographic language, its basic writing units are characters, which correspond to a syllable and usually a morpheme. There is no visual-sound correspondence at segmental level. The visual-spatial configurations of characters are rather complex, involving the spatial arrangement of strokes

* Corresponding author. Tel.: +86 10 5880 2911; fax: +86 10 5880 2911.
E-mail address: zzhhan@bnu.edu.cn (Z. Han).

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doi:10.1016/j.neuropsychologia.2008.11.006

into a two-dimensional square in complicated ways. The degree of homophony is also high in Chinese, with each syllable corresponding to multiple characters. Indeed, how these differences from alphabetic languages influence cognition has been the subject of most cognitive neuropsychological work with acquired reading and writing disorders (e.g., Bi, Han, Shu, & Caramazza, 2007; Han, Zhang, Shu, & Bi, 2007; Law & Leung, 2000; Law & Or, 2001; Law, Yeung, Wong, & Chiu, 2005). Within the current context, Tan et al. (2005) assumed that the linguistic differences between Chinese and alphabetic languages led to learning differences, and therefore result in different processing mechanisms of Chinese and English words – reading in Chinese depends on writing while reading in English does not. Corroborating the effects of learning strategy, Longcamp et al. (2008) recently showed that the learning modality of novel characters shapes the visual recognition efficiency as well as brain activation patterns. In their study speakers of alphabetic languages learnt novel characters by either writing or typing and were tested on mirror image judgment tasks. It was found that characters learnt by writing were not only judged better behaviourally, comparing to the characters learnt by-typing they also elicited more activations in areas that are involved in normal letter identification (left Broca's area, bilateral parietal inferior lobes, left dorsal premotor, and left postcentral regions). Such results confirmed the potential participation of motor processing in visual word perception, and further indicated that learning strategy plays an important role in inducing this participation.

While seemingly counterintuitive, the proposal that writing (an output process) mediates reading (an input process), echoes an important notion developed in the "simulationist framework", which roots in the motor theory of speech perception (e.g., Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967). The core assumption of this school of simulationist or "embodied cognition" theories is that in order to understand a physical stimulus one must internally "run" or "simulate" the corresponding production process. Recent discovery of mirror neurons in both monkeys and humans has revived and further highlighted this notion. Researches using both single-cell recording and functional neuroimaging studies on macaques and humans have observed a specific population of neurons in the premotor cortex that are activated both by the performing of an action and the viewing an action performed by others (e.g., Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Kohler et al., 2002). The existence of these mirror neurons advocates the hypothesis that the recognition of action (and even objects) might entail the same production processes that are associated with this action (and corresponding object) (e.g., Gallese et al., 1996; Martin, Ungerleider, & Haxby, 2000; see Caramazza & Mahon, 2006; Mahon & Caramazza, 2005; Mahon and Caramazza, 2008, for alternative arguments and review of counter evidence). This notion has been adopted in theories about a wide range of cognitive processes (e.g., Federmeier, 2007; Pickering & Garrod, 2007).

Along the same vein, it is not unreasonable to imagine that the visual recognition of word stimuli involves the simulation of producing such visual stimuli – writing. This proposal of reading-by-writing simulation can be taken with various degree of strength. The extreme hypothesis would be that reading *depends* on writing, i.e., successful reading has to go through some kind of writing process. A weaker hypothesis could be that the writing process influences or modulates the reading process in some manner but is not a necessary step in reading. And finally there is a theoretical possibility that the writing process is activated but does not influence reading at all. Moreover, there might be a distinction between the developing system and the mature system. For instance, being able to write might be necessary in learning-to-read but not in the adult system. Although Tan et al. (2005) opted for a strong version of the hypothesis – reading depends on writing in both developmental and adult systems – to explain the developmental data and the adult imaging data, these empirical findings by themselves do not necessitate a strong version of the reading-through-writing hypothesis.

This strong hypothesis should predict that an individual who fails at developing writing should also fail at developing reading.[1] Also if a literate Chinese speaker loses writing ability due to brain damage, his or her reading ability would also be impaired. In the current article, we present a case that is contradictory to this prediction. Our patient, HLD, is severely impaired throughout the whole writing process, including both accessing abstract orthographic knowledge for output and on more peripheral motor programming

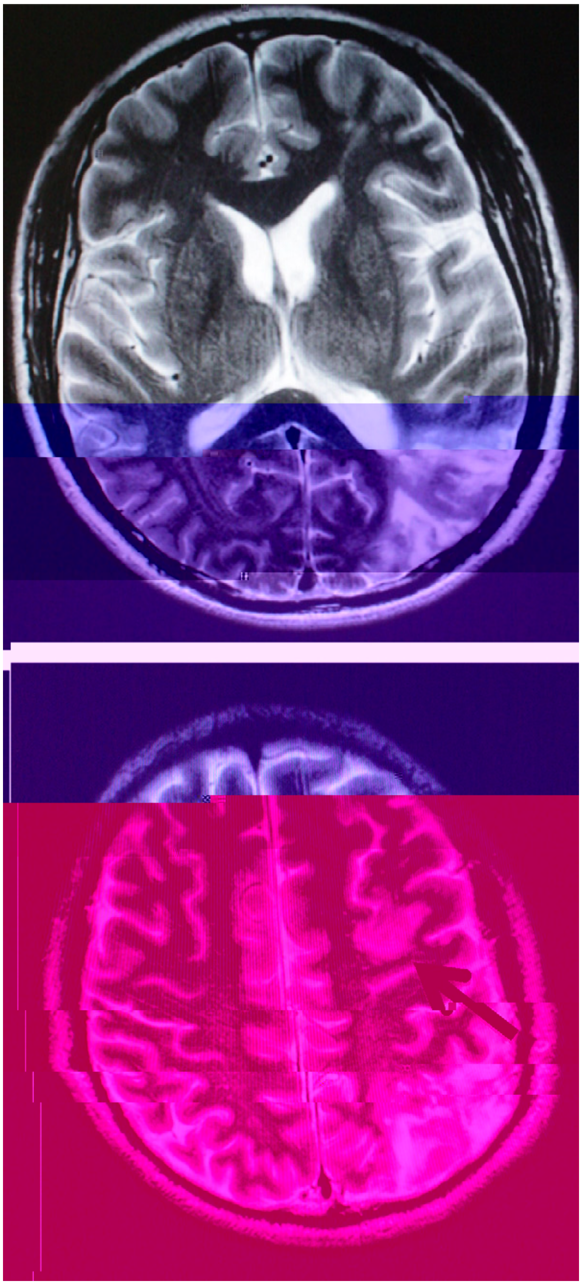

Fig. 1. MRI scans of HLD.

3. Experimental study

To understand the nature of HLD's writing difficulties, we chose tasks based on the generic models of writing (Han et al., 2007; Rapp & Caramazza, 1997), which included the following cognitive components: accessing the orthographic (output) representation, temporarily storing the orthographic units in an output buffer (logographemes[2] for Chinese), transferring such abstract logographeme entities into a series of allographic shapes and calling upon motor programs for neuromuscular execution. Tan et al. (2005) suggested explicitly that both the orthographic awareness and motor program components in this process contribute to reading. We administered a series of writing tests that attempted to probe these potentially relevant components as extensively as possible. The same principal is applied in designing reading tasks. The rationale for each test is explained below.

3.1. Method

The following tasks were administered to HLD in four 1.5-h sessions during March and April 2007. Tasks employing the same set of items were given to him in different sessions. His performance was relatively stable during the time of the testing. Oral responses were all tape recorded and later transcribed for scoring. In all the tasks HLD was given unlimited time to respond for all tasks and he was encouraged at least twice when a "don't know" response occurred. The same tasks were given to seven control participants who matched with HLD in age (mean = 49 ± 7 years) and education level (mean = 11 ± 2 years). HLD and the control subjects performed all tasks with their right hand.

3.2. Writing and copying

3.2.1. Written and oral picture naming

In this test 25 line drawings of common objects were presented and the participant was asked to write down the names of the objects. All pictures were taken from the Snodgrass and Vanderwart (1980) picture set that were normed for Chinese speakers by Shu, Cheng, and Zhang (1989). In this test we aimed to assess the ability to access and output written form from semantics. The same stimuli-set was given to the participant for oral naming in a separate block to examine whether any of his written naming errors was due to problems in recognizing the pictures.

3.2.2. Writing to dictation

The same 25 items in the picture naming test above were read aloud to the participant and the participant needed to write the words down. This was to assess the ability to access and produce the orthographic representation through phonological input.

3.2.3. Orthographic imagery judgment

In this test, the participant heard a character along with a visual probe. The participant was asked to judge whether orthographic form of the auditory stimulus contained the target visual component. Because homophones are prevalent in Chinese, the character/syllable was presented in a compound word context, e.g., 冰 (/*bing1*/, "ice") as in "滑冰" (/*hua2 bing1*/, slide-ice, meaning "ice-skating"). Each visual component target (e.g., 氵) is presented on the central of a piece of paper. This task was designed to examine whether the participant retained the visual shape properties of a character without the need to explicitly produce the character, i.e., without the neuromuscular execution process. Given that some Chinese characters contain a semantic radical and/or a phonetic radical providing semantic and phonetic cue, the task might be achieved by "guessing" through semantic or phonological information of the target character. Therefore we made sure that the target component did not have a pronunciation similar to the auditory word and that the majority (75%) of the trials the answer could not be deduced from semantic cues. There were 40 trials in total, including 20 "yes" trials and 20 "no" trials.

3.2.4. Delayed copying

[2] Logographemes, or 部件, /*bu4jian4*/ (components or subcomponents) are the smallest units in a character that are spatially separated. Conventionally, a character is spatially analyzed into a hierarchical structure of different-sized units, including radicals, logographemes, and strokes (Standards Press of China, 1994; State Language Commission, 1998). Strokes are defined as the traces between a pen down and a pen up movement.

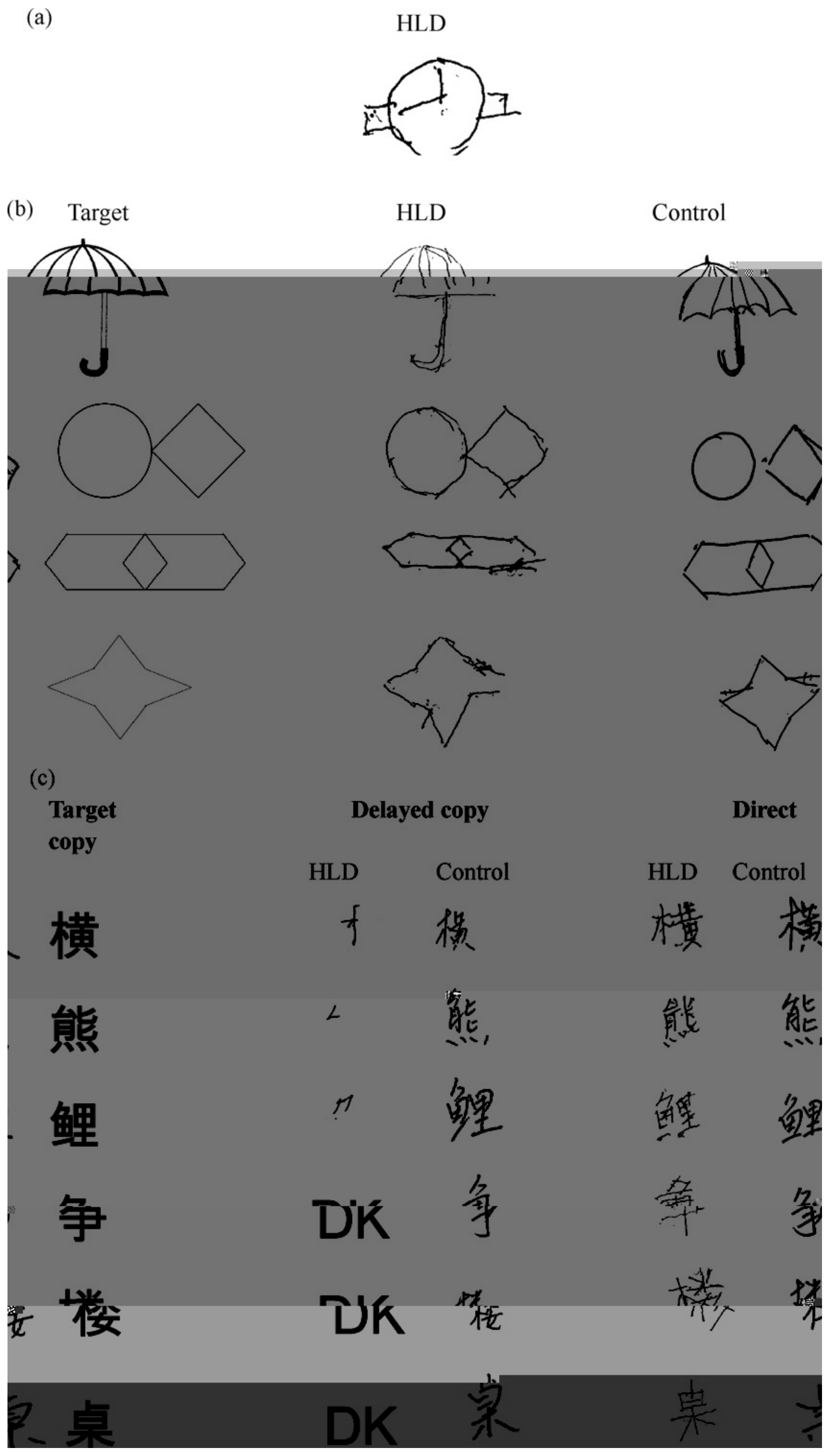

Fig. 2. Examples of HLD's and the control's drawing, copying, and writing responses: (a) drawing from memory, (b) direct-copying of pictures, and (c) delayed- and direct-copying of characters.

(legal vs. illegal), frequency and visual complexity properties in two subsets. The first subset included 10 legal ones and 10 illegal logographemes, which were constructed by prolonging or shortening a stroke of the 10 legal logographemes. In the second subset two frequency levels (high, frequency rank > 3 vs. low, frequency rank ≤ 3, Standards Press of China, 1994) and visual complexity levels (number of strokes: 6 vs. 2–3) were constructed, including 10 logographemes in each cell. Each stimulus was presented for 2 s, after which the experimenter covered the stimulus with a piece of paper. The participant then wrote down the target stimulus immediately. Each stimulus was presented in the center of a piece of paper.

3.2.5. Direct copying

The stimuli were consisted of the characters and the first logographeme set in the delayed-copying task, and nine simple geometric figures (e.g., circle, triangle, square). The participant was asked to copy down the target stimuli directly. In this task the basic visual perception and motor execution abilities are assessed.

3.2.6. Stroke-counting

Twenty logographemes were visually presented to the participant and he was asked how many strokes it takes to write each logographeme. This task aims at evaluating the graphic/stroke motor program knowledge of strokes. For instance, the knowledge that certain ways of changing directions are conventionally written with one stroke (e.g., "㇉"), but not others (e.g., "匚" is written by two strokes – "–" and ";").

3.3. Word reading and recognition

3.3.1. Visual word-picture matching

This was a test from the Beijing Normal University Cognitive Neuropsychology Laboratory (BNU-CNLab) language screener (see Bi et al., 2007). The participant was presented with two pictures and one word on a piece of paper and he was asked to point to the picture that matches the word. There were 25 trials and in different trials the foil pictures were semantically, phonologically, or visually related to the target word. The target pictures were the identical stimuli-set to the one used in the written/oral picture naming test. This was to examine whether the participant could access the meaning of visually presented words.

3.3.2. Oral reading

The participant was asked to read a list of 25 words, which were the names of the pictures used in written/oral picture naming.

3.3.3. Visual character decision 1

In this task 10 real characters and 10 pseudo-characters were randomly presented. The participant judged whether the stimulus was an existing character. The pseudo-characters were constructed by scrambling the logographemes of the 10 real characters on their legal positions. The test probes the participant's orthographic (input) representation and orthographic awareness.

3.3.4. Visual character decision 2 (minimal feature)

In Chinese some characters do not have many close orthographic neighbors the participant might correctly recognize and read them without accessing the precise orthographic representation. We designed this minimal feature test to further examine the fine orthographic knowledge.[3] In this test there were 60 real characters and 90 non-characters, among which 2/3 were constructed by changing a minimal feature, i.e., adding or removing one stroke from a real character. The other 30 foils were pseudo-characters.

3.4. Results

The same scoring criteria were used for HLD and the controls, and the first complete responses were scored. In naming tasks, any responses that were acceptable to describe the pictures were considered correct. The response accuracies for HLD and the controls in the writing and reading tasks are presented in Table 1, along with the p values of the statistical comparisons between the performances of HLD and the controls, which were calculated using the program that accompanies the paper by Crawford and Garthwaite (2007). The program tests whether an individual's score is significantly different from a normative sample. To examine HLD's performances across tasks or stimuli sets, we used The Revised Standardized Difference Test (RSDT, Crawford & Garthwaite, 2005, 2006), which takes into consideration the correlation within normal controls across the different tasks. The RSDT method evaluates whether a patient shows either of the following two types of dissociations on two tasks: Classical dissociations, where a patient is impaired comparing to normal controls on Task A, but is within the normal range on Task B; Strong dissociations, where a patient is impaired on both Tasks A and B, but is relatively more impaired on Task A.

Table 1
The response accuracies of HLD and the controls in the writing and reading tasks.

Task	HLD	Controls ($n=7$)	p-value
Writing and copying			
Written picture naming ($n=25$)	0%	73% (±18%)	<0.01
Oral picture naming ($n=25$)	100%	91% (±3%)	<0.05
Writing to dictation ($n=25$)	0%	79% (±12%)	<0.001
Orthographic judgment ($n=40$)	55%	84% (±8%)	<0.01
Delayed copying			
Character ($n=20$)	5%	96% (±5%)	<0.00001
Logographeme subset 1 ($n=20$)	30%	93% (±5%)	<0.0001
Logographeme subset 2 ($n=40$)	32%	91% (±5%)	<0.0001
Stroke ($n=31$)	61%	94% (±5%)	<0.05
Direct copying			
Character ($n=20$)	86%	98% (±4%)	<0.05
Logographeme ($n=20$)	85%	96% (±3%)	<0.05
Geometric figure ($n=9$)	100%	100% (±0%)	n.s.
Stroke-counting ($n=20$)	45%	90% (±8%)	<0.01
Word reading and recognition			
Visual word-picture matching ($n=25$)	100%	100% (±0%)	n.s.
Oral reading ($n=25$)	100%	100% (±0%)	n.s.
Visual character decision			
Subset 1 ($n=20$)	95%	82% (±11%)	n.s.
Subset 2 ($n=150$)	97%	89% (±7%)	n.s.

It is evident that HLD's writing was severely impaired. The majority of HLD's writing errors were "don't know" responses or fragments. He was unable to write the name of any picture, for which his oral naming was perfect. He was not able to write any characters to dictation. He was also extremely poor at the delayed-copying task, making mostly omission and stroke errors. In delayed-copying logographemes, he showed no lexical effect: legal logographemes (HLD: 40.0%; control: 94.3 ± 5.0%) vs. illegal logographemes (HLD: 20.0%; control: 91.4 ± 6.4%) ($t < 1$). His performance was affected by the visual/motoric complexity of the logographemes, as measured by number of strokes: many strokes (HLD: 15.0%; control: 85.0 ± 9.6%,) vs. few strokes (HLD: 50.0%; control: 97.9 ± 2.5%) ($t = 6.6$, $p < 0.001$). His direct-copying performance was also impaired. His errors included part omission and stroke errors. Even for the ones that his copying responses were recognizable as the correct target, as judged by a novel scorer, the strokes were clearly nonfluent (see Fig. 2c). The scorer described that the responses resembled picture-drawings or those produced by a nonnative speaker. For items involving more than three strokes, HLD's stroke sequences within the characters or logographemes often deviated from the canonical sequences. In direct-copying logographemes, he showed no lexical effect: legal logographemes (HLD: 90.0%; control: 95.7 ± 5.4%) vs. illegal logographemes (HLD: 80.0%; control: 95.7 ± 5.4%) ($t = 1.9$, $p = 0.19$). His direct-copying responses for simple geometric graphs retained acceptable configurations, indicating that the basic visual structural description and basic motor execution ability was preserved, even though his strokes were judged by the novel scorer as nonfluent, which might be due to his subtle motor weakness (see finger tapping performance in Section 2). He was at chance on the orthographic imagery judgment task, suggesting that he was not able to retrieve the orthographic properties of a target character. His performance on the stroke-counting task was far below normal performance and showed a particularly interesting pattern. He was almost at floor whenever the logographeme contained one or more curved strokes

[3] We thank Sam Po Law for suggesting this possibility and this test.

involving a sharp change of direction (e.g., 口) (HLD: 16.7%; control: $92.9 \pm 6.2\%$) and was more severely impaired than those (e.g., 扌) without such curved strokes: (HLD: 85.5%; control: $91.1 \pm 8.8\%$) ($t = 6.4$, $p < 0.001$). This result further indicates the loss of the knowledge about the graphic/stroke motor programs.

By contrast, he was within normal range on all reading tasks. His only errors were on the visual character *decision* (minimal feature) task, and the error instances were within normal range.

4. General discussion

We presented a profile showing clear dissociation between reading and writing in a Chinese-speaking individual with brain damage with large left hemispheric lesions including the white matter of the left middle frontal gyrus. HLD was severely impaired in the whole process of writing. He was impaired in accessing the orthographic representation as revealed by the poor performance in orthographic imagery judgment. His deficit at the orthographic awareness was shown by the absence of legal/illegal logographeme difference. He retained little graphic/stroke motor programs knowledge, as indicated by his poor copying performance, nonfluent stroke production, and the stroke complexity effect in copying and stroke-counting. Worth emphasizing is that, the patient's impairment in stroke-counting and orthographic imagery judgment ruled out the possibility that his impairments were attributable to a problem with fine motor movement that might be especially important in producing characters. In other words, he was impaired even when no motor output was required. Nevertheless, he was perfect at visual word-picture matching and read aloud tasks showing his intact ability to access both the semantics and phonology. He was also able to distinguish between fine visual features of characters. The implication of the case is straightforward – reading does *not* depend on writing, even in Chinese.

How to reconcile our current findings with the results of Tan et al. (2005)? To recapitulate, Tan et al. observed that Chinese readers differ from alphabetic readers in the following two aspects: (1) the writing ability predicts reading ability in Chinese children and (2) a particular region in left middle frontal lobe (BA9), which is adjacent to the premotor cortex, associates with reading tasks for Chinese adults, at least in those emphasizing the phonological access. We propose that there are at least three types of explanations to accommodate these results and our current results. First, because the empirical data obtained from the developmental perspective and functional neuroimaging paradigm are correlational in nature, writing may not play any role in reading at all. The activation in left middle frontal lobe, if indeed is related with writing, might be the by-product of reading and/or induced by the particular tasks (see a detailed discussion about similar evidence for simulationist theories in Caramazza & Mahon, 2006). Alternatively, it is possible that writing difficulty indeed had a causal relationship with reading difficulty in the course of *acquisition* but is no more a necessary component in the matured system. Such discrepancy between different stages of the system development is possible (e.g., Caramazza, 1994). Finally, the observations in Tan et al.'s studies might reflect a modulatory influence of writing in normal reading and is not revealed in the current case study, which reflects the necessity relationships between writing and reading. In any case, our current case suggests that writing is not a necessary component of reading in Chinese, at least for the matured systems.

By embracing a strong language-specific view for language processing, Tan et al.'s viewpoints are significant for various reasons. The assumption that linguistic parameters and learning strategies shape the cognitive and neural system supports the plasticity assumption of brain; the notion that reading entails its output counterpart (writing) is in line with the influential simulation notion for perception. Appealing as it is, the current case clearly showed that reading does not depend on writing, even in Chinese. Our case parallels the western counterparts and adds a further data point that advocates the functional independence of reading and writing (see, Hamilton & Coslett, 2007). The precise manners in which writing might modulate reading, as well as the strength of this influence and its specificity to a subset of languages, are all still open issues.

Acknowledgments

The research reported here was supported in part by the PCSIRT (IRT0710), NSFC (30700224) and BJSF (7082051) grants to YB, and the NSFC (30770715) and NSSFC (07CYY009) grants to ZH. We thank Gabriele Miceli, Christopher Honey, Francesco Vespignani and Stefano Anzellotti for their comments on an early version of the manuscript. We are most grateful to HLD for his participation.

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