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Effects of Noun-Verb Conceptual/ Phonological Relatedness on Verb Production Changes in Broca's Aphasia

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Abstract

Background—Individuals with Broca's aphasia show better performance on nouns than on verbs, but distinction between nouns and verbs is not always clear; some verbs are conceptually and/ or phonologically related to nouns, while others are not. Inconsistent results on effects of noun-verb relatedness on verb production have been reported in the literature.

Aims—We investigated (1) whether verb instrumentality (a conceptual relationship to nouns) or homonymy (a phonological relationship to nouns) would affect verb production in individuals with Broca's aphasia and (2) whether conceptual/ phonological noun-verb relationship would affect responsiveness to aphasia therapy that focused on verb production.

Methods & Procedures—Three English speaking individuals with Broca's aphasia produced 96 verbs in sentences in response to picture stimuli. The target verbs included those that use an instrument and those that do not (e.g., to hammer vs. to yawn) and verbs that are phonologically identical to a related noun (e.g., to comb – a comb), morpho-phonologically-related to a noun (e.g., to grind – a grinder), and verbs for which there is no phonologically similar noun (e.g., to lean). The participants' verb retrieval ability was assessed before and after a 4-week period of aphasia therapy.

Outcomes & Results—The participants produced more accurate instrumental than non-instrumental verbs both pre- and post-treatment. They also produced more verbs correctly that are homonyms of nouns than verbs that are phonologically related or unrelated to nouns before treatment. However, the effect of homonymy was not observed following treatment.

Conclusion—Individuals with Broca's aphasia were more accurate in their production of verbs that were conceptually and phonologically related to nouns than on verb that were not. The performance on verb production improved significantly after therapy. We interpret the results to

indicate that whereas prior to treatment the participants relied on phonologically related nouns to retrieve the target verbs, this reliance on knowledge of nouns decreased following therapy that was designed to improve verb production.

Keywords

Broca's aphasia; Verbs; Instrumentality; Homonymy; Therapy; Efficacy

INTRODUCTION

Many studies have revealed noun–verb dissociations in individuals with aphasia, reporting that people with Broca's aphasia have more difficulty producing verbs than nouns and people with anomic aphasia demonstrate relatively better production on verbs (Druks, 2002; Faroqi-Shah, 2012; Miceli, Silveri, Villa, & Caramazza, 1984; Zingeser & Berndt, 1990). The underlying reasons for the differential difficulty for verbs have been debated in the literature. Possible accounts include those that point to grammatical differences (e.g., argument structure and morphological processing associated with verbs), lexical differences (reference to objects versus action, degree of abstractness), and distinct neural substrates for verbs and nouns (e.g., Mätzig, Druks, Masterson, & Vigliocco, 2009; Pulvermüller, Cook, & Hauk, 2012; see a review in Vigliocco et al., 2011). Yet, the distinction between nouns and verbs is not always clear; many verbs are conceptually related to nouns (i.e., instrumental verbs that require instruments to perform, such as *to sweep –broom vs. to yawn*) and others verbs are phonologically identical or similar to nouns (i.e., homonymous verbs that have the same phonological forms as nouns, such as *to hammer –the hammer vs. to lean*). Among studies focusing on verb production in aphasia, only a few have investigated whether these verb characteristics affect verb production in individuals with Broca's aphasia and the data – available from individuals speaking Dutch (Jonkers & Bastiaanse, 2007), Greek (Kambanaros, 2009; Kambanaros & van Steenbrugge, 2006), and English (Kemmerer, & Tranel, 2000) – have not yielded consistent results. To better understand how the relationship of verbs to semantically and phonologically related nouns influences lexical retrieval, we set out to investigate (1) whether verb instrumentality (a conceptual relationship to nouns) or homonymy (a phonological relationship to nouns) would affect verb production in individuals with Broca's aphasia and (2) whether these parameters affect responsiveness to aphasia therapy that focuses on verb production.

The concept of instrumentality and the classification of verbs based on instrumentality are accepted universally across different languages. In the study of Jonkers and Bastiaanse (2007), a Dutch action naming task was administered to individuals with anomic aphasia and Broca's aphasia. A positive effect of instrumentality on verb production was found in participants with anomic aphasia, but no significant difference retrieving instrumental verbs compared to non-instrumental verbs was found in participants with Broca's aphasia. When individual data of the Broca's aphasia group were analyzed, great inter-individual variability was found.

Kambanaros and van Steenbrugge (2006) showed that speakers with anomic aphasia produced instrumental verbs significantly better than non-instrumental verbs in Greek and English during action naming tasks. However, in Kambanaros (2009) the same participants who were bilingual speakers of Greek and English showed no effect of instrumentality on verb production in a different task – a sentence production task – in either language. Similarly, in the study of Kemmerer and Tranel (2000), when data were analyzed at the group level, no significant differences between the two verb types were found, but at the individual level, some participants produced instrumental verbs significantly better than non-instrumental verbs. However, it is difficult to discern which aphasia syndrome shows

benefit from instrumental verbs as Kemmerer and Tranel (2000) did not specify the aphasia classification of their participants.

Unlike instrumentality, existence of noun-verb homonymy is a language-specific phenomenon such that classification of verbs based on noun-verb phonological relations differed among the above-mentioned studies. For example, noun-verb homonymy does not exist in Dutch and Greek. Instead, some verbs and nouns share the same root, whereas other verbs do not (e.g., /skoup-izi/ *to sweep* and /skoup-a/ *a broom* in Greek, from Kambanaros, 2009). Therefore, instead of using the concept of *homonymy*, verbs were divided into noun-related and non-noun-related verbs in the studies of Jonkers and Bastiaanse (2007), Kambanaros (2009) and Kambanaros and van Steenbrugge (2006). In contrast, unlike Dutch and Greek, homonymous verbs do exist in English. Therefore, Kemmerer and Tranel (2002) divided the verbs they used into noun-verb homonyms and others.

Jonkers and Bastiaanse (2007) revealed positive effects of noun-verb phonological relatedness in individuals with anomic aphasia, but no effect in individuals with Broca's aphasia at the group level. However, again in this study, great inter-individual variability was observed in the data from the participants with Broca's aphasia. In the study of Kambanaros and van Steenbrugge (2006) and Kambanaros (2009), there was no effect of noun-verb relatedness in individuals with anomic aphasia in Greek, but the authors found that their participants performed better on noun-related verbs in English. Although both Dutch and Greek have nouns and verbs with similar phonological forms, the verb production patterns of different verb types in the two languages were inconsistent. In English-speaking individuals with aphasia, Kemmerer and Tranel (2000) found better production of noun-related verbs, but as mentioned above, their data were analyzed at the group level without distinguishing among different aphasia types.

It is difficult to predict, then, on the basis of previous studies, the patterns of instrumentality effects and noun-verb phonological relatedness on verb production in aphasia. Additionally, Jonkers and Bastiaanse (2007) and Kambanaros and van Steenbrugge (2006) used instrumental verbs only and classified them into those that have a phonological relationship with related nouns and those that have no phonological relation. It is assumed that they intended to avoid the effect of instrumentality on noun-verb phonological relationship during analyses, although they did not mention it in their studies. In contrast, Kemmerer and Tranel (2000) used the same verbs to investigate both the effect of instrumentality and that of homonymy in their study.

An additional caveat for generalizing the existing data to other individuals with aphasia is that the above studies focused mainly on the performance of people with anomic aphasia. Jonkers and Bastiaanse (2007) included a group of people with Broca's aphasia, an interesting group due to their dissociated noun and verb production skills, but the other studies either recruited participants with anomic aphasia or a group of people with aphasia without specifying the syndromes represented. Lastly, none of the previously mentioned studies aimed to investigate the effects of these different verb types on verb production changes after aphasia therapy.

Dell's spreading activation model of word production (Dell, 1986; Dell et al., 1997) can be used to predict whether the relationship of verbs to their corresponding nouns would affect verb retrieval. The model incorporates the two retrieval stages proposed by Levelt (Levelt, 1989), a lemma level in which semantic and lexical features are processed (e.g., word class, gender) and a lexeme level, during which word-form features are accessed. Dell's model proposes that activation at the lemma and lexeme stages overlaps such that there is

simultaneous activation of lemmas and lexemes, and that there is forward and backward flow of information between the two levels.

Instrumentality, which is a conceptual factor, would be considered a lemma feature. For instance, when processing a verb *to sweep*, the lemma features of the verb are activated as well and other relevant lemmas, such as a corresponding instrumental concept *a broom*. In contrast, noun-verb phonological relationship is related to both lemma and lexeme features. The interactive, simultaneous processing of lemma and lexeme retrieval would predict that a successful activation of a noun lexeme that is phonologically related to the target verb would facilitate the retrieval of the target verb.

For the current study, a set of 96 English verbs varied on the parameters of instrumentality and homonymy. To investigate the effect of instrumentality, the verbs were divided into two groups; (1) instrumental verbs: verbs that require instruments to perform (e.g., *to sweep – broom*) and (2) non-instrumental verbs: verbs that do not require instruments to perform (e.g., *to yawn*). Then, the same 96 verbs were divided into three groups for the investigation of noun-verb homonymy; (1) homonymous verbs: verbs that have the same lexical form of a noun (e.g., *to hammer – a hammer*) (2) morpho-phonologically related verbs: verbs that have a verb-derived noun (e.g., *to grind – a grinder*) and (3) phonologically unrelated verbs: verbs that have no phonological relation with a noun (e.g., *to lean*). See Table 1 for examples of the different verb types and Appendix for 96 verb items.

To achieve the research goals, as part of a larger study (Goral & Kempler, 2009; Kempler & Goral, 2011), three speakers with chronic Broca's aphasia received language therapy that was provided over a four-week period (2.5–3 hrs/day, 3–4 days/week), and a sentence production task was administered before and after treatment to measure baseline performance of verb production and patterns of change in verb production after therapy.

The treatment borrowed several principles of Constraint-induced aphasia therapy (CIAT) (Meinzer, Djundja, Barthel, Elbert, & Rockstroh, 2005; Meinzer, Elbert, Djundja, Taub, & Rockstroh, 2007) and provided a focused approach to improve verb production in this population. The main goal of the treatment was for the participants to produce verbs in sentences. During the treatment sessions, the participants were discouraged from using any unaffected communicative modalities (e.g., gesture and writing) and relied solely on oral production; all tasks were geared to elicit the production of verbs in complete sentences.

Predictions based on verb instrumentality were derived from both theory and prior experimental results. Based on Dell's spreading activation model of word production, it can be assumed that the close relationship between the lemma of the instrument name (e.g., *broom*) and of the related verb form (e.g., *to sweep*) will facilitate the retrieval of instrumental verbs, and that this advantage is not present for those verbs that do not share a related noun lemma (e.g., *to lean*). Based on this, it is straightforward to predict that prior to treatment, participants would show better performance on instrumental verbs than on non-instrumental verbs. This prediction is supported by previous findings that showed a positive effect of instrumentality in English speaking individuals with and without aphasia (Arevalo et al. 2007; Kemmerer & Tranel, 2000).

Predictions of response to treatment are not so straightforward. On the one hand, the inherent facilitation effects of instrument names on the retrieval of instrumental verbs might be so strong, that the relationship would be unchanged and therefore following therapy retrieval of instrumental verbs would still have a significant advantage over non-instrumental verbs. Alternatively it is possible that focused training on verb production might reduce reliance on the instrument noun's lemma in verb retrieval, and, therefore

participants' performance on non-instrumental verbs would improve to a level comparable to that of non-instrumental verbs.

Similarly, Dell's model would predict that verbs that share their lexemes with nouns would be easier to produce than verbs that do not because both lemmas might be activated following the activation of the noun lexemes. This prediction is supported by previous findings (e.g., Kemmerer & Tranel, 2000). Response to treatment here too may be predicted to preserve the advantage of those verbs that share lexemes with nouns, or, it is possible that this advantage may be diminished if a successful retrieval of verbs is gained following treatment.

We note that additional verb characteristics, such as word length, word frequency and imageability, as well as the verb argument structure, could affect retrieval; we included such characteristics in our analysis.

METHOD

Participants

Three monolingual speakers of American English (P1, P2, and P3) with chronic Broca's aphasia were recruited. The ages of the participants were 38, 54 and 60 years, respectively. The participants presented language impairments due to a single, left hemisphere CVA (confirmed by MRI or CT) 7, 3.6 and 2 years, respectively, prior to the time of the study. The aphasia type of the participants was determined based on the results of the Western Aphasia Battery (WAB) or the Boston Diagnostic Aphasia Exam (BDAE); the participants presented a mild-moderate to severe Broca's aphasia¹. The participants were right handed and had no history of other neurological disorders, learning disability, or cognitive deficits, and no marked apraxia of speech. See Table 2 for detailed information about the participants.

Additionally, five male and five female monolingual speakers of American English (age range 50–64; mean 56.8) who had no history neurological or communication disorders performed the same assessment to examine verb production skills in healthy adults as a control group.

Outcome measure

The outcome measure employed in this study was an action-naming test, using the 96 items from Almor et al. (2009). An example of a picture stimulus is shown in Figure 1. To evaluate whether the conceptual relation to nouns facilitates verb production, the 96 verbs were divided into two groups: instrumental verbs (n=47) and non-instrumental verbs (n=49). Then, to evaluate whether phonological relatedness between nouns and verbs facilitate verb production, the same 96 verbs were divided into three groups: homonym (n=62), morpho-phonologically related (n=14) and unrelated (n=20). It should be noted that the present analysis of these verb characteristics was a post-hoc analysis, so the list is not composed of even numbers of these three verb types.

In general, the verb sub-groups did not differ in other verb characteristics, including verb transitivity, word frequency, word length, and imageability. Using Pearson Chi-square tests, we confirmed no difference in terms of the portion of transitive versus intransitive verbs in the three noun-relatedness sub-lists (Homonymous, Morpho-phonologically related, and

¹When we tested P2, who was actually the first participant recruited for this study, we administered the Boston Diagnostic Aphasia Examination to confirm the aphasia type. For all remaining participants, we used the WAB. Based on the BDAE results, P2 was diagnosed as having language characteristics of Broca's aphasia.

Unrelated) ($X^2(2, 96=3.42, p=.181)$). A multinomial logistic regression (see, for example, Powers & Xie, 2008), revealed that the distribution of each verb item's frequency, imageability, and letter length was not different from homonymous verbs and phonologically unrelated verbs. Phonologically related verbs also had no different distribution of letter length compared to homonymous and phonologically unrelated verbs. However, more verbs with lower imageability ($p=.016$) and higher frequency ($p=.012$) were found in phonologically related verbs, compared to homonymous verbs and phonologically unrelated verbs.

In addition, a logistic regression confirmed no different distribution of imageability and letter length in two instrumentality sublists (instrumental and non-instrumental). The distribution of transitive versus intransitive verbs approached significance, and higher frequency was found in instrumental verbs.

Testing Procedures

The action-naming test was administered prior to and following treatment of the three participants with aphasia, and once to the healthy individuals. Testing was completed in three sessions. During the task, an action picture was shown and the participants were asked to describe in a sentence what the person in the picture was doing. Elicited speech during the task was recorded and transcribed and inter-rater reliability was measured for transcription and scoring. Production of the target verb was considered a correct response, whether or not a complete or grammatical response was produced. For homonymous noun/verb production, a response was considered a verb only if there was evidence that the participant intended a verb production (e.g., "iron" alone was not interpreted as a verb; but in the sentence "the woman iron the shirt," it was). Percent accuracy was measured for each verb type.

Treatment

After collecting the pre-treatment baseline, language therapy was provided individually to each participant, focusing on verb production in complete sentences. Adapting some principles of CIAT, we designed this aphasia therapy to be intense, to constrain the communication to the oral modality, to use materials that are functional for the participants, and to progressively shape the language tasks to increase in difficulty as the participants' performance improved. Therapy was provided for four weeks with 7–8 hours of treatments per week ($2.5\text{--}3\text{hr/day} \times 3\text{days/week} \times 4\text{ weeks}$). During the therapy session, the participants were discouraged from using any communicative modalities (e.g., writing, gesture) other than oral production. To induce spoken communication, a visual barrier was placed between the participant and the experimenter. During the language tasks, we placed the same pictures in front of the participant and the experimenter, but the existence of the visual barrier prevented both of them from seeing each other's pictures. Therefore, the participant was encouraged to use oral production instead of using other gestural communication modes, such as pointing to a picture, to play the game.

During each treatment session, we worked with a set of 64 verbs, 32 drawn from the testing set of 96 and 32 additional verbs related to the participants' interests, hobbies and activities of daily living to increase variety and relevance to the participants. We utilized different types of language games (e.g., card matching, memory game, picture sequencing, and story generation) during treatment to make the treatment environment as functional as possible. Along with these newly selected verbs, a subtest of the verbs from the action-naming task that was administered at pre-treatment measurement was used, although always with different pictures that are used in the assessment. Depending on the participants' progress of verb use, we increased the difficulty levels of sentence production from simple *Subject-Verb-Object* sentences to complex sentences containing adjective, adverbs, and

prepositional phrases. Details of the treatment were described in Goral and Kempler (2009), and Kempler and Goral (2011).

Statistical Analysis of Response Accuracy

To examine accuracy of verb production among the different verb types (e.g., effects of homonymy and instrumentality) before and after treatment and the impact of other characteristics of verbs (e.g., transitivity, frequency, familiarity, imageability, and word length) on verb production, a mixed logistic regression was employed (Jaeger, 2008; Powers & Xie, 2008). Two separate analyses were conducted, one for accuracy of verb production at pre-treatment and one for production at post treatment. Mixed logistic regression was used because the outcome variable is binary, for which logistic regression is appropriate. Ordinarily we would like to employ a crossed random effect model for both random participants and random words (Baayen, Davidson & Bates, 2008). However, there are only a small number of participants, so we used random words but not random participants. The logistic regression method used here is a generalization of a chi square test pre-post methodology in that the test of pre- vs. post- is a likelihood ratio chi square test that has been adjusted for the verb characteristics. In addition it also generates an effect size estimate (a log-odds), which adds more information than simply a chi square test p-value. To help ensure that inference was not affected by participant effects, we always included dummy variables for each participant in the analysis of pre-treatment accuracy and interacted participant with treated verbs for post-treatment accuracy.

In addition, we employed transformations on three continuous variables: frequency, imageability and letter length. Unsurprisingly, frequency was highly skewed so we used the inverse hyperbolic sine transformation to approximately normalize it. This transformation is well-defined for 0 values, of which there are many in this variable, precluding the use of the natural logarithm. It behaves like the natural logarithm for large values of Frequency but like the square root for small values (Burbidge, Magee & Robb, 1988). We then converted it to z-scores, along with the other two variables. All categorical variables were dummy coded.

RESULTS

Individuals with Broca's Aphasia

Table 3 shows accuracy percentages for each participant based on instrumentality and noun relatedness. Table 4 provides the results from the mixed logistic regression.

Pre-treatment measurement

Our three individuals with Broca's aphasia showed similar performance patterns at pre-treatment given that the coefficients for them were not statistically significant after adjusting for word characteristics. Instrumentality and homonymy predicted verb accuracy, with higher accuracy associated with instrumental compared to non-instrumental verbs and with homonyms compared to phonologically related and phonologically unrelated verbs, demonstrating that the participants with Broca's aphasia performed better when verbs were conceptually and phonologically related to nouns than when they were not. Three additional verb characteristics predicted verb accuracy at pre-treatment: Verbs with high frequency, high imageability, and shorter letter length were associated with better production. We note that while instrumental verbs were also higher in frequency, the correlations among the predictors used in the model are quite modest. Transitivity did not emerge as a significant predictor.

Post-treatment measurement

The three participants' overall accuracy of verb production was significantly improved from 51.34% at pre-treatment to 64.93% at post-treatment (see Table 3 and related regression results in Table 4). Following aphasia therapy, instrumentality still predicted accuracy, but no significant effect of homonymy was found; accuracy of phonologically related verbs and phonologically unrelated verbs was comparable to accuracy of homonymous verbs. As in the pre-treatment measures, higher frequency and higher imageability were associated with higher accuracy, but letter length was no longer a significant predictor. However, transitivity, which did not predict performance pre-treatment, was found to be a significant predictor with higher accuracy of transitive verbs than intransitive verbs following treatment. In addition, we investigated the effect of treatment by comparing accuracy of treated vs. untreated verbs produced by each participant, because as mentioned earlier, we used a subtest of the verbs from the sentence production task that was administered pre-treatment along with new verbs during aphasia therapy. Two participants did not show any significant effect of treated verbs on verb production at post-treatment (P1 and P3); one participant showed a positive effect of treated verbs on verb production (P2). However, we note although this participant exhibited a positive effect of treated verbs ($X^2 = 9.2$, 2 df, $p = 0.01$), verb production pattern of this participant was not generally different from the other two participants.

Healthy Individuals

Accuracy of total verb production for the ten healthy individuals was significantly higher than the accuracy of the individuals with Broca's aphasia at pre-treatment measurement. However, post-treatment the performance of the individuals with aphasia was comparable to that of the healthy individuals. See Table 5 for accuracy data of control participants and Table 6 for accuracy comparison between individuals with aphasia and healthy participants². One healthy individual (C7) showed lower accuracy than the rest of the healthy individuals. Re-analysis of the data without C7 did not change the results at the group level. For the healthy individuals, the only significant predictors were instrumentality and imageability.

DISCUSSION

This study examined effects of conceptual and phonological relationships between nouns and verbs on verb production and how these relationships might influence the response to treatment in people with Broca's aphasia. As it has been known that individuals with Broca's aphasia typically produce nouns better than verbs, we questioned whether verbs that are conceptually and phonologically related to nouns would be easier for our participants to produce than verbs that have no (or partial) relation to nouns and respond differently to treatment. We compared accuracy of verb production in sub-lists of the 96 verbs we used in our pre- and post-treatment measure: instrumental verbs (verbs that are conceptually/semantically related to the nouns that represent the instrument which is used for the action) vs. non-instrumental verbs; homonymous verbs (verbs that have the same phonological form of a noun) vs. phonologically related verbs (verbs that have a verb-derived noun), and phonologically unrelated verbs (verbs that have no phonological relationship with a noun). We also examined if other verb characteristics, such as transitivity, frequency, imageability and letter length would affect verb production across different verb types. Then, we examined whether production accuracy changed after treatment, and how these changes

²The accuracy of the control participants ranged from 40–75%. This low accuracy reflects the strict scoring rule we used. Although the control participants described the target action appropriately (e.g., “eating” for “nibbling”, “cooking” for “frying”) in virtually every instance, if they didn't use the specific target verb, the response was not counted as “correct”.

were related to the verb characteristics. Finally, we compared the accuracy results and their relations to verb types to those of healthy adults.

Individuals with Broca's aphasia were more successful at retrieving instrumental than non-instrumental verbs both before and after treatment. This advantage for instrumental verbs was also found for the healthy individuals. In contrast, a positive effect of homonymy before treatment (with better performance on verbs associated with homonymous nouns compared to verbs that are associated with phonologically related nouns or verbs without a phonologically related noun), but after aphasia therapy, the existence of a phonologically related noun did not predict performance. The existence of a phonologically related noun was not a significant predictor of verb retrieval among the healthy adults. Following treatment, verb production accuracy of the individuals with Broca's aphasia was comparable to that of control participants.

When additional verb characteristics were examined, both groups more accurately produced verbs that had high imageability. Unlike people with Broca's aphasia who performed better on verbs with high frequency and on transitive verbs, control participants' performance was not affected by verb frequency or transitivity.

We predicted a positive instrumentality effect on verb production in people with Broca's aphasia before treatment because instrumental verbs are linked to conceptual/ semantic knowledge of those nouns that are the corresponding instruments to the verbs, and this conceptual knowledge of nouns may be helpful in verb production. This is consistent with the hypothesis that co-activation of a noun lemma (an instrument) facilitates verb lemma processing in people with Broca's aphasia. Indeed, we found a positive effect of instrumentality prior to and following treatment, suggesting a robust reliance on the activation of multiple lemmas.

Nevertheless, our results are different from those reported in previous studies. For example, Jonkers and Bastiaanse (2007) found that their Dutch-speaking participants with Broca's aphasia presented no significant performance difference between instrumental and non-instrumental verbs. However, it should be noted that there was great inter-individual variability in their data. Moreover, Jonkers and Bastiaanse (2007) used a relatively small number of non-instrumental verbs, 40 instrumental verbs and 20 non-instrumental verbs; we had 47 instrumental verbs and 49 non-instrumental verbs. Kemmerer and Tranel (2000) also reported no significant difference between the two verb types, but did not identify the participants by aphasia syndrome whereas we focused our study on people with Broca's aphasia.

This hypothesis and our results are consistent with the account put forward in Almor et al. (2009) with data from individuals with Alzheimer's disease (AD). In that study, the authors reported lower accuracy and slower latency of object (noun) than action (verb) naming in people with Alzheimer's disease. Importantly, lower accuracy of noun production correlated with poorer production of instrumental verbs. In other words, individuals with Alzheimer's disease, who had greater difficulty producing nouns, also showed disproportionate difficulty retrieving instrumental verbs. The researchers reasoned that intact semantic representations of instruments, such as a *hammer* or a *comb*, likely supported production of instrumental verbs. As the relative difficulty producing nouns and verbs contrasts in these two groups (better noun in Broca's aphasia; better verb production in Alzheimer's), Almor et al. (2009)'s assumption can be inverted to apply to our results: individuals with Broca's aphasia who produce nouns more accurately than verbs, may be aided in their naming of instrumental verbs by their conceptual/semantic knowledge of the related nouns. This assumption can explain the underlying reason why all three participants in our study

performed better on instrumental verbs compared to non-instrumental verbs at pre- and post-treatment measurements. This pattern can be explained by arguing that better production of instrumental verbs is due to the co-activation or positive support of intact conceptual knowledge of nouns in people with Broca's aphasia.

Furthermore, the positive instrumentality effect was not changed after aphasia therapy in our participants. Moreover, a similar positive effect was evident for the healthy individuals included in our study as well as in previous studies. For example, Almor et al. (2009) and Arevalo et al. (2007) found that neurologically intact people use semantic/conceptual knowledge to facilitate comprehension and naming, as evident by a better production of instrumental than non-instrumental verbs. At this time, we cannot separate over-reliance on using conceptual knowledge of nouns from a normal processing strategy in our participants with Broca's aphasia.

For the noun-verb homonymy effect, we demonstrated that, as predicted and consistent with Dell's spreading activation model, people with Broca's aphasia benefit from a phonological noun-verb relation when they produce verbs in sentences. This facilitation was only observed for verbs that had the same form as their corresponding nouns (homonyms). The verb production pattern between phonologically related verbs that have related derived nouns and phonologically unrelated verbs was comparable. Moreover, this homonym advantage was unique to the participants with aphasia and did not emerge for the healthy individuals. The existence of homonyms in English may explain the differences between our results and those reported for Dutch (Jonkers & Bastiaanse, 2007) and Greek (Kambanaros, 2009). Also, the relatively small number of stimuli in the study of Jonkers and Bastiaanse (2007) and performance of bilingual speakers with Broca's aphasia in Kambanaros (2009) may have contributed to the differences in the results. Lastly, when Kemmerer and Tranel (2000) tested English-speaking individuals with aphasia, they found a positive effect of noun-verb phonological relation.

When the verb production patterns in the individuals with Broca's aphasia were examined post-treatment, we found them to be similar to those revealed by the neurologically intact participants. Both groups had comparable accuracy rates and both showed a positive instrumental effect and no homonymous verb advantage. Our interpretation of the present results is that a four-week period of intensive aphasia therapy helped people with Broca's aphasia to avoid relying on phonological knowledge of nouns during verb production. However, we note that other production characteristics (not examined here), such as the grammaticality of the sentences produced, differed between the people with aphasia and the healthy participants even following the aphasia therapy.

We speculate that the reason why the participants with Broca's aphasia showed poorer performance on phonologically related verbs than on homonymous verbs pre-treatment is due to morphological difficulty. That is, impaired morphological abilities might have interfered with the production of those verbs and made it as difficult as the production of phonologically unrelated verbs, despite their partial phonological relationship with nouns. It is also possible that differential frequency effects of the corresponding nouns may have interacted with the production of their corresponding verbs, a possibility that we were unable to address in our verb selection.

In sum, the present study revealed a positive instrumentality effect and a positive noun-verb homonymy effect on verb production in people with Broca's aphasia. The positive instrumentality effect remained following aphasia therapy whereas the noun-verb homonymy effect disappeared. Thus this study, focusing on English-speaking individuals

with Broca's aphasia, revealed that conceptual and phonological noun-verb relation affected verb production before and after aphasia therapy.

However, there are several limitations to this study. First, the number of participants was small and therefore generalizations to other individuals with Broca's aphasia should be made with caution. Second, if additional participants are recruited and tested, correlations between different severity levels and the results should be analyzed to examine the effects of severity levels on performance. Additionally, an equal number of stimulus items of the different verb types should be used and repeated measurements should be obtained; the numbers of phonologically related verbs and phonologically unrelated verbs were relatively smaller than those of homonymous verbs in this study. The small number of stimulus items may have affected accuracy so those verbs should be matched in future study. Lastly, further study should investigate the maintenance of the changes associated with aphasia therapy. To reveal efficacy of aphasia therapy on improving verb production, further measurements should be made at extended intervals post-treatment.

CONCLUSION

Effects of noun-verb conceptual and phonological relation on verb production in people with Broca's aphasia were examined. Participants showed a positive instrumentality effect on verb production at both pre- and post-treatment measurements. Additionally, the participants showed best performance on homonymous verbs and comparable performance on phonologically related and phonologically unrelated verbs at pre-treatment measurement and no difference in performance among these three verb types at post-treatment measurement. Thus, with a four-week period of intensive aphasia therapy, performance of verb production in individuals with Broca's aphasia was significantly improved and their verb production patterns changed. This change may be associated with participants' facilitated access to verbs and a decreased need to rely on phonological similarities to the corresponding nouns.

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APPENDIX: 96 VERBS

arranging	frowning	rolling
baking	frying	rowing
balancing	grinding	sailing
bathing	hammering	scraping
bending	hanging	screaming
blowing	hugging	screwing
bouncing	hurdling	sculpting
bowing	ice-skating	sewing
boxing	ironing	shaving
breastfeeding	jumping	shoveling
brushing	kissing	showering

buttoning	kneeling	singing
chaining	knitting	sipping
clamping	laughing	skiing
climbing	leaning	sneezing
combing	licking	squatting
confessing	locking	stapling
cooking	lying	sucking
coughing	marching	sweeping
crawling	marrying	taping
crying	mixing	teaching
cutting	mopping	tiptoeing
drinking	nibbling	toasting
driving	panting	tossing
dusting	parachuting	vacuuming
eating	pasting	warning
feeding	petting	washing
fighting	playing	whispering
filing	pouring	whistling
floating	preaching	wrestling
flossing	raking	yawning
flying	roller-skating	yelling

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Figure 1.
An example of the picture stimuli: *To hammer – the hammer*

Table 1

Examples of verb types

Examples	Instrumental verbs	Non-instrumental verbs
Homonymous verbs	to iron – the iron	to balance – the balance
	to rake – the rake	to crawl – the crawl
	to shovel – the shovel	to yawn – the yawn
Phonologically related verbs	to mix – the mixer	to hanger – the hanger
	to staple – the stapler	to confess – the confession
	to toast – the toaster	to teach – the teacher
Phonologically unrelated verbs	to sew – $\emptyset$	to lean – $\emptyset$
	to shave – $\emptyset$	to <i>pant</i> – $\emptyset$
	to row – $\emptyset$	to tiptoe – $\emptyset$

Table 2

Information about the participants

(1) Participants with aphasia

Participant	Gender	Age	Race	Education (yrs)	Handedness	Years Post Onset	WAB AQ	Aphasia Type
P1	Female	38	White	18	R	7	69.6	Broca's
P2	Female	60	Black	13	R	3.6	N/A	Broca's
P3	Female	54	White	16	R	2	75.9	Broca's

(2) Control Participants

Participant	Gender	Age	Race	Education (yrs)
C1	Female	56	White	12
C2	Female	58	White	18
C3	Female	51	White	12
C4	Female	53	White	15
C5	Male	56	White	12
C6	Female	57	White	16
C7	Male	61	White	18
C8	Male	64	White	13
C9	Male	62	White	12
C10	Male	50	White	16

Table 3

Accuracy of the participants with aphasia

(1) Effect of instrumentality

% Accuracy (Numbers of Correct Verbs)	Instrumental Verbs (n=47)		Non-instrumental Verbs (n=49)	
	Pre-tx	Post-tx	Pre-tx	Post-tx
P1	55.32% (29)	68.09% (32)	32.65% (16)	63.27% (31)
P2	57.45% (27)	78.72% (37)	46.94% (23)	57.14% (28)
P3	61.70% (29)	72.34% (34)	48.98% (24)	51.02% (25)
Mean	58.16% (28.33)	73.05% (34.33)	42.86% (21)	57.14% (28)

(2) Effect of Homonymy

% Accuracy (Numbers of Correct Verbs)	Homonymous verbs (n=62)		Phonologically-related verbs (n=14)		Non-noun related verbs (n=20)	
	Pre-tx	Post-tx	Pre-tx	Post-tx	Pre-tx	Post-tx
P1	50.00% (31)	64.52% (40)	35.71% (5)	57.14% (8)	45.00% (9)	75.00% (15)
P2	61.29% (38)	64.52% (40)	35.71% (5)	78.57% (11)	35.00% (7)	70.00% (14)
P3	66.13% (41)	64.52% (40)	35.71% (5)	64.29% (9)	35.00% (7)	50.00% (10)
Mean	59.14% (36.67)	64.52% (40)	35.17% (5)	66.64% (9.33)	38.33% (7.67)	65.00% (13)

Table 4

Mixed logistic regression results for three individuals with Broca's aphasia

(1) At Pre-treatment measurement

	Coef	Std.Err	z	P
P1				
P2	-.243	.349	-.70	.487
P3	.546	.353	1.55	.121
Homonymous verbs				
Phonologically-related verbs	-1.66	.603	-2.75	.006
Phonologically-unrelated verbs	-1.55	.495	-3.13	.002
Instrumentality	1.29	.405	3.19	.001
Transitivity	-.526	.415	-1.27	.206
Frequency	.516	.232	2.23	.026
Imageability	.419	.201	2.08	.037
Letter Length	-.411	.213	-1.93	.053
Constant	-.096	.364	-.26	.791

(2) At Post-treatment measurement

	Coef	Std.Err	z	P
Acc changes after tx	1.850	.330	5.61	.000
P1_Untreated Verbs				
P1_Treated Verbs	.201	.595	.34	.735
P2_Untreated Verbs	.0374	.399	.09	.925
P2_Treated Verbs	3.039	.832	3.65	.000
P3_Untreated Verbs	-.275	.400	-.69	.492
P3_Treated Verbs	.914	.559	1.64	.102
Homonymous verbs				
Phonologically-related verbs	.701	.461	1.52	.128
Phonologically-unrelated verbs	.477	.405	1.18	.239
Instrumentality	1.012	.340	2.98	.003
Transitivity	-1.009	.336	-3.00	.003
Frequency	.375	.189	1.98	.048
Imageability	.332	.162	2.05	.040
Letter Length	.127	.170	.75	.453
Constant	-.969	.387	-2.50	.012

Table 5

Accuracy data of control participants

(1) Effect of instrumentality in control participants

% Accuracy (Numbers of Correct Verbs)	Instrumental Verbs (n=47)	Non-instrumental Verbs (n=49)
C1	72.34% (34)	57.14% (28)
C2	72.34% (34)	65.31% (32)
C3	72.34% (34)	63.27% (31)
C4	68.09% (32)	59.18% (29)
C5	53.19% (25)	59.18% (29)
C6	76.60% (36)	59.18% (29)
C7	53.19% (25)	44.90% (22)
C8	61.70% (29)	51.02% (25)
C9	72.34% (34)	69.39% (34)
C10	76.60% (36)	65.31% (32)
Mean	61.87% (31.9)	59.39% (29.1)

(2) Effect of homonymy in control participants

% Accuracy (Numbers of Correct Verbs)	Homonymous verbs (n=62)	Phonologically-related verbs (n=14)	Non-noun related verbs (n=20)
C1	66.13% (41)	50% (7)	70% (14)
C2	69.35% (43)	57.14% (8)	75% (15)
C3	67.74% (42)	57.14% (8)	75% (15)
C4	66.13% (41)	35.71% (5)	75% (15)
C5	50% (31)	42.86% (6)	85% (17)
C6	74.19% (46)	50% (7)	60% (12)
C7	51.61% (32)	21.43% (3)	60% (12)
C8	56.45% (35)	42.86% (6)	65% (13)
C9	70.97% (44)	50% (7)	85% (17)
C10	74.19% (46)	50% (7)	75% (15)
Mean	64.68% (40.1)	45.71% (6.4)	72.5% (14.5)

Table 6

Accuracy comparison between three individuals with Broca's aphasia and ten controls

(1) Accuracy comparison pre-treatment

Pre-treatment	Coef.	Std.Err.	z	P
Aphasia	−260	.048	−5.39	.000
Constant	.211	.106	1.98	.047
rho	.460	.049		

(2) Accuracy comparison post-treatment

Post-treatment	Coef.	Std.Err.	z	P
Aphasia	−0674	.0487	−1.38	.116
Constant	.422	.114	3.71	.000
rho	.492	.0507		