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Article

Reading comprehension without phonological mediation: Further evidence from a Chinese aphasic individual

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An important issue in visual word comprehension literature is whether or not semantic access is mediated by phonological processing. In this paper, we present a Chinese individual, YGA, who provides converging evidence to directly address this issue. YGA has sustained damage to the left posterior superior and middle temporal lobe, and shows difficulty in orally name pictures and reading printed words aloud. He makes phonological errors on these tasks and also semantic errors on picture naming, indicating a deficit at accessing the phonological representations for output. However, he is intact at understanding the meaning of visually presented words. Such a profile challenges the hypothesis that semantic access in reading is phonologically mediated and provides further evidence for the universal principle of direct semantic access in reading.

word reading, phonological mediation, Chinese, case study

1 Introduction

How readers access meaning from a visual word input is a central issue in word processing research. One of the debates has concerned whether or not this semantic access process is mediated by phonological access. The phonologically-mediated hypothesis assumes that a visual stimulus only accesses its meaning by firstly activating a phonological form which subsequently accesses the meaning[1−11]. An alternative hypothesis, the direct access hypothesis, assumes that the semantic representation is directly activated by orthographic encodes[12−15].

The phonological mediation hypothesis was motivated and supported by a number of chronometric studies on normal subjects. The most important findings were reported by Lukatela and Turvey[3−6] and Van Orden et al.[8−11]. For example, in a semantic category task (e.g., Flower-is X a flower?), Van Orden et al.[8−9] found that the participants had more difficulty rejecting words and pseudo-words (e.g., "rows") which are homophones of a "yes" response ("rose") than control words ("robs"). In a semantic priming study, Lukatela & Turvey[5−6] observed that the target words (e.g., "frog") benefited equally from a semantic-related word ("toad"), a word that is homophonic to the semantic-related word ("towed") and a pseudo-word that is homophonic to the semantic-related word ("tode"). The semantic priming effect produced by these homophone words was explained as followings: the visual input (e.g., "towed" or "tode") accesses its phonological representation (/toud/), which is identical to the phonological representation of the semantic neighbor ("toad") of the target; this phonological representation serves as an input to activate the corresponding semantic representations and therefore activates both "towed" and "toad" to the same degree, resulting in the priming of "frog". In other words, the results are readily explained by the phonological-me-

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diation hypothesis of semantic access in visual word recognition.

Subsequent studies have challenged this hypothesis. For example, using a broader semantic category in the semantic judgment task (e.g., living thing?) than the ones used in Van Orden et al.'s experiments[8−9], Jared and Seidenberg[16] failed to find the homophone semantic priming effect. Jared & Seidenberg reasoned that the homophone effect observed by Van Orden and colleagues was, at least in part, due to the subjects' strategic factors. In the experiments where narrow semantic categories were used, the phonological representation of their members might be pre-activated, and the phonological activation of homophonic words comes from the semantics system (the narrow semantic category) but not from the orthographic input, so successful reading comprehension is possible without phonological knowledge.

The most challenging evidence to the phonological-mediation semantic access hypothesis comes from the studies of brain-damaged individuals. The logic is straightforward. If phonological mediation is mandatory in the semantic access of visual word comprehension, it might be expected that impairment in retrieving the phonological representation might result in poor per-

dence which directly addresses this issue. YGA showed a clear deficit in phonological retrieval tasks such as oral picture naming and oral word reading. Nevertheless, he was perfect at visual word comprehension and oral repetition tasks, suggesting the existence of a direct access route of semantic representation from visual input.

2 Case background

YGA is a 58-year-old, right-handed, Mandarin-speaking man with a middle school education. He had been the manager of an auto service company before he retired three years ago. Ten days before be admitted to a hospital, he was suddenly not able to read the newspaper, and had occasional sharp pain on the top of left brain hemisphere. He had no dizziness or nausea. His family members reported that five days later he had some paraphrasias in speech, without symptoms of headache, nausea, limb paralysis, dysarthria or ataxia. A brain magnetic resonance imaging (MRI) scan on the day of hospitalization revealed that YGA had an infarct in the left posterior superior and middle temporal lobe (Figure 1). He was diagnosed with anomic aphasia according to the Chinese adaptation[35] of the Western Aphasia Battery[36].

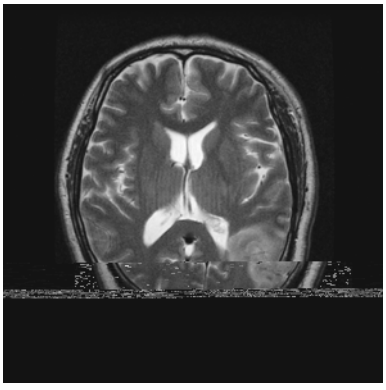

Figure 1 MRI scan of YGA

YGA's spontaneous speech was fragmented with word finding difficulties. He produced the following to describe the Cookie theft picture from the Boston Diagnostic Aphasia Examination[37]: "At home, children, his mother in, in kitchen, prepare, just that, wipe stuff, son and daughter go onto window, cabinet to take food. At home, at, there is big cabinet, small closet, that is about it. (Where is it?). /*chui2fang2*[1]/ (a nonword phonologically similar to kitchen, /*chu2fang2*/), room to make food stuff, wash clothes. (, , , , , , , , , , , , , , , , , , , . (: ?) chui2 , ,). We started testing him about one month post onset of his stroke using the BNU-CNLAB language screening battery (see Bi, Han, Shu, & Caramazza[38]). He had no errors on the Bucco-facial apraxia task (15/15 correct), and only one error in the oral repetition (39/40), had a mildly reduced auditory digital span (forward: 5, backward: 3). He showed intact auditory comprehension abilities (auditory lexical discrimination: 40/40; auditory lexical decision: 19/20; auditory word/picture matching: 50/50), and was also spared concerning visual comprehension tasks (visual word/picture matching: 50/50; visual sentence completion where he needed to choose one of four printed words to complete a visually presented sentence: 20/20). He had difficulty with oral picture naming (35/68) and oral word reading (47/57). He was poor at written picture naming (3/10) and writing to dictation (2/10), although he could perform direct-copying well (10/10). His main error types in oral picture naming were semantic substitutions (16/33, e.g., (/*tuo1xie2*/, slipper) → (/*jiao3*/, foot); (/*sao3*/, sweep) → (/*ca1*/, wipe) and phonological errors (13/33, e.g., /*shu4*/ (, tree) → /*lu4*/; /*shui3bei1*/ (, cup) → /*shui3pei1*/). Other errors included unrelated lexical errors (1/33, (/*tiao4sheng2*/, rope skipping) → (/*xiang4pian1*/, photo) and no responses (3/33). In word reading-aloud, all of his erroneous responses were phonologically related to the targets (8/10, e.g., (/*zhu4*/, wish) → /*chu4*/; (/*qian1*/, signature) → /*jian1*/) except for the "don't know" response trials (2/10).

YGA's good performance on comprehension tasks in the screening test showed that his semantic knowledge was relatively spared. The prevalence of semantic and phonological errors in oral picture naming and word reading suggests that his deficit was due to the phonological (output) lexicon or the access to it. Critically, despite this impairment of accessing phonological lexical representations, his understanding of visual words

[1] The number denotes one of four tones in Chinese.

did not seem to be affected. However, one may argue that the picture-word matching task used in probing the comprehension abilities should have been relatively easier, as the subject could complete the task by either successfully identifying the target or rejecting the foil, and therefore the tasks were not sensitive enough to detect mild semantic impairment.

Hence, in experimental study, we investigated the reading comprehension and phonological access abilities of YGA using a much larger set of stimuli and more sensitive comprehension tasks.

3 Experimental study

To closely examine YGA's reading comprehension and phonological production ability we presented the following five tasks using the same stimuli set[39]: visual word/picture verification, auditory word/picture verification, oral picture naming, oral repetition, and oral word reading. In three experimental sections we studied these relevant functions by analyzing YGA's overall performances and the contributing variables. Note that a further set of stimuli was constructed for the reading task due to specific nature of the reading process (see 3.3).

3.1 Experiment a: visual and auditory word comprehension

The two verification tasks were constructed using 162 pictures from the Chinese adaptation of the Snodgrass and Vanderwart set[40]. Each of the critical items (e.g., tiger) was presented in three separate blocks, once along with the target word (e.g., (/*hu3*/, tiger)), once with a semantically related word ((/*bao4*/, leopard)) and once with a phonologically and/or orthographically related word ((/*gu3*/, drum)). The inclusion of these related foils ensures the sensitivity of the task in detecting mild semantic, phonological, or orthographic impairments in word comprehension. The aee words associating with each picture were assigned into aee blocks using the Latin-square ign. In the al word/picture ation the word was printed below the pictuae on the e sheet and in the ditory version the word was spoken by the experimenter. The subject needed to say "yes" or "no" whether the word matched the pictuae. An item was scored as correct only if he was correct in all aee blocks, i.e., correctly accepting the target and rejecting the two foils. This task is found to be more sensitive to word-pictuae matching because the subjects cannot make correct decisions based solely on the knowledge of a foil[41]. Given that visual word comprehension is the focus here, we specifically compared YGA's visual word rification performance to the corresponding control data. The able control .data unpublished) were based on the performance of 15 college students Beijing Normal University (Mean age: 23).

The first plete response s of controls YGA's were scored. YGA's correct percentages in all given in Figuae His performance on the o word-pictuae verification 8asks had few errors. In the visual verification 8ask, there was even a ant trend th YGA (96%) performed better than the controls .mean: 94%, range: 86%−98%) (P = 0.31). The statistical program developed by Crawford & Garthwaite[42] was used here for this comparison. Therefore, YGA's semantic knowledge, least for the concrete objects that we assessed, was preserved and the semantic access from visual input was spared.

3.2 Experiment b: oral production I (oral picture naming and oral word repetition)

Both of the o oral production tasks used the stimuli of all 232 items from the Chinese adaptation of the Snodgrass and Vanderwart set[40]. YGA showed evident impairment in oral word pictuae naming (Figuae). Given that he made no errors in oral repetition of the same items, his difficulties were not due peripheral oral producon deficit. As shown in Table 1, in oral pictuae naming, ade semantic errors and phonological errors.

We carried out a multiple logistic regression analysis to elucidate the variables that influenced YGA's naming performances. The accuracy of the responses was treated as a dependent variable (1 for correct and 0 for incorrect). The independent variables included word length (number of syllables), name consistency, image consistency, familiarity, visual complexity[39], and log frequency of words[43]. Using the "enter" method, we found that word frequency was the only significant predictor of his oral picture naming accuracy (P = 0.02). This result further confirms our deduction t YGA was impaired at the stage f retrieving phonological (output) lexical representation for oral production. This is because, it is generally agreed that familiarity is a variable affecting semantic/conceptual representations and word frequency is a variable playing a role at ge of lexical access[44−48].

YGA's semantic errors in oral picture naming, despite having spared semantic knowledge, may be attributed to the deficit in accessing phonological output lexicon. As firstly articulated in Caramazza and Hillis[49], semantic errors in production may either arise from the semantic level or from the lexical retrieval stage. This is because the semantic representation of a target during oral production activates a cohort of semantically related lexical nodes in phonological output lexicon. In a normal situation, the target phonological representation is most highly activated, reaching the selection threshold and is produced correctly. If the target lexical representation is not available due to brain damage, however, a semantic related word is then most likely to be selected, leading to the occurrence of semantic errors.

3.3 Experiment c: oral production II (reading words aloud)

Material Set 1: The same set of items used in Experiment b was presented to YGA and he was asked to read the words aloud. YGA had impairment of this task (Figure 2), although his performance was better than oral picture naming of the same items ($\chi^2(1) = 51$, $P < 0.00001$). In oral reading, most of his errors were phonological (Table 1). We also conducted a similar multiple logistic regression analysis to understand the nature of his reading difficulty. The dependent variable was the reading accuracy of a particular item. The independent variables included word length, familiarity[39], and log lexical frequency[43]. No variables were observed to significantly predict his reading accuracy ($P > 0.25$).

The lack of lexical frequency effect in YGA's reading might be due to the existence of a reading pathway that bypasses the phonological lexicon. It is widely accepted that at least two routes underlie the reading aloud process – the semantic route and the nonlexical grapheme-phoneme conversion route[50,51]. In Chinese the nonlexical conversion process might be achieved by means of the phonetic radicals. A majority of Chinese characters are composed of a semantic radical that provides cues of meaning and a phonetic radical that gives cues of sound. In the case of so-called regular characters, where the phonetic radical is pronounced the same to the whole character, successful reading aloud of the whole characters may be deduced from the phonetic radical without the involvement of the target phonological lexical representation. Because the stimuli set we used contained a mixture of regular and irregular words, the effect of the lexical frequency of entire words might be shadowed.

Material set 2: Given that the current issue is whether or not YGA is impaired with accessing the phonological (output) lexicon and at least partly underlies the reading-aloud difficulty, we designed a further set of stimuli that manipulated both the lexical frequency and the phonetic regularity of characters. A 2 (word frequency: high, low) × 2 (phonetic regularity: regular, irregular) design was used and forty items were selected for each cell. We observed that the reading of regular characters was not affected by frequency (34/40 vs. 30/40, $\chi^2(1) < 1$), whereas concerning irregular characters, high frequency characters were read significantly more accurately than low frequency ones (35/40 vs. 23/40, $\chi^2(1) < 9.03$, $P < 0.003$). Thus, the impairment in the phonological lexicon indeed played a role in YGA's reading impairment.

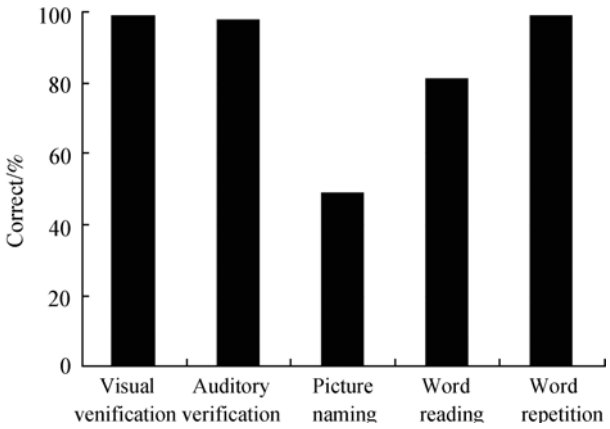

Figure 2 YGA's correct percentages across tasks in the Experiment

Table 1 The error distributions in YGA's picture naming and word reading performances (number of errors in parentheses)

Error type	Picture naming	Word reading
Semantic error	52% (62)	4% (2)
Phonological similar error	32% (38)	93% (42)
Visual similar error	2% (2)	0% (0)
Neologism	2% (2)	2% (1)
Unrelated errors	1% (1)	0% (0)
No response	12% (14)	0% (0)
Total	100% (119)	100% (45)

4 Discussion

We present a clear profile showing dissociation between visual word comprehension and visual word reading/oral production in a Chinese case. YGA performed normally in a variety of visual and auditory word comprehension

tasks, including word/picture matching, sentence/picture matching, sentence completion, and word/picture verification. Critically, in the visual verification task which has proven to be sensitive to the breakdown of the semantic system[41], YGA's performance was even higher than the control subjects who were of a higher education level and younger age than him. However, he had difficulty reading aloud the same visual words which he had correctly comprehended. He also made semantic errors and phonological errors in oral picture naming for the same items. Furthermore, he presented a word frequency effect in these oral production tasks including picture naming and word reading aloud. Together these results demonstrated that YGA's deficit was localized to the access of the phonological output representation and/or the phonological representation itself.

YGA's error-free visual word comprehension ability despite his phonological output lexicon (or access to it) deficit challenges the phonological mediation semantic access hypothesis for reading. This hypothesis assumes that successful reading comprehension is mediated by phonological access and hence predicts that semantic access in reading will be compromised due to phonological processing deficit. The proponents of this theory might argue that YGA achieves an error-free performance task via partially preserved phonological representation, which was impaired in oral reading aloud and picture naming, yet preserved enough to sustain accurate semantic access. However, in our word comprehension test, foils were semantically or orthographically/phonologically related to the target. It is unlikely that the partial phonological knowledge would allow YGA to correctly refuse the foils in this task but lead to errors in production tasks.

YGA's performance is readily explained by the direct access hypothesis, which assumes that there is a direct connection from the orthographic input lexicon to the semantic system. If we assume that the brain-damage in YGA disrupted access to the phonological output lexicon and spared the direct pathway from the orthographic input lexicon to semantic representation, YGA's behavioral patterns may be accounted for (e.g., Coltheart et al., 1980[12], 1997[13]; see also some connectionist theories for a similar notion[52−54]).

In the following sections we discuss the implications of this conclusion in a more general framework of lexical access in reading firstly by addressing the following two aspects of YGA's performances. First, why did YGA show superior performance on oral reading over oral picture naming? If the phonological representation was impaired, why did not it affect oral reading and oral picture naming to the same degree? This discrepancy in the two tasks may be attributed to the classical dual route model of reading aloud[13], which assumes a nonlexical grapheme-phoneme conversion route to generate phonology from visual input and a semantic route that goes through the semantic representation of words. The output of these two routes may also integrate with each other to optimize the production accuracy and to prevent semantic errors in reading aloud[50,51,55,56]. In oral picture naming, by contrast, the only processing pathway is the semantic route – activation from the semantic system activates corresponding the phonological representation and there is no additional compensation mechanisms available.

The other issue is why YGA was intact in auditory word comprehension and oral word repetition while he had difficulty in accessing the phonological output lexicon information, as shown by impaired performance in or045 m5lutoc3oor0t3iininn (in)4d.3(re(o)-4i)(3i)4.6iin045 mo.6(o)

ing phonological lexical processing[62].

One caveat[2] to consider here is that we have granted that the phonological mediation semantic access hypothesis assumes that the phonological mediation happens by going through the phonological *output* lexicon because there is no phonological input available in the visual word stimulus, and it is the same phonological *output* lexicon which underlies the oral production processes such as picture naming and reading aloud. Nevertheless, as discussed earlier, it is a generally accepted view that the phonological *input* process and the phonological *output* process are functionally autonomous and are therefore independently damaged[17−21, 49, 58−61]. It has been posited that there is a direct connection from the orthographic input lexicon to the phonological input lexicon, and the phonological input lexicon may serve as a mediating component for semantic access[19]. Such a theory would indeed accommodate our data because YGA had good performance on auditory word comprehension and lexical tasks showing that his phonological input lexicon was preserved and might mediate successful semantic access. However, the premise of the theory – the direct connection between the orthographic input lexicon and phonological input lexicon – is not intrinsic to the lexical representation framework and would require support from independent motivation and evidence.

In conclusion, the case presented here parallels those cases reported in alphabetic languages. They together support a universal principal that successful reading comprehension does not rely on phonological mediation, but rather is achieved through a direct connection between the orthographic input lexicon and semantic representations[21].

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