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Demonstrating a wordlikeness effect on nonword repetition performance in a conduction aphasic patient☆

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Abstract

The purpose of this study was to identify the nature of the deficit for a conduction aphasic patient in order to evaluate two different theories of conduction aphasia. First, a conduction aphasic patient FS was tested on auditory word-pair discrimination, word-repetition, and picture-naming. The results of these tasks indicated that her deficit was likely to be post-lexical rather than perceptual or lexical. Next, we examined her repetition performance for two types of nonwords (high-wordlike and low-wordlike nonwords) to distinguish the two theories. FS exhibited a wordlikeness effect: she produced more correct moras and more correct combinations of moras for high-wordlike nonwords than low-wordlike nonwords. We conclude that she had difficulty in maintaining stable phonological representations of verbal materials in the output buffer.

1. Introduction

Conduction aphasia is characterized by impaired repetition combined with relatively intact auditory comprehension. Another symptom of this aphasia is the production of sublexical errors (phonemic paraphasias) across different tasks that measure output ability (e.g., picture naming and word repetition: Caplan, 1992; Kohn, 1989). Sublexical errors involve addition, deletion, substitution, and misordering of segments. Substitution errors occur when the target segment is replaced by an adjacent one (e.g., Crete → [krik]) or by a contextually unrelated sound. Order errors happen when two target segments exchange their place within or between the words (e.g., degree → [gədriz]—from Blumstein, 1990).

Within standard models of speech production, sublexical errors in conduction aphasia arise from a deficit at the post-lexical or phonological-encoding stage in speech production (e.g., Kohn, 1984; Pate, Saffran, & Martin, 1987; see Fig. 1). At this stage, the phonological representation of the intended word that has been retrieved from the phonological lexicon is temporarily stored in an output buffer and each segment in the word is placed in the correct position. Three lines of evidence suggest that the critical impairment occurs at the post-lexical stage and not at the lexical retrieval stage.

First, conduction aphasic patients tend to show performance on picture naming that is qualitatively similar to that on other word production tasks (e.g., Caplan, 1992; Kohn, 1989; Shallice, Rumiati, & Zadini, 2000; Wilshire & McCarthy, 1996). Word production tasks such as repetition or reading depend relatively less on the lexicon than naming does because the surface form of the target word activates sublexical phonology directly. Naming, however, involves the retrieval of the target word's phonological representation, implying that naming performance should be directly affected by a retrieval deficit. On the other hand, when the deficit is in the post-lexical stage, naming performance should not differ greatly from word reading or repetition performance (Nickels, 1997).

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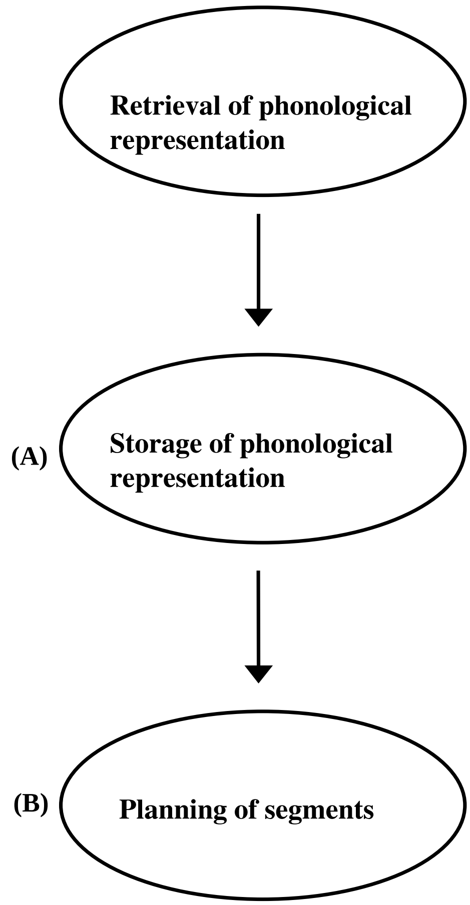

Fig. 1. Post-lexical or phonological encoding stage in speech production processes. Retrieved phonological representation of the target from the lexicon is stored in an output buffer (A), and then each segment in the target is ordered in the correct position (B).

Second, sublexical errors produced by conduction aphasic patients are closely related phonologically to their target words (e.g., Butterworth, 1992; Kohn & Smith, 1994; Wilshire & McCarthy, 1996), suggesting that problems arise after the successful retrieval of the target phonological representation from the lexicon, where it has been activated normally. If activation of phonological representations in the lexicon were impaired, the target's representation might not be retrieved from the lexicon and incorrect responses caused by an impairment at this level would show less resemblance to their target words than those caused by a post-lexical deficit.

Third, conduction aphasic patients are often aware of their sublexical errors when they fail to produce a target word and they try to correct themselves by making repeated attempts to produce the correct target (*conduite d'approche:* e.g., Caplan, 1992; Joanette, Keller, & Lecours, 1980; Kohn, 1984; Wilshire & McCarthy, 1996). This suggests that they know the target representation but do not arrange the constituent segments correctly. Finally, since conduction aphasic patients do not usually show articulatory problems, it is unlikely that the deficit is in the articulatory process.

Although there has been general agreement that the hypothesized deficit for conduction aphasia is in the post-lexical stage of speech production, there are two differing explanations of the nature of the deficit. Kohn (1984) argued that conduction aphasic patients possess a stable phonological representation in the output buffer,[1] but experience a breakdown in sequencing the target's segments in the correct order (hereafter, the phonological planning deficit hypothesis). In contrast, Yamadori and Ikumura (1975) proposed that the deficit in conduction aphasia arises from a difficulty in maintaining a stable acoustic image of the target word. As their subject, similar to other conduction aphasic patients, did not exhibit differences between picture-naming and word-repetition performance, it seems that the deficit did not arise from a difficulty in activating the target representation in the lexicon. That is, it is unlikely that her deficit reflected incomplete or impaired activation of phonological representations in the lexicon. Rather, Yamadori and Ikumura's (1975) assumption about her deficit could be interpreted as a difficulty in maintaining a stable phonological representation in the output buffer (hereafter, the unstable phonological representation hypothesis).

These two hypotheses provide different predictions for single word and nonword repetition for conduction aphasic patients since each hypothesis assumes different levels of phonological activation in the output buffer. The phonological planning deficit hypothesis suggests that accuracy for words and nonwords should be similar. Kohn (1984) assumed that the output buffer is intact and, therefore, that every item in the buffer should be represented strongly and to the same degree, irrespective of their differences (e.g., real words versus nonwords). In contrast, the unstable phonological representation hypothesis predicts a lexicality effect. As this hypothesis postulates that the output buffer is impaired, phonological representations in the buffer should decay rapidly. The stability of the target representation in the buffer could be strongly affected by differences between real words and nonwords.[2] These differences may

[1] Although Kohn (1984) refers to the buffer as working memory, to the extent that she has conceived the function of working memory as retaining a trace of the phonological representations, its function resembles that of the output buffer proposed by Pate et al. (1987). That is, its primary function is storage. For this reason, we have interpreted Kohn's concept of working memory (1984) as an output buffer.

[2] The unstable phonological representation hypothesis would also predict length effects. Because the output buffer is impaired, repetition performance of a patient with an impairment of the buffer would decrease as the number of segments or words that have to be maintained increases. In fact our conduction aphasic patient examined in the following experiment fails to repeat all sentence stimuli, implying that she may have an impaired output buffer

include not only the lexical status of the target—real words are in the lexicon but nonwords are not—but also the phonotactic (sound sequence) pattern of the target. Items in the lexicon and/or with a familiar phonotactic pattern should increase the stability of the phonological representation in the output buffer.

Results reported in Kohn (1989) and Kohn and Smith (1994) support the phonological planning deficit hypothesis: they found no difference between real words and nonwords in repetition performance for a conduction aphasic patient. These results would seem to contradict the unstable phonological representation hypothesis. There are, however, many studies that have obtained results showing a strong lexicality effect on repetition performance (Caplan, Vanier, & Baker, 1986; Caramazza, Miceli, & Villa, 1986; Dubois, Hecaen, Angelergues, Maufras de chatelier, & Marcie, 1964/1973; Notoya, Suzuki, & Kurachi, 1982; Shallice et al., 2000; Strub & Gardner, 1974; but see Valdois, Joanette, Nespoulous, & Poncet, 1988). In addition, the unstable phonological representation hypothesis is able to account for Kohn's results (1989); (Kohn & Smith, 1994). In their studies, they made half of the nonwords resemble real words by replacing only one segment of a real word.[3] As this type of nonword does not deviate greatly from familiar phonotactic patterns in the language, these similarities in phonotactic pattern could reduce the lexicality effect in repetition of real words and nonwords. The unstable phonological representation hypothesis maintains that the phonotactic pattern of a target is an important factor in determining the stability of a target representation in the output buffer. If a nonword has a familiar phonotactic pattern, the stability of the representation for that nonword should not differ greatly from the corresponding real word.

If the phonotactic pattern of nonwords was a primary cause of the lack of lexicality effect in Kohn's studies, manipulating this factor would make it possible to distinguish the two hypotheses. In this study, we created two types of nonwords (phonotactically common and uncommon nonwords) and compared single nonword repetition performance for the two types in a conduction aphasic patient. The phonological planning deficit hypothesis predicts that there will be no differences in performance between phonotactically common and uncommon nonwords because the intact output buffer has enough capacity to retain any type of phonological representations. The unstable phonological representation hypothesis, on the other hand, predicts that phonotactically common nonwords will be repeated better than phonotactically uncommon nonwords because the former type of nonwords are retained more strongly in the output buffer than the latter type of nonwords. We will discuss possible mechanisms for this effect in more detail in Section 6 suffice it to say that the general underlying assumption is that pathological phonological decay in the output buffer might be counteracted by input from/interaction with lexical and phonological knowledge.

In the current study, we selected stimuli from a set of nonwords provided by Saito, Saito, and Yoshimura (2000). Most nonwords in the set were constructed by a procedure similar to that of Kohn and Smith (1994): one type of nonword was constructed by replacing one or two moras[4] of real words (nonwords related to real words, e.g., *shikori* (tumor in English) → *chikori*: here *shi* is replaced by *chi*) and the another type is made up of moras combined randomly (nonwords unrelated to real words, e.g., *yuhahe*).

As the stimuli in the set consisted of two-, three-, four-, and five-mora nonwords, it was necessary to maintain qualitative differences between phonotactically common and uncommon nonwords across nonwords of differing number of moras. For example, to construct nonwords related to two-mora real words, we replaced one of the moras in a given word by another mora which did not appear in the word. To make five-mora nonwords, however, we replaced up to two moras in the word. It remains uncertain, therefore, whether the two-mora and five-mora nonwords had similar phonotactic properties. For this reason, we asked normal adults to rate how wordlike each nonword was. Then, according to the wordlikeness values of the nonwords, we divided these nonwords into two categories, *high-wordlike nonwords* and *low-wordlike nonwords,* following a procedure similar to that of Gathercole, Willis, Emislie, and Baddeley (1991). We recognize that the concepts of phonotactic commonness and wordlikeness are not the same: the former is determined by examining the frequency of sound combinations objectively, whereas the latter depends on the subjective evaluation of sound patterns. However, phonotactic commonness is an important factor influencing the evaluation of wordlikeness, and high-wordlike nonwords reflect phonological sequences with high phonotactic probabilities (Gathercole & Martin, 1996). In fact, the normal adults in this study generally rated *nonwords related to real words* as high-wordlike nonwords and *nonwords unrelated to real words* as low-wordlike nonwords, confirming this supposition.

In this study we investigated the performance of a conduction aphasic patient. First, we examined her

[3] There are no specific descriptions regarding the criteria of selecting or making nonwords in the other studies where the lexicality effect did occur.

[4] The mora is a subsyllabic unit that includes a vocalic nucleus (V), a nucleus with onset (CV or CCV), or a nasal consonant (N) in syllabic coda position (Cutler & Otake, 1994). For example, a two-syllable word *Kyoto* has three morae (CCV-V-CV; Kyo-o-to) and *Ninja* has also three (CV-N-CV; ni-n-ja). Analysis of naturally occurring phonological speech errors has demonstrated that the mora is a basic unit in phonological processing in Japanese (Kubozono, 1989; Terao, 1988).

performance on the following three tasks to confirm that her deficit was at the post-lexical level in speech production: (1) auditory word-pair discrimination, (2) word-repetition task, and (3) picture-naming task. Because repetition performance involves auditory input-side processing (e.g., perceiving and recognizing auditorily presented materials), we had to examine first whether input-side impairments for auditorily presented materials would cause problems in speech output. In the auditory word-pair discrimination task, we investigated her ability to determine whether the auditorily presented word-pair was identical or not. We then examined her performance on picture naming and word repetition to confirm the location of her deficit.

Second, we investigated her ability to repeat nonwords. By comparing her performance on high-wordlike and low-wordlike nonwords, we were able to assess the two hypotheses regarding the nature of the deficit for conduction aphasia.

2. Experimental studies

2.1. Case report

The patient (FS) was a 68-year-old right-handed female. She was admitted to the hospital for exhibiting language difficulties in November 1998. Angiography revealed an occlusion at the left angular artery, affecting the left angular gyrus. In December 1998, FS was tested on the Standard Language Test of Aphasia in Japanese, the SLTA (Hasegawa, Takeda, Tukuda, Takeuchi, & Wada, 1975). She had no marked problems in recognizing either auditorily presented words and short sentences or visually presented words and short sentences; in fact, her performance was nearly perfect. However, her output ability was impaired. She named only 40% of the pictures correctly; in addition she was only able to repeat 60% of singly presented words and failed to repeat any sentence stimuli. She was unable to write words or sentences to dictation. Her verbal output was described as fluent with sublexical errors and she made a lot of repeated attempts when she tried to produce an intended word. She was diagnosed with mild conduction aphasia.

3. Auditory word-pair discrimination

3.1. Method

3.1.1. Material

Sixty word-pairs were used as experimental stimuli, of which 30 were identical and 30 were different. There were three different types of word-pairs, each type containing 10 word-pairs, as follows (dashes indicate mora boundaries): (1) a word-pair differing in one mora (e.g., *ha-i-ki-n-gu* (hiking) and *ba-i-ki-n-gu* (smorgasbord)); (2) a word-pair whose constituent moras are the same or differ in fewer than two moras,[5] with identical moras occurring in a different order (e.g., *ta-ma-tu-ki* (billiards) versus *ta-tu-ma-ki* (tornado)); (3) a word pair that does not share the same moras (e.g., *so-ba-ka-su* versus *te-mi-ya-ge*). Identical word-pairs consisted of 12 pairs of five-mora words and 18 pairs of four-mora words. Each type of different word-pairs contained four pairs of five-mora words and six pairs of four-mora words. The number of word-pairs with the same accent patterns within a pair was matched between the identical and different word-pair conditions.

3.1.2. Norms

We examined 31 normal young adults' performance on this task as control (mean age: 19.7, $SD = 3.58$). Their range of correct discrimination of identical word-pairs was from 28/30 to 30/30 and that of different word-pairs was from 27/30 to 30/30 (their range of correct discrimination of all word-pairs was from 57/60 to 60/60).

3.1.3. Procedure

The order of presentation of stimuli was randomized. The patient heard each word-pair and had to indicate whether the word-pair was identical or different; her responses were tape-recorded.

3.2. Results

She was able to discriminate correctly 29/30 of identical word-pairs and 27/30 of different word-pairs (56/60 in total). This performance was within normal range for each word-pair condition, and her total correct responses (56/60) did not differ greatly from the mean correct responses for normal adults ($\text{mean} = 58.74$, $SD = 0.62$). This result suggests that the patient recognized auditorily presented words without problems.

4. Single word production (word repetition and picture naming tasks)

4.1. Method

4.1.1. Material

Each task contained 30 two-, three-, and four-mora concrete nouns (10 each).[6] Word familiarity ratings were matched approximately between the target words for

[5] Even when moras in a word-pair differ, they nevertheless bear some phonological similarity in this condition. For example, shi-zu-o-*ka* versus shi-o-zu-*ke* (underlined portions indicated different moras). In this case, though the vowels differ, the consonants are the same.

[6] Although the stimuli for the repetition task include five-mora words, repetition performance of these five-mora words was not scored because the stimuli in the picture-naming task did not contain five-mora words.

picture naming (range = 2.04–4.43, $M = 3.38$) and those for word repetition (range = 2.03–4.43, $M = 3.26$; Ukita, Sugishima, Minagawa, Inoue, & Kashu, 1996). Five words in each word-length group (sum = 15 items) were repeated across the tasks. Stimuli used in picture naming were black-and-white drawings of objects.

4.1.2. Procedure

The patient first performed word repetition and then picture naming. In word repetition, the patient heard each word and was required to repeat it; in picture naming, she was shown one picture at a time and asked to name it. The presentation order of the target words was randomized. In neither task was response time limited. All responses were tape-recorded and later transcribed by two of the authors.

4.2. Results

The initial response on each trial was scored as correct or incorrect, and the number of correct responses was calculated. As 15 words were presented in both word repetition and picture naming, we examined whether any practice effect occurred on picture naming. We compared accuracy on repeated words (8/15) with newly presented words (7/15) and found no significant difference ($\chi^2 = 0.133$, *n.s.*). We analyzed, therefore, all of her responses on both tasks. She scored 11/30 on word repetition and 15/30 on the picture naming. The difference in accuracy was not statistically significant ($\chi^2 = 1.086$, *n.s.*).

We chose picture naming to examine whether her error responses were phonologically related to their targets because in this task the surface form of the target is not presented to the subject. We analyzed the items in which errors occurred by counting the number of items in which she made more than one phonologically related error during the presentation of each target. We considered an error that shared more than one mora with the target as a phonologically related error. Thirteen/15 items contained phonologically related errors and 2/15 did not, indicating that she produced significantly more phonologically related errors than unrelated errors ($\chi^2 = 8.07$, $p < .01$).

Patients with a post-lexical deficit can produce qualitatively similar responses across different word production tasks (e.g., Caplan, 1992; Kohn, 1989; Shallice et al., 2000). To confirm that FS fitted this pattern we compared the distribution of her responses across nine categories (Table 1) in picture naming with the distribution of responses in word repetition. These nine categories were defined as follows: (1) correct responses; (2) circumlocutions: explaining the target's property or function peripherally, such as, "a kind of kimono" for *yukata* (summer kimono); (3) semantic errors: producing words semantically related to the target (e.g., *wolf* for *fox*); (4) mixed errors: producing words phonologically and semantically related to the target (e.g., *pe-n* (pen) for *e-n-pi-tsu* (pencil)); (5) formal errors: producing words phonologically similar but semantically unrelated to the target (e.g., *hen* (a word that has several homonyms such as "strange" or "edited by")) for *se-n-su* (Japanese folding fan); (6) unrelated lexical errors: responding with words neither semantically nor phonologically related to the target (e.g., *ge-n* (a word that has several homonyms including string or reduction)) for *hi-sa-shi* (visor); (7) phonologically related nonword errors (PRNW): producing nonwords phonologically similar to the target (e.g., *chi-chi-do-ri* for *chi-ri-to-ri* (dustpan)); (8) unrelated nonword errors (URNW): responding with nonwords phonologically unrelated to the target (e.g., *ha-n-nya-ko* for *ra-ku-da* (camel)); and (9) no response. We considered an error that shared more than one mora with the target as a phonologically related error. We compared the proportion of response types between the two tasks and found the effect of response type insignificant, indicating that her responses on the two tasks were not qualitatively different ($\chi^2 = 4.027$, *n.s.*).

Table 1
Distribution of response types in word production tasks—proportion of responses in each category for FS

	Picture naming	Word repetition
Correct	0.50	0.37
Circumlocutions	0.07	0.10
Semantic errors	0.10	0
Mixed errors	0.10	0
Formal errors	0.10	0.10
Unrelated lexical errors	0	0.07
PRNW errors	0.13	0.13
URNW errors	0	0.03
No responses	0	0.20

Furthermore, like other patients with a post-lexical deficit (Shallice et al., 2000; Wilshire & McCarthy, 1996), the most common type of all sublexical errors FS made in naming pictures and repeating words was single segmental substitution where one segment within a word was substituted by another and they occurred at a similar rate for the two tasks (naming—48.3%, repeating—47.6%).

Finally, we examined whether she made multiple attempts to produce the same target. We defined more than two attempts to produce each target word as a multiple-attempt response and counted the number of multiple-attempt responses for each target on the word-production task (repeating words and naming pictures). On this task, FS produced 17/60 multiple-attempt responses, of which 9 multiple-attempt responses showed a continuous progression towards the target or resulted in eventual success (conduit d'approche). In all examples of conduit d'approche, FS stopped when the target was reached, suggesting that she recognized the sound form of the target.

5. Nonword repetition task

5.1. Method

5.1.1. Materials

Sixty nonwords were selected from a set provided by Saito et al. (2000). The stimuli contained 60 two-, three-, four-, and five-mora nonwords (15 each) of which 35 items were high-wordlike nonwords ($M = 3.60$, range $=$ 2.80–4.63)[7] and 25 were low-wordlike nonwords ($M = 1.93$, range $= 1.40$–2.50).

5.1.2. Procedure

The patient heard each nonword and was asked to repeat it. Response time was not limited and the presentation order of the stimuli was randomized. All responses were tape-recorded and later transcribed by two of the authors.

5.2. Results

Responses that the two authors could not agree on were excluded in the following analyses. Her performance on this task was poor: she produced only three of 60 nonwords correctly. Therefore, instead of examining the number of correct responses, we evaluated her performance on the repetition task by using the following two criteria to analyze the initial response for each item:

1. We counted the number of correct and incorrect moras, scoring a mora as correct only when a target mora was produced in the same position the mora occupied in the nonword. When a mora different from the corresponding mora in the target word was produced, or when the target mora in a given position was omitted, we scored it as incorrect. We then compared the proportion of correct mora production for high-wordlike nonwords to that for low-wordlike nonwords. FS produced significantly more correct moras for high-wordlike nonwords than low-wordlike nonwords ($\chi^2 = 10.67$, $p < .01$; see Table 2).
2. Next, we counted the number of correctly combined moras. For example, when the target is ABC, there are two combinations of sounds: A–B and B–C. If all the sequences of ABC were correctly produced, we gave two points (one point for A–B and one point for B–C). We compared the number of points for high-wordlike nonwords with low-wordlike nonwords. Again, a greater number of correct mora sequences were produced for high-wordlike nonwords than for low-wordlike nonwords ($\chi^2 = 6.593$, $p <$ .05; see Table 2).

Table 2
Proportion of correct moras or correct mora sequences for each nonword type for patient FS

	Moras	Mora sequencies
High-wordlike nonwords	0.27	0.20
Low-wordlike nonwords	0.09	0.06

Table 3
Distribution of FS's repetition responses

	Proportion
Correct	0.05
Formal errors	0.14
Unrelated lexical errors	0.12
PRNW errors	0.33
URNW errors	0.33
No responses	0.03

The distribution of her repetition response types is shown in Table 3. There are six categories of response type: (1) correct responses; (2) formal errors, which are words that share more than one mora with the target (e.g., *ka-re-n* (lovely), for *go-re-n*); (3) unrelated lexical errors, which are words that have no phonological relationship with the target (e.g., *ku-i* (pile) for *u-ge*); (4) phonologically related nonword errors (PRNW), which are nonwords that share more than one mora with the target (e.g., *a-i-ko-u-do* for *a-i-do-u-shi*); (5) unrelated nonword errors (URNW), which are nonwords that do not have any moras of the target word (e.g., *ni-ko-chi* for *myu-n*); and (6) no response, i.e., no attempt to repeat the target. As is shown in Table 3, the proportion of sublexical errors (URNW and PRNW errors) is high in comparison to lexical errors (unrelated lexical and formal errors) ($\chi^2 = 9.981$, $p < .01$).

6. Discussion

In the present experiment, we attempted to identify the nature of the deficit for a conduction aphasic patient in order to evaluate two different theories of conduction aphasia. First, we examined the conduction patient's (FS) performance in an auditory word-pair discrimination task. She showed almost normal performance on this task, suggesting that her output problems were not caused by input-side processing impairments. Second, we investigated her performance in both word repetition and picture naming in order to confirm that her deficit was in the post-lexical rather than the lexical retrieval level. Her qualitatively similar performance on picture naming and word repetition, the nature of her sublexical

[7] The ratings were based on a 5-point scale with 1 representing "not like a word at all" and 5 "very like a word."

errors (phonologically closely related to their targets) and the occurrence of multiple attempts to produce the target confirm that her deficit was likely to be in the post-lexical level.

Finally, we examined whether FS showed a wordlikeness effect on nonword repetition performance in order to evaluate two hypotheses concerning the locus of the deficit in conduction aphasic patients. That she showed a wordlikeness effect on her nonword repetition performance suggests she had difficulty in maintaining a stable phonological representation—the conclusion predicted by the unstable phonological representation hypothesis. According to this hypothesis, single nonword repetition performance is sensitive to the phonotactic pattern of items when the output buffer is impaired. As high-wordlike nonwords have relatively familiar sequences of sounds, phonological representations of high-wordlike nonwords should be maintained more strongly in the output buffer than those of low-wordlike nonwords. Consequently, the patient's performance for high-wordlike nonwords should be better than that for low-wordlike nonwords. In contrast, if the output buffer were intact as the phonological planning deficit hypothesis maintains, the phonotactic pattern of the nonwords should not strongly affect the patient's repetition performance because phonological representations for any type of word and nonword should be maintained equally and strongly enough in the output buffer.

These results pose the obvious question of how the phonotactic pattern of sound sequences affects the stability of items in the output buffer. Some researchers have argued that elements of the sound structure of the language, such as the phonotactic pattern, are stored as long-term phonological knowledge (Gathercole & Martin, 1996; Gathercole, Frankish, Pickering, & Peaker, 1999). This knowledge has been thought to reflect the frequency of sound combinations in a given language. As the number of times we experience a combination of sounds increases, the connections between the constituent sounds of the phonological sequences grow stronger. Because relatively common sequences of sounds in the language have a comparatively stronger representation in the organization of phonological knowledge, they are more strongly activated than relatively unfamiliar sound sequences. This knowledge of phonological sequences has also been found to help repetition in normal subjects (e.g., Gathercole et al., 1999).

The claim that repetition is aided by phonological knowledge explains how the phonotactic pattern affects the stability of items in the output buffer. Although the patient's output buffer is damaged to the extent that she cannot repeat even single words or nonwords perfectly, her repetition performance could still be influenced by her intact phonological knowledge. That is, even though phonological representations in the output buffer are unstable and decay quickly, these representations can be reactivated by the aid of phonological knowledge to some degree. Since high-wordlike nonwords reflect common phonotactic patterns, this phonological knowledge strengthens the phonological activation of high-wordlike nonwords in the output buffer more strongly than those of low-wordlike nonwords, facilitating better performance for high-wordlike nonwords.

Next, we will briefly discuss the implications of the wordlikeness effect in conduction aphasia for evaluating several speech production models proposed in the literature (e.g., Caramazza et al., 1986; Dell & O'Seaghdha, 1991; Dubois et al., 1964/1973; Kohn & Smith, 1994; McCarthy & Warrington, 1984; Notoya et al., 1982; Strub & Gardner, 1974).

The wordlikeness effect in our conduction aphasic patient could be accounted for by the interactive activation model proposed by Dell and O'Seaghdha (1991). Their model assumes interactivity between different levels of processing; it is a model that consists of a network structure, which has three levels of representation: semantic features, lexical nodes, and phonemic nodes. Since adjacent levels of representations (e.g., lexical nodes and phonemic nodes) are directly connected to each other in this model, we can explain our patient's nonword repetition performance if we regard the phonemic node as the output buffer and assume that the phonotactic knowledge is represented in the lexical node layer, or by the interaction between lexical and phonemic layers. If the functioning of the phonemic node layer is damaged causing the activation of each phonemic node to decay quickly, and if the lexical node layer works normally, the lexical nodes will tend to reactivate decayed phonemic nodes by virtue of the direct connections between these layers. As high-wordlike nonwords are assumed to have more related words with respect to phonological sequences at the lexical layer than low-wordlike nonwords do, high-wordlike nonwords represented at the phonemic layer will receive more activation from the lexical layer than low-wordlike nonwords, leading to the wordlikeness effect as observed in FS.

According to Caramazza et al. (1986), nonwords suffer from disruptions in the output phonological buffer but words do not because real words can bypass the buffer and be sent to the articulatory system directly from the lexicon. A patient with an impaired output phonological buffer should, therefore, show the superior performance for words over nonwords. As this account assumes that all nonwords are disrupted, one would not expect the wordlikeness effect on nonword repetition observed in the present experiment. However, because Caramazza et al. (1986) assumed that the role of the buffer is to hold representations for further processing, the wordlikeness effect would be expected if they postulated that the difference in the phonotactic commonness affects the stability of representations in the buffer.

McCarthy and Warrington (1984) argued that there are two different routes to the output buffer (one is a semantic route and the other is nonsemantic route) and suggested that when the nonsemantic route is disrupted, nonword repetition is severely impaired. The presence of a wordlikeness effect indicates that not every type of nonword is processed in the same way and thus, our results may not be compatible with McCarthy and Warrington (1984).

Kohn and Smith (1994) provided another model of nonword production. They proposed that the representation of a nonword is constructed on the basis of related words (neighborhood words) in the lexicon. Under this scheme, constructing nonwords depends on the normal activation of multiple, related words in the lexicon. Producing nonwords is assumed to be more difficult than producing real words for a patient with retrieval deficit because this type of patient has difficulty in activating representations in the lexicon. In contrast, their model predicts that a patient with post-lexical deficit does not necessarily show the superior performance of words over nonwords because this type of patient has an intact lexicon and, therefore, can construct nonword forms without any difficulties. If this model's assumption is correct, the performance of a patient with post-lexical deficit who has an intact lexicon should be equivalent for different types of nonwords since this type of patient should be able to construct any type of nonword. Clearly, FS's results run counter to the predictions of this model.

Dubois et al. (1964/1973) and Notoya et al. (1982) are similar to the theoretical stance adopted here in that both suggest that phonotactics contribute to repetition performance. For example, Notoya et al. (1982) argued that one of the causes of repetition impairment in conduction aphasia may be the disturbance in maintaining phonological patterns of speech and that because of this disturbance, relatively unfamiliar sequences of sounds would be more difficult to retain than familiar sequences of sounds. Since the degree of phonotactic commonness is assumed to affect repetition performance, one can expect the superior performance of high-wordlike nonwords over low-wordlike nonwords.

In conclusion, the results of this study suggest that the source of the deficit in our conduction aphasic patient is the difficulty in maintaining a stable phonological representation of verbal materials in the output buffer. We believe that pinpointing the precise mechanism of the deficit for individual patients will point us toward developing appropriate clinical treatment.

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