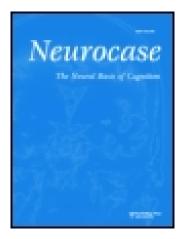
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Writing Errors of a Cantonese Dysgraphic Patient and their Theoretical Implications

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Abstract

This paper reports a case study of a Cantonese-speaking dysgraphic patient. Among his written errors were phonologically plausible errors that were mostly homophonous or differed only in tone from their target. They occurred not only in writing-to-dictation but also in written naming. Since his lexico-semantic system is hypothesized to be largely preserved, as evidenced by normal performance on non-verbal semantic tests and word-picture matching, the presence of homophone and tonal errors strengthened previous claims about the existence of a lexically-mediated non-semantic pathway of writing Chinese and access from the phonological output lexicon to the orthographic output lexicon. In addition, his non-character responses, particularly those involving substitution of constituent(s), almost always maintained the configuration of their target. This observation implies that orthographic representations contain not only information on the identity of components but also structural information. The latter may, among other possibilities, take the form of a template indicating the internal organization of the character or specification for position of occurrence for each constituent within the character.

The Chinese writing system is logographic in nature. All Chinese characters are monosyllabic,¹ and the great majority of them represent morphemes. Unlike alphabetic scripts where letters are associated with individual phonemes, there are no elements within a character that correspond to phonemes. In other words, the mapping between a character and its sound is at the level of a syllable. Although Chinese is a lexical tone language, in which variations in pitch signify differences in lexical meaning, tones are not marked orthographically. Chinese characters are made up of spatial arrangement of strokes, which combine to form constituents/ radicals, which may further combine to form more complex characters. Over 80% of all characters are so-called phonetic compounds, containing a signific radical and a phonetic radical. The signific radical provides a clue to the meaning of the character whereas the phonetic radical provides a cue to its pronunciation. For instance, the character 34 wu4² 'lake' has a signific radical (three dots) on the left meaning 'water/ liquid' and a phonetic radical in on the right whose pronunciation wu4 is the same as the character. It must, however, be emphasized that the situation with phonetic compounds as characters carrying phonetic information is somewhat more complex. It is not always possible to arrive at the correct

pronunciation of such a character based on the phonetic radical for several reasons: (i) although in the majority of phonetic compounds, the phonetic radical appears on the right, it may occupy other positions of a character, e.g., the phonetic radical 其 kei4 in 棋 kei4, 期 kei4, 基 gei1, and 箕 gei1; (ii) a character may contain more than one pronounceable constituent, e.g., 棋 (木 muk6 and 其 kei4), 期 (其 kei4 and 月 *jyut6*); and (iii) the phonetic radical is more often than not an unreliable cue to the sound of a character. Law (1997) surveyed more than 12,000 phonetic compounds listed in a Cantonese dictionary and found that only about 34% of the entries are identical in sound (including tone) to their phonetic radical. Given the important differences in form-sound mapping between Chinese and alphabetic writing systems, questions naturally arise about how the architecture of the cognitive system supporting the recognition and production of written and spoken Chinese words and about the structures of form representations may differ from those of alphabetic systems, such as English.

In recent years, a number of detailed case reports of Chinese-speaking patients with acquired reading and/or writing disorders have appeared. These studies have provided crucial information on the functional architecture of the

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Chinese lexical system and the structures of phonological and orthographic representations. Weekes et al. (1997), Weekes and Chen (1999), and Law and Or (2001) have argued for a direct route of reading Chinese connecting the orthographic and phonological lexicons. Evidence for this claim comes from Mandarin- and Cantonese-speaking patients with hypothesized disruptions to the semantic system or the access from the semantic system to the phonological lexicon. These patients demonstrated preserved reading vis-à-vis impaired oral naming, and made reading errors by pronouncing a constituent in the target character, which have been referred to as legitimate alternative reading of components (or LARC) errors (Patterson et al., 1995; Weekes and Chen, 1999). The preserved performance on reading aloud and the presence of LARC errors are believed to reveal the intact functioning of the direct reading route. Given that there is no sub-lexical grapheme-phoneme conversion in Chinese, the direct route is lexically-mediated. Similarly, the better performance on writing-to-dictation than written naming and the production of homophones by a patient, CML, in Law and Or constitute evidence for a non-semantic pathway of writing. CML's errors in oral and written naming offer further information on the connections among the modules of form representations. More specifically, many of her oral naming errors involved the insertion of a small number of syllables that corresponded to the extraneous characters occurring in her jargon responses in written naming. Making the assumption of an input/output distinction in processing phonological and orthographic information, Law and Or argue that the correspondence between extraneous syllables in spoken production and inserted characters in written output may indicate access from the phonological output lexicon to the orthographic output lexicon in written word production. If this is the case, the mediated version of nonsemantic route of writing is favored (Patterson, 1986; Patterson and Shewell, 1987).

In addition, spoken and written errors are available that can be used to make inferences about the structural representations of syllables and characters. While CML could read aloud single words better than writing them, her reading was not flawless. About 70% of the reading errors were unambiguous tonal errors (i.e., the error was not the result of reading one of the character constituents that differed in tone from the whole character). A post-lexical phonological or articulatory deficit was ruled out as the cause because in a written word-written word matching task where no oral output was required, she scored 60% correct overall and 80% of her errors involved choosing the tonal distractor (Law and Or, 2001). The preponderance of tonal errors effectively means that suprasegmental information can be selectively impaired; this led to the proposal that the representations of segmental and suprasegmental features are independent of each other, and the representation of a Chinese syllable may have a non-linear structure with the two types of information represented at separate levels, as suggested in autosegmental phonology (Yip, 1980). The characteristics of writing errors produced by another Cantonese patient, SFT, in a delayed copying task

reported in Law and Leung (2000) shed light on the issue of the basic unit in writing. About one-third of SFT's writing errors involved the substitution, deletion, addition, or transposition of orthographic constituents that were larger than a stroke but did not correspond to the signific radical or the phonetic radical. Instead, they matched the structures that are considered the building blocks of Chinese characters, referred to as the "logographemes" in logography (the study of the formal properties of characters). Logographemes are conceptually comparable to letters in alphabetic writing systems. To illustrate, the phonetic compound 幔 maan6 'curtain' contains a signific radical \ddagger and a phonetic radical \equiv . The latter can be further decomposed into three constituents \square , \square , and \checkmark . Hence, 幔 consists of a total of four logographemes. Another example is the character 章 zoengl 'chapter' which is not a phonetic compound. It is analyzed into three logographemes $\forall \tau$, \exists , and +. Given the pattern of SFT's writing errors, Law and Leung propose that logographemes are also the basic units in written production, and as such, orthographic representations of characters are composed of logographeme-like units.

The aforementioned studies mark an initial contribution from neuropsychology to the understanding of the Chinese lexical system. This paper adds to the previous reports through describing a Cantonese-speaking patient with acquired dysgraphia. The characteristics of his written word production, character or non-character output, in writing-to-dictation and naming tasks provide further confirmation to previous speculations about the functional architecture of the lexical system in Chinese and insights into the structural representation of characters.

Case report

CK is a 31-year-old right-handed male speaker of Cantonese with a Form 3 education (equivalent to nine years of formal education). He worked as a salesperson in a drug company before a sudden collapse on February 2, 1999. An acute CT scan taken that day revealed right temporo-parietal occipital intracranial hematomas, intra-ventricular hemorrhage, midline shift and diffused cerebral oedema (Fig. 1a). A craniotomy for clot evacuation and a ventricular catheter for drainage of cerebral spinal fluid were performed on the same day (Fig. 1b). The patient's post-operative recovery was uneventful. A digital subtraction arteriogram (DSA) was later done on April 29 revealing a right posterior temporo-occipital arteriovenous malformation (AVM). On May 10, a DSA and embolization of the AVM were performed. The nidus and perinidal aneurysm were occluded. The residual AVM was supplied by temporal branches of the middle cerebral artery. A craniotomy was performed on May 28 to remove the residual AVM.

CK was first referred to us for an evaluation of his reading and writing abilities in April 2002. He showed no evidence of physical or sensory impairment. His speech was fluent and he could carry on a meaningful conversation. He attended a vocational training school full-time and maintained an active social life. When asked about his premorbid writing ability, CK told

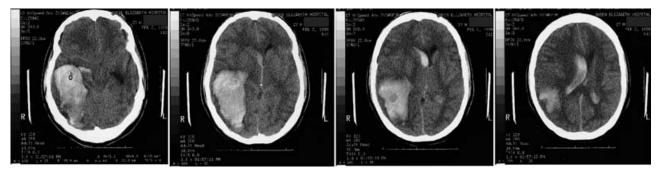


Fig. 1a. CT scan taken before operation.

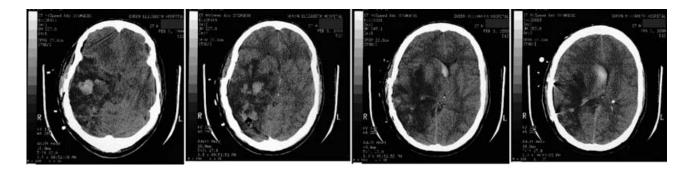


Fig. 1b. CT scan taken after operation.

 Table 1. CK's performance on a screening test of acquired dyslexia and dysgraphia in Cantonese

| ask | # of trials correct | |
|-----------------------|---------------------|--|
| epetition | 30/30 | |
| opying | | |
| Direct copying | 14/15 | |
| Delayed copying | 15/15 | |
| ral naming | 35/40 | |
| ritten naming | 26/40 | |
| eading aloud | 39/40 | |
| riting-to-dictation | 26/40 | |
| uditory comprehension | 18/20 | |
| eading comprehension | 17/20 | |

us that he used to write sales slips at work and had the habit of keeping a diary. Unfortunately, he was not able to locate his diary for us to examine his premorbid writing samples. His performance on a screening test for acquired dyslexia and dysgraphia in Cantonese (Law and Leung, 1999), as shown in Table 1, indicated a mild impairment to reading and a moderate disruption to writing. Further assessment was conducted between November 2002 and February 2003.

Method

Materials and tasks

The tasks administered to CK included (i) non-verbal semantic tests, (ii) spoken word-picture matching, (iii) written-word picture matching, (iv) reading object names and single words, (v) oral picture naming, (vi) writing-to-dictation object names and single words, (vii) written naming, and (viii) function word processing.

The non-verbal semantic tests were the associative match task from the Birmingham Object Recognition Battery (BORB) (Riddoch and Humphreys, 1993) and the Pyramids and Palm Tree test (PPT) (Howard and Patterson, 1992). Twenty-three and 37 culturally appropriate items were selected from the BORB and PPT, respectively.

The Snodgrass and Vanderwart picture set (1980) was used for reading aloud, writing-to-dictation, oral and written naming (n = 217). A subset of the pictures was employed in the two word-picture matching tasks with 60 trials each. On each trial, an object name in written or spoken form and three pictures were presented, i.e. the target, a semantic distractor and an unrelated distractor with the same word length as the target.

The single word stimuli for reading aloud and writing-todictation were items from various word lists described in Law and Caramazza (1995). They included the "imageability" list (n = 60 disyllabic words), the monosyllabic "form class" (n = 60) and disyllabic "form class" lists (n = 60) with an equal number of function words, nouns, and verbs, the "frequency" list (n = 90), and the "phonetic radical" list (n = 120) consisting of phonetic compounds varying in the degree of phonological similarity between the phonetic radical and the character containing it, and in the position of the phonetic radical within the character, totaling 390 words. Given the extent of homophony in the Chinese writing system, each monosyllabic stimulus was presented in a word context in writing-to-dictation so as to make clear to CK the particular character being dictated.

Given that CK was assessed on the production of items of different grammatical word classes, in cases where form class effects were found, other tests would be needed to localize the deficit. For poor performances on content words, the auditory/ written word-picture matching tasks could help determine whether the impairment was at the semantic level or the levels of form representations. However, word-picture matching and non-verbal semantic tests are not intended to properly assess the processing of functors. Moreover, spontaneous speech may not reliably inform us about a patient's processing of grammatical morphemes (Kendall et al., 1998; Silverberg et al., 1998). Hence, a function word processing test developed by Law and Cheng (2002) was administered. It is a Cloze test that aims to elicit target grammatical morphemes in highly constrained contexts. On each trial, the subject is presented with a written sentence with a line indicating the position of the missing functor. While the sentence remains in sight, the experimenter reads aloud the whole sentence and pauses briefly at the missing item. The subject is to provide the grammatical morpheme orally. Six types of function words are examined, including classifiers (n = 57), negative markers (n = 12), coverbs (n = 30), pro-forms (n = 18), structural suffixes (n = 12), and structural and modal particles (n = 24), totaling 153 trials. Law and Cheng tested five normal subjects on these items. They were able to provide the target morphemes for all the stimuli. For 87% of the items, the subjects produced the target on the first attempt; for the rest, no subject required more than three subsequent attempts to arrive at the target grammatical morpheme.

Sixty normal subjects, 30 female and 30 male Cantonese speakers with ages ranging from 25 to 72 years of age scored a mean of 22.25 (SD = 1.17) on the BORB and 32.88 (SD = 5.79) on the PPT. A control subject matched in age, gender, and education level with CK made 2 errors in reading object names (1 tonal and 1 semantic), 3 semantic errors in oral naming, 2 errors in reading single words (1 "no response" and 1 semantic error). He also produced 6 errors in writing object names, 6 in written naming, and 11 in writing single words. The written responses were of different types including semantic errors, substitution, deletion, or insertion of character constituent(s), phonologically plausible errors, and failures to respond.

Error analysis of spoken production

Spoken errors were categorized into the following types:

- (i) Partial response Only a subset of the characters in a disyllabic or multisyllabic word was correctly read (e.g. *fan1saan3* 'to separate' → *saan3*).
- (ii) Semantic error The target and the response were semantically related (e.g. *ceng1ziu1* 'green pepper' \rightarrow

ke2zi2 'squash') or they formed a word together (e.g. zyu2 'to cook' \rightarrow *suk6* 'done' where zyu2suk6 'to cook until it is done').

- (iii) Phonologically similar response The target and the response shared at least half of the phonetic features (segment and tone). For instance, *mat6* 'not' \rightarrow *fat6* 'to punish', *zeoi6* 'crime' \rightarrow *zeoi3* 'most'.
- (iv) LARC For example, $\frac{1}{2}$ $\frac{1}{2}$
- (v) Visual error The output corresponded to a character that was orthographically similar to the target (e.g. 奢 *ce1* 'luxurious' → 屠 *tou4* 'to butcher') in the case of reading, or the response refers to an object that was visually similar to the pictured object in the case of naming (e.g. *zi2gaap3co3* 'nail-file' → *mak6seoi2bat1* 'fountain pen').
- (vi) Unrelated For example, 惑 waak6 'to bewitch' \rightarrow 書 syu1 'book'.

Error analysis of written production

Written errors were first classified according to their lexicality, that is, whether they were real characters or nonexisting characters. Finer categorization of existing characters was then applied as follows.

- (i) Semantic error Examples are *lou5fu2* 'tiger' → *paau3* 'leopard' in written naming, *bo1* 'ball' → *kau4* 'ball', 業 *bui3* → 份 *fan6* where 準份 together means 'status' in writing-to-dictation.
- (ii) Phonologically plausible error The response was orthographically dissimilar to the target, and was either homophonous with or phonologically similar to the target to the extent that they shared at least half of the phonetic features (e.g. 既然 gei3jin4 'nevertheless' → *記賢 gei3jin4 'remember-virtuous' where the response was not an existing word; 敬 ging3 'respect' →經 ging1 'to pass by').
- (iii) Orthographic error The target and the output had one or more character constituents in common (e.g. 恤衫 seotl-saam1 'shirt' → *血衫 hyut3saam1 'blood-clothes').
- (iv) Phonologically and orthographically similar For example, 駐 zyu3 'to station' →註 zyu3 'to footnote'; 楓葉 fung1jip6 'maple leaf' → *風葉 fung1jip6 'wind-leaf'.
- (v) Unrelated For instance, $\Re zeoi6$ 'to gather' $\rightarrow \pm zyu2$ 'to host'.
- (vi) Partial An example from written naming was 頭盔 'helmet'→頭.

Non-character responses mainly involved the substitution, deletion, insertion, or transposition of character components, or the deletion of a stroke.

Results

CK performed within normal range on the BORB (21/23) and the PPT (32/37), perfectly on spoken word-picture matching

Table 2. Distribution of spoken errors

| | Single words $(n = 390)$ | Object names $(n = 217)$ | Oral naming (n = 217) |
|------------------------|--------------------------|--------------------------|--------------------------|
| Semantic | 7 (13.2%) | 3 (30.0%) | 20 (87.0%) |
| Phonologically similar | 12 (22.6%) | 5 (50.0%) | · · · · · |
| LARC | 7 (13.2%) | 1 (10.0%) | |
| Visual | 5 (9.4%) | · · · · | 3 (13.0%) |
| Partial | 10 (18.9%) | 1 (10.0%) | · · · · · |
| Unrelated | 7 (13.2%) | · · · · | |
| No response | 4 (7.5%) | | |
| Others | 1 (1.9%) | | |
| Total | 53 | 10 | 23 |

(60/60), and made only one error on written word-picture matching (59/60). These results suggest that semantic processing of content words in CK was largely intact.

He correctly read 337/390 single words (86%), 207/217 (95.4%) object names, and named 194/217 (89.4%) pictures of objects. The distribution of his spoken errors is given in Table 2. The occurrence of semantic, phonologically similar, LARC, and even partial errors indicates that orthographic input was properly processed. The reading errors could be the result of a mild deficit to the phonological output lexicon.³ When the target phonological representation was unavailable, an entry that was either phonologically or semantically related to the target might be selected for production. No effects of grammatical word class (functors: 35/40, verbs: 32/40, nouns: 36/40), imageability (high: 24/30, low: 26/30), word frequency (high: 43/45, low: 38/45), phonological similarity between a phonetic compound and its phonetic radical (identical: 35/40, similar: 36/40, unrelated: 32/40), and the position of phonetic radical (left: 26/30, right: 25/30, top: 24/30, bottom: 28/30) were found.

CK's performance on the written tasks was far poorer, compared with the spoken tasks. He scored 53% correct (207/390) on writing single words, 66.4% (144/217) on writing-to-dictation object names, and 66.4% (144/217) on written naming, respectively. The correct response rates of the different lists were (i) form class: functors (16/40 or 40%)vs. verbs (23/40 or 57.5%) vs. nouns (27/40 or 67.5%), (ii) frequency: high (31/45 or 68.9%) vs. low (21/45 or 46.7%), (iii) imageability: high (19/30 or 63.3%) vs. low (16/30 or 53.3%), (iv) phonetic compound: phonological similarity between phonetic radical and phonetic compound - identical (17/40 or 42.5%) vs. similar (18/40 or 45%) vs. unrelated (19/40 or 47.5%); position of phonetic radical - left (12/30 or 40%) vs. right (19/30 or 63.3%) vs. top (12/30 or 40%) vs. bottom (11/30 or 36.7%). CK wrote nouns significantly better than function words $[\chi^2(1) = 6.08]$, p < .05], high frequency items better than low frequency words [$\chi^2(1) = 4.55$, p < .05], and phonetic compounds with the phonetic radical on the right better than at the bottom $[\chi^2(1) = 4.27, p < .05]$. No effects of imageability and phonological similarity were observed. The distribution of errors over various error types is given in Table 3.

Table 3. Distribution of written errors

| | Single words (n = 390) | Object names $(n = 217)$ | Written naming (n=217) |
|-----------------------------|------------------------------|--------------------------|------------------------------|
| Character response | 164 (88.6%) | 36 (49.3%) | 42 (57.5%) |
| Semantic | 3 (1.6%) | 5 (6.8%) | 14 (19.2%) |
| Phonologically plausible | 41 (22.2%) | 7 (9.6%) | 12 (16.4%) |
| Orthographic | 1 (0.5%) | 3 (4.1%) | 3 (4.1%) |
| Phonological & orthographic | 26 (14.1%) | 8 (11.0%) | 5 (6.9%) |
| Unrelated | 2 (1.1%) | 1 (1.4%) | 3 (4.1%) |
| Partial | 91 (49.2%) | 12 (16.4%) | 5 (6.9%) |
| Non-character response | 7 (3.8%) | 27 (37.0%) | 25 (34.2%) |
| Con. deletion | 3 (1.6%) | 4 (5.5%) | 3 (4.1%) |
| Con. substitution | 4 (2.2%) | 16 (21.9%) | 14 (19.2%) |
| Con. insertion | | 2 (2.8%) | 3 (4.1%) |
| Con. transposition | | 1 (1.4%) | 2 (2.7%) |
| Stroke deletion | | 4 (5.5%) | 3 (4.1%) |
| No response | 14 (7.6%) | 10 (13.7%) | 6 (8.3%) |
| Total | 185 | 73 | 73 |

Note. There were two disyllabic stimuli in the single word list where CK erred on both component characters, resulting in a total of 185 writing errors. Con. = constituent.

CK also performed poorly on the function word processing test, scoring only 59.6% correct on classifiers, 58.3% on negative markers, 43.3% on coverbs, 33.3% on pro-forms and structural suffixes, and 25% on particles. Of the 83 errors, 57 involved providing a content word as a response, 10 were substitutions with a functor of a type different from that of the target, and 16 were within-type substitutions. On those occasions where CK gave a content word, the word often modified the following item, e.g. *one <u>classifier</u> stone \rightarrow one <u>big</u> stone. His level and pattern of performance across functor types were not dissimilar to those of the fluent aphasic speakers reported in Law and Cheng (2002).*

In the written tasks, CK produced many phonologically plausible errors that may or may not be orthographically similar to their target. This was particularly the case for writing single words. We analyzed "phonologically plausible" and "phonologically and orthographically similar" errors from all three written tests in terms of degree of phonological similarity between the target and the response and found 33 homophones and 18 tonal errors (or 51/60) among "phonologically plausible" errors and 25 homophones and 13 tonal errors (or 38/39) among "phonologically and orthographically similar" errors.

To determine whether character frequency influenced CK's written output, an analysis was done on all the errors with character responses and those "constituent substitution" errors with both the substitute and the replaced component corresponding to real characters. Among these errors, a distinction was made between content word and function word targets. This was because CK tended to produce content word responses for many of the function word stimuli, and functors generally have much higher frequency than content words. A frequency count based on printed materials in Hong

Table 4. Character frequency contrast between stimulus and response

| | Response more frequent than target | Response not more frequent than target |
|-----------------------------|------------------------------------|--|
| Content word target | | |
| Orthographically similar | 32 | 15 |
| Orthographically dissimilar | 45 | 11 |
| Function word target | | |
| Orthographically similar | 0 | 1 |
| Orthographically dissimilar | 4 | 10 |

Kong (Ho and Kong, 1994) was consulted. For an output to be classified as "more frequent" than its stimulus, there must be a minimum difference of 10 in frequency of occurrence; otherwise, it was considered as "not more frequent". Note that error responses sharing one or more components with their target were distinguished from those that did not, since orthographically similar errors could have been the result of substitution, deletion, or insertion of character constituent. Table 4 shows that character frequency seemed to play a role in written production regardless of whether the output was similar in form to the stimulus. A significant difference was found for orthographically dissimilar errors [$\chi^2(1) = 11.37$, p < .001]. As for function word targets, the opposite pattern was observed as expected.

Finally, non-character responses accounting for 17.8% of all written errors were examined with a focus on "constituent substitution" errors since they constituted the largest proportion. A question was asked whether the output maintained the overall configuration of the target after one or more of the components were replaced. That is, whether an erroneous response to a character with a left-right configuration 種 or one with a top-bottom configuration 雷 would similarly have a left-right and a top-bottom configuration, respectively.⁴ Some examples of non-character responses respecting the target configuration are 檸檬 \rightarrow *擰濠, 螺→*縲, 斧→*斧, and 櫃→*櫃; instances of errors not maintaining the target structure are illustrated by 熨 \rightarrow *戽, and 窗 \rightarrow *窗. The last two examples involve multiple errors, constituent substitution and deletion for 熨, and substitution and insertion for 窗. The character 熨 has a top-bottom structure at the first level; its top component 尉 further has a left-right configuration. The corresponding response contains only a top and a bottom component, ⊢ and 斗. The stimulus 窗 has a top-bottom structure, the signific radical 穴 and 囟. These constituents were replaced, respectively, by another signific radical without the strokes Λ and the constituent Π . In addition, two radicals arranged in a left-right structure were inserted. The overall results showed that in the great majority of cases, the output kept the configuration of the target (writing single words: 3/3 left-right, 1/1 top-bottom; writing object names: 9/9 leftright, 6/7 top-bottom; written naming: 9/9 left-right, 2/5 topbottom).

Discussion

CK's performance on non-verbal semantic tasks and wordpicture matching suggests largely preserved semantic processing. The below normal level of performance on reading and oral naming tasks is hypothesized to be the result of a mild deficit to the phonological output lexicon. This is evidenced by the production of phonologically similar and semantic errors. One may notice that semantic errors were found in both reading and naming; nevertheless, their rate was much lower in the former than the latter task (7/53 and 3/10 vs. 20/23). The discrepancy is consistent with the summation hypothesis that orthographic information and semantic information interact in the selection of a phonological representation in word reading (Hillis and Caramazza, 1995a). A lower proportion of semantic errors is due to constraints imposed by phonological information associated with orthographic input.

Given CK's much lower performance on writing tasks, his difficulty in writing is the focus for the rest of the discussion. In writing-to-dictation of single words and object names, CK produced unambiguous phonologically plausible errors, of which many were homophones. The source of homophone errors can be argued to be associated with the non-semantic pathway of writing (Law and Or, 2001). The presentation of an auditory stimulus activates a relevant entry in the phonological input lexicon, which then activates all the orthographic representations in the output lexicon that are associated with the same pronunciation, and to some extent units that are highly similar to the stimulus. Under normal circumstances, the selection of an entry for production is guided by semantic input and a correct representation is chosen. However, in a disrupted orthographic lexicon, the target unit might not be available or have the highest level of activation; as a consequence, an orthographic representation that closely resembles the stimulus phonologically could be selected. Although unlike CML in Law and Or, CK did not exhibit a dissociation in performance between written naming and writing-to-dictation, his production of homophone errors replicates part of the findings from CML, and thus strengthens the claim about the existence of a lexically-mediated non-semantic route for writing Chinese.

CK not only made phonologically plausible errors in writing-to-dictation but also in written naming. The 12 errors in question included 8 homophones and 2 tonal errors. In a naming task, a pictured object activates corresponding semantic features, which then simultaneously access the phonological and orthographic lexicons. The activated phonological representations may subsequently address the orthographic lexicon. If this is the case, the presence of phonologically plausible errors in naming argues for access from the phonological output to the orthographic output lexicon, suggesting a mediated pathway of writing Chinese. A similar claim has been made in Law and Or (2001), although based on a different observation. The authors postulated such a connection in light of the similarity in CML's neologistic responses in oral and written naming. The extraneous characters in her written naming errors were homophonous with the irrelevant syllables inserted in her oral naming output. In other words, phonologically plausible naming errors by CK reinforce the proposal that written production may be mediated by the phonological lexicon, but it must be emphasized that their occurrence, along with the observation about CML's jargon naming responses, does not preclude the unmediated version.

It was mentioned earlier that CK showed greater difficulty in writing functors than nouns, but no form class effect was found in reading. Of the 15 trials on which he actually produced a written response to a functor stimulus, 14 were unambiguous phonologically plausible errors and one was a phonologically/orthographically similar error. In addition, 12/ 15 involved a change of word class. In other words, CK tended to produce a noun, verb, or adjective for a function word target. His difficulty with writing functors did not seem to be related to the effects of word frequency or concreteness. His responses were in most cases (11/15) lower in frequency than their target and his performance on the "imageability" word list revealed no effect of word concreteness (high imageability items: 19/30 vs. low imageability items: 16/30). A similar tendency of substituting content words for functors was observed in the function word processing test where 68.7% (57/83) of the errors involved a change of form class. The disruption to function word production may be attributed to impairment at the semantic and/or orthographic levels. For the latter deficit, there have been case studies of English-speaking patients with form class dissociations in written production. Hillis and Caramazza (1995b) described a patient, Jeanette, who exhibited a dissociation between nouns and verbs (with nouns superior to verbs) in written picture naming vis-à-vis intact lexical comprehension. Rapp and Caramazza (1997) presented the results of a patient, PBS, indicating opposite patterns of performance on nouns and function words in written and spoken sentence production, more specifically, better performance on functors than nouns in speech but near absence of functors with largely spared production of nouns in written tasks. These findings argue for grammatical category distinctions in the orthographic lexicon. CK's poor production of function words in the Cloze test suggests that the deficits underlying his inferior performance on functors to nouns in writing cannot be limited to an impaired orthographic lexicon but must include disruption at the semantic level. The relatively good performance on reading aloud words of different form classes is believed to be due to the functioning of the direct reading route.

Besides character output, a good proportion of CK's responses were non-existing characters resulting from the substitution, deletion, insertion, or transposition of character components. Of these error types, radical substitution was the most frequent and the resultant non-characters preserved the configuration of their target in most cases (30/34). That the overall makeup of the target was retained at such high frequency may have implications for the structural representations of characters in the lexicon. Two possibilities are proposed. It is conceivable that an orthographic representation

contains not only the identity of its constituents but also a template of its configuration. When a deficit selectively compromises identity information on some of the constituents while leaving the structural information intact, the system may fill in the missing information with another radical, such that the overall construction of the character remains unchanged. Alternatively, the representation has identity information on its components, each of which is further specified for positional information. For example, 姑 gul 'aunt' is composed of \pm , \pm , and \Box ; the three radicals are further marked as \pm : left, \pm : top-right, \equiv : bottom-right. When one of these components is unavailable in an impaired representation, the system will look for a replacement with compatible positional information. The proposal for the specification of spatial information at the level of character constituent has been put forth in Taft et al. (1999).⁵ These researchers studied the transposability effect on Chinese character decision responses. In English, the effect refers to the longer decision time to words like tort that create another word trot through reversing the order of two letters than words that do not (e.g. tart), or slower reaction time to nonwords (e.g. graet) that were created by switching two letters of a real word (i.e. great) than nonword control (e.g. brane). The researchers found minimal transposability effect on real characters and noncharacters composed of two radicals in either lexical decision or naming. A significant effect, however, was obtained when the stimuli were noncharacters constructed out of transposing two radicals of four-radical characters, or when they were two-character words. Taft et al. argued that a character representation would only be adequately activated when at least half of its components were in their correct location to create interference in character recognition. Since positional information was not represented at the character level, two-character stimuli would activate word representations containing the characters, which then caused interference (or transposability effect) in lexical decision. The results were taken to signify the presence of positional information in radical representations. Returning to CK's errors, the "template" and "spatially-specified radical" hypotheses both make the prediction that constituent substitutions will keep the character configuration, whereas they differ in that the former expects the occasional occurrence of errors with a substituting component appearing in a position where it normally does not. The substitution errors retaining the overall character structure produced by CK were then examined. A substituting radical was considered position-appropriate if it occupied the same location as that in at least one real character. Position-inappropriate substitution was found to take place once, $_{::ii} \rightarrow * 抗$, where the constituent JL does not occupy the middle position of a character but may occur at the top 凰, the bottom 登, or on the right 劉. Since at present the conception of the "template" hypothesis is too rudimentary to properly estimate the frequency at which such substitutions may occur, and given the small number of relevant cases here, it seems more reasonable to say that the present data were insufficient to address the issue, they nevertheless strongly suggest that character representations contain information more than the identity of constituents.

Conclusion

CK's production of unambiguous phonologically plausible errors, mostly homophones and tonal errors, in writing-todictation and written naming supports the existence of a nonsemantic pathway of writing Chinese. Their occurrence in written naming entails access from the phonological lexicon to the orthographic lexicon. In addition, the finding that his non-character responses with substitution of character component(s) retain the overall configuration of their target at high frequency raises the possibility that orthographic representations contain not only the identity of the constituents but also information related to the structure of the character, perhaps in the form of a structural template or specification of position of occurrence for each constituent. In short, observations from this case study reinforce previous claims about the connections among modules in the lexicon and shed light on the nature of the structural representations of characters.

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Notes

¹It is the case for Cantonese. In Mandarin, the character 兒 is a retroflex.

²Phonetic transcriptions are given in *jyutping*, a romanisation system developed by the Linguistics Society of Hong Kong. The tone of a syllable is represented by the number in the transcription.

³In this report, an input/output distinction is assumed in the processing of phonological and orthographic information in Chinese for the purpose of relating certain aspects of CK's performance with those of CML in Law and Or (2001).

⁴For many Chinese characters, the overall structure is mixed. For instance, \pm has a left-right configuration at the "first level", \pm and \pm ; \pm itself has a top-bottom structure, \pm and \Box . In the analysis in question, we considered the configuration of the structure that immediately contained the constituent being substituted for. In other words, if \pm is substituted, the structure concerned has a left-right configuration; if \Box is replaced, the configuration will be top-bottom.

⁵Taft and Zhu (1997) reported faster lexical decision times to characters containing components with high type frequency (i.e. components that appear in many different characters) compared with characters with low type frequency constituents. Furthermore, this radical frequency effect was restricted to the right-hand position of a character with a left-right structure and to those radicals that frequently appear on the right. The authors concluded that radical frequency is position sensitive. The claim was challenged by Feldman and Siok (1997) on the grounds that the right position advantage might have been confounded with the function of a radical. In particular, the right component is overwhelmingly the phonetic radical in phonetic compound characters. Feldman and Siok demonstrated that when the function of a component was also considered, the effects of radical frequency on decision latencies persisted while the position effects were not reliably found.

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