The role of frequency in the retrieval of nouns and verbs in aphasia

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The role of frequency in the retrieval of nouns and verbs in aphasia

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Introduction

It has frequently been demonstrated that the ease and speed with which words are retrieved is influenced by several linguistic and non-linguistic factors, both in non-brain-damaged speakers and in individuals with aphasia. Word frequency and word length are two examples of linguistic factors that are supposed to affect retrieval, whereas imageability and familiarity are examples of non-linguistic factors. Age of Acquisition (AoA) may be either linguistic or non-linguistic, depending on whether the age of the acquisition of the word or the concept is meant. In the current paper, AoA is assumed to be the age at which the word is learned.

In the paper of Brysbaert and Ellis (this issue), it is argued that Age of Acquisition is a robust predictor of word retrieval, more so than word frequency, despite frequency being responsible for some of the variation as well. Similar to many studies on this topic, the discussion is limited to the influence of AoA and word frequency on retrieval and processing of nouns. The current study extends this research and assesses the influence of word frequency on the retrieval of both nouns and verbs. Apart from an object-naming test, 3 different tests for verb retrieval were used: (1) action naming; (2) filling in infinitives in sentence context; and (3) filling in finite verbs in sentence context.

A model for spoken language production

Before discussing the different processes involved in these tests, a simple language production model will be sketched on the basis of Levelt (1989). This model was used by Bastiaanse and Van Zonneveld (2004) to describe the influence of grammatical operations on verb production in agrammatic aphasia. A model for sentence production is needed, because simple models like the one from Ellis and Young (1988) do not suffice to describe verb retrieval. In Figure 1, a graphical representation of the sentence production model is sketched.

[Figure 1 about here]

When a *concept* is triggered, it will activate a *lemma*. The lemma contains information about the meaning of a word, but also information about word class and, in case of verbs, information about argument structure, thematic roles and subcategorization. For example, for a verb like 'to bike', the lemma contains the information that it is a verb with one argument, an agent, that is subcategorized for a simple subject – verb sentence. The lemma for the noun 'bike' only contains the information that it is a (count) noun: nouns usually have no argument structure.

The *grammatical encoder* gets input from two sources (preverbal message and lemma level) and uses this information to form a sentence frame. The idea that a speaker wants to express (which may be a name of an object or action, but can also be a complete proposition) is formulated in a preverbal message. This stage is not relevant for the current study and is not further discussed here (but see Levelt, 1989). The grammatical encoder uses the verb-argument structure that is represented in the lemma to generate a sentence frame that suits the intention of the speaker (the concept / proposition). In the case of a verb, the grammatical encoder uses the lemma information to build a sentence frame. Notice that grammatical encoding is always needed, even when a single word is produced. A single word is seen as a minimal sentence frame.

When the lemma has been retrieved, it activates the *lexeme*, that is, the underlying phonological word form. The lexeme is inserted in the sentence frame that is constructed by the grammatical encoder. This is the process of *phonological encoding:*

the phonemes are inserted and the phonological rules are applied to plan and execute the articulation process.

The ease with which concepts, lemmas and lexemes are activated is dependent on several factors that influence one or more stages of word retrieval. The factors that are relevant for the current study are (1) imageability; (2) grammatical class and lemma complexity; (3) word frequency; (4) AoA.

Imageability

Imageability plays a role at the conceptual level. When concepts are less imageable (or more abstract), they are harder to process. This has an influence on access to the lemmas. It is well known that imageability affects word retrieval in (at least some types of) aphasia (e.g., Franklin, Howard and Patterson, 1995). Imageability has even been mentioned as the main cause of the often-reported discrepancy between object and action naming. Objects are usually better named than actions and according to Bird, Howard and Franklin, (2000) this is due to the fact that imageability of verbs is lower than for nouns. Luzzatti, Raggi, Zoca, Pistarini, Contardi and Pinna (2002) has partially confirmed this explanation, but Berndt, Haendiges, Burton and Mitchum (2001) and Jonkers and Bastiaanse (2007) showed that imageability alone is not responsible for the relative poor performance of aphasic individuals on action-naming tests. Clearly, verbs have lower imageability than nouns, but that does not mean that verbs are necessarily more difficult than nouns because of imageability. One of the reasons why we think imageability is not the crucial factor is that within the class of verbs other factors influence retrieval, regardless of imageability, such as instrumentality of the verb, name relation between an instrumental verb and the name of the instrument and argument structure (see Jonkers and Bastiaanse, 2007). Hence, if one wants to find out what the role of imageability is, or of any factor that may influence word retrieval, all other factors that are known to influence word retrieval should be controlled.

Word class

The more complex the lemma is, the harder it is to retrieve the word for aphasic speakers. This is illustrated by several studies to verb and noun production in aphasia. Verbs are harder to retrieve than nouns, because verb lemmas are more complex than noun lemmas, that is, verb lemmas contain information about argument structure, thematic roles and subcategorisation frame and noun lemmas do not (Bastiaanse and Van Zonneveld, 2004; Jonkers and Bastiaanse, 2007; Kambanaros and Van Steenbrugge, 2006; Kim and Thompson, 2000). Also, it has been reported that the more complex argument structure is, the harder verbs are to retrieve for agrammatic speakers (Luzzatti et al., 2002; Thompson, 2003). Thompson and colleagues showed that verbs with complex argument structures (e.g. 3 argument verbs like *to give* and unaccusatives like *to fall*) are more difficult than verbs with simple argument structure (like *to bike*). The question is why this is the case. Is it because the lemma representations are affected? This is probably not true, since verb comprehension in the same agrammatic speakers is relatively well preserved (Jonkers and Bastiaanse, 2006; Shapiro, Gordon, Hack and Killackey, 1993). Bastiaanse and Van Zonneveld (1998; 2005) argued that it is neither the lemma representation, nor the lemma retrieval that is affected in agrammatic speakers. Rather, grammatical encoding is impaired: the more information needs to be encoded, the more problems arise. This explains why agrammatic speakers are more impaired in action naming than in object naming: for action naming more grammatical encoding is needed, even though only one lemma has to be retrieved (Bastiaanse and Van Zonneveld, 2004). Bastiaanse (2011) argued that this does not only hold for agrammatic speakers, but also for individuals with fluent aphasia: when more information needs to be processed by the grammatical encoder, the diversity of the produced verbs decreases, whereas at the same time the verbs that are produced are of relative high frequency. In sum, it is argued that word class differences play a role at the level of lemma retrieval and grammatical encoding.

Word frequency and Age of Acquisition

Word frequency plays a role at the lexeme level (Jescheniak and Levelt, 1994): the idea is that the more frequently a word is used in a language, the easier it will be retrieved, because the activation threshold is lower. Lately, this idea has been disputed and AoA has been mentioned to be the critical variable at this level. Of course, AoA and frequency are closely related: words that have been acquired early are usually more frequent than words learned later in life (Brysbaert and Ellis, this issue). The reason that an early AoA and a high word frequency facilitate word retrieval is that the ties between the concepts, the lemmas and the lexemes become tighter when they are more often accessed. However, it is not always the case that frequency and AoA are related. Many names of exotic animals, such as *turtle*, *monkey* and *lion*, and many playsets, such as *swing* and *seesaw*, are acquired early but are of low frequency. Notice that these object and animals are often included in a naming task. Nickels and Howard (1995) disentangled the influence of AoA, (written) word frequency, imageability and several other factors on aphasic behaviour on an object- naming task. They found a significant influence of AoA and imageability, but not of word frequency, when the other factors were controlled.

Kittredge, Dell, Verkuilen and Schwartz (2011), dispute that AoA and word frequency only influence the lexeme level. In a large-scale study with a group of individuals with aphasia not selected for type, they found that AoA was related to phonological errors, whereas word frequency was associated with both phonological and semantic errors. From this, they conclude that AoA only influences retrieval of the lexeme, whereas word frequency plays a role at both the semantic (lemma) and phonological (lexeme) level.

Interestingly, in most of the studies on action naming in aphasia, frequency is not found to be a relevant factor (e.g., Kemmerer and Tranel, 2000; Luzzatti et al. 2002). Furthermore, in a study on the influence of frequency of sentence structure in agrammatic speakers, it was reported that the only relevant factor was grammatical complexity: grammatically complex sentences (that is, sentences with derived word order) were harder to produce than grammatically simple sentences, even if the grammatically complex structures were more frequently used in a given language (Bastiaanse, Bouma and Post, 2009). This means that frequency may have an effect on noun retrieval, but that its influence is limited or absent when it comes to the production of verbs or sentences. There is one exception, however: Bastiaanse (2011) analysed the use of verbs in the spontaneous speech of fluent aphasic speakers. She found that the production of non-finite verb forms (i.e., infinitives and participles) was normal in number, diversity and frequency. The finite verbs that were produced by the fluent aphasic speakers, however, had a lower diversity and a higher frequency than those of non-brain-damaged speakers. However, AoA was not taken into account in this study.

In sum, word frequency has often been mentioned to play a crucial role in word retrieval in aphasia. According to theories such as the ones from Levelt (1999), this is related to retrieval of the underlying phonological word forms or lexemes, although Kittredge et al., (2008) claim that word frequency may play a role at the lemma level as well. However, it may not be word frequency but rather AoA that influences lexeme retrieval. Since word frequency and AoA are highly correlated, the role of word frequency is not clear. Another confounding factor is imageability: this variable is probably also related to frequency and AoA: words that have low imageability are usually acquired relatively late and often have a low frequency. One should keep in mind, however, that imageability does not affect retrieval of lexemes, but rather access to the concepts and lemmas. A second finding is that word frequency has repeatedly been shown to influence retrieval of nouns (but see Nickels and Howard, 1995), however, evidence that it also affects retrieval of verbs is scarce. So far, only one case study to noun and verb retrieval in a person with progressive fluent aphasia reported an effect of AoA (Bradley, Davies, Paris, Fan Su and Weekes, 2006).

The current study addresses these two points. The research question is: Is noun and verb retrieval in well-controlled test conditions influenced by lemma and / or lexeme frequency when AoA and imageability and other factors that have been shown to influence verb retrieval (argument structure, instrumentality, name relation with a noun) are controlled? Considering the results of earlier studies, we do not expect to find a frequency effect on verb retrieval, neither at the word, nor at the sentence level. Whether noun retrieval is influenced by frequency is an open question.

Test construction

A list of 180 action verbs was created and pictures were drawn of these verbs. The pictures were included in a PowerPoint presentation and tested for name agreement by 10 native Dutch speakers (mean age 28.70; range 20-54). Only when the pictures elicited the same verb in at least 7 participants, were they included in the final test. This resulted in a list of 132 action pictures. For these 132 verbs the lemma and lexeme frequencies were represented by the log frequency of the verb lemmas/lexemes extracted from the *Corpus Gesproken Nederlands* (Spoken Dutch Corpus; Oostdijk, 2000).[1]

An online questionnaire was developed to obtain the AoA data. Students in Linguistics were asked to fill in this questionnaire online via Survey Monkey (www.surveymonkey.com). Nineteen participants filled in the entire questionnaire (17 females;[2] mean age 19.95 years, range 17-27). They received a list of verbs and were asked to indicate at what age they acquired these verbs. There were 5 response categories: 1 = 0-3 years; 2 = 4-6 years; 3 = 7-9 years; 4 = 10-12 years; 5 = 13 years and older.

The same procedure was used for imageability: 22 (different) students in Linguistics were recruited to fill in the entire questionnaire (21 females; mean age 19.36, range 18-23). They got a list of verbs and had to rate how easy it would be to make a drawing of the verbs. There were 5 response categories: 1 = very easy; 2 = easy; 3 = average; 4 = difficult; 5 = very difficult. Since all verbs referred to actions and were expected to have high imageability, 75 verbs that were supposed to be of low imageability were added to the list of 132 verbs (n=207) to allow for variation.

For action naming, the verbs with highest name agreement were preferred. For the tests involving filling in verbs in a sentence frame, name agreement was less important, since the sentence context helped to select the correct verb. For example, the verb *stirring* was sometimes named as *cooking*, but in the context of the sentence *the girl is .... in the pot,* the target verb was produced. The verbs were divided over 3 tests.[3] For each verb test, the items were balanced as well as possible for the factors transitivity, instrumentality and name relation, since these factors are known to influence verb retrieval (Jonkers and Bastiaanse, 2007; Kemmerer and Tranel, 2000):

- **Action naming (50 items).** There were 25 intransitive and 25 transitive verbs.[4] Fifteen verbs were non-instrumental and of the 35 instrumental verbs 16 were name-related to the instrument and 15 were not. There were 4 verbs in which the name of the instrument was included in the verb, but was not identical to the stem (as in *to drill – drilling machine*).
- **Filling in infinitives (20 items).** The verbs were balanced for transitivity: 10 transitive and 10 intransitive items. There were 13 non-instrumental and 7 instrumental verbs (2 of which were completely name-related to the instrument; 3 were included in the name of the instrument but the stem was not identical; 2 were not name-related).
- **Filling in finite verbs (20 items).** Again, 10 items were transitive, 10 were intransitive. Of the 6 instrumental verbs, 4 had complete name-relatedness, 1 had partial name-relatedness and 1 had no name-relatedness to the instrument.

Once the action-naming test had been developed, the object-naming test was composed. The purpose was to have an optimal balance of both tests. The object-naming test also has 50 items; 20 were pictures of instruments, of which 10 were name-related with the verb. Most of the instruments corresponded to the name-related verbs of the action-naming test. The 30 other objects were related to the other verbs of the action-naming test (e.g., *climbing – mountain; singing – microphone*). Table 1 shows an overview of the tests; the data of all the individual nouns and verbs used in the tests are given in the Appendix.

[Table 1 about here]

The frequency of the target verbs and nouns on the four tests was similar (lemma frequency: action naming vs object naming: $t(98)=0.2324$, $p=0.817$; action naming vs filling in infinitives: $t(68)=0.7653$, $p=0.447$; action naming vs filling in finite verbs $t(68)=0.7566$, $p=0.225$; lexeme frequency: action naming vs object naming: $t(98)=0.1264$, $p=0.209$; action naming vs filling in infinitives: $t(68)=-0.1314$, $p=0.896$; action naming vs filling in finite verbs $t(68)=-1.178$, $p=0.243$). However, AoA and imageability differed. AoA was higher for the items of the action-naming test than for the items on the object-naming test ($W=2080.5$, $p=0.002$). There was no difference between the items on the 3 verb tests, although the verbs of the test for filling in finite verbs were acquired marginally earlier than those for the other 2 verb tests (for both $W=570$, $p=0.069$). There was no difference between the imageability of the items on the action-naming and object-naming tests ($W = 2400$; $p = 0.391$), but the verbs on the action naming tests were more imageable than those on both tests for filling in verbs (action naming vs filling in infinitives: $W = 937.5$; $p = 0.003$; action naming vs filling in finite verbs: $W = 862.5$, $p = 0.047$). However, these differences did not influence our results, because we controlled for AoA and Imageability when measuring the influence of word frequency.

Methods

Participants

For this study, 65 non-brain-damaged speakers (from now on: NBDs) and 54 aphasic speakers were included. They were all native speakers of Dutch and recruited from different parts of The Netherlands. All participants signed an informed consent and gave permission to send the results to the researchers. The NBDs were matched on age with the aphasic speakers: the mean age of both groups was 55,5 years (range aphasic speakers 19-77; range NBDs 18-84). The NBDs were also from different regions in The Netherlands.

The demographics of the aphasic group are given in Table 2. In 52 aphasic speakers, the aphasia was caused by a single stroke in the MCA area in the left hemisphere, 1 had a stroke in the left cerebellum and 1 had several small infarctions in the left hemisphere. All aphasic speakers were in the subacute phase, that is, between 3-6 months post-onset. The aphasia had been diagnosed with the Dutch version of the Aachen Aphasia Test (Graetz, de Bleser and Huber, 1992), which also allows for classification of the aphasia type. However, this classification is not always accurate (De Jonge, Van der Sandt-Koenderman and Van Harskamp, 1996). Therefore, we took into account the clinical aphasia types that were provided by well-experienced speech and language pathologists.

[Table 2 about here]

Between 3 to 5 aphasic speakers who participated in the study were unable to complete the full set of tasks. Object naming and filling in infinitives was done by 51 participants; action naming by 50 participants; filling in finite verbs by 49 participants.

Materials

The tests for action and object naming (50 items each; for examples, see Figure 2) and filling in infinitives and finite verbs (20 items each; for examples see Figure 3) were digitized and an iPad App was created that allowed for automatic administration.

All instructions were audio-recorded and included in the App. For the tests filling in infinitives and finite verbs, a written sentence was presented under the picture in which the verb was left out. If needed, the participant could press the little speaker icon to hear the sentence aloud. The answers were audio recorded by the iPad.

[Figure 2 and 3 about here]

Procedure and scoring

The NBDs were tested by either a student or a speech and language pathologist. Aphasic speakers were tested by speech language pathologists. In principle, a tester was not needed because administration of the tests was automatic. However, the tester was sitting opposite or next to the participant to guide him or her through the tests.

Each test started with a short instruction and two examples. For these examples, the participant was invited to name the picture (action and object naming) or to fill in a verb in a sentence (filling in infinitives and finite verbs). When this was done, the participant could swipe the screen and the correct answer was provided. After these two examples, the participant was told that the test would start. The participant could go on to the next item by swiping over the screen. There was no time limit.

All answers were audio-recorded. When all tests were administered, the tester scored the answers. For scoring, a built-in program was used that allowed the scorer to listen to the participant's answer per item. Self-corrections were allowed and the final answer was scored. There were several error categories: correct, semantic paraphasia, phonemic paraphasia, noun-verb substitution, inflectional error (only for filling in verbs), and 'other' (neologisms, no reaction, unrelated answers, etc.). Once scoring was finished, the test results and the audio files were sent by email to the researchers. For the current study, we only focused on correct versus incorrect and did not conduct further analysis of the error types. The scores on the individual items are given in the Appendix.

Statistical analysis

Since we were interested in the effect of lemma and lexeme frequency, AoA and imageability on word retrieval in aphasia, we only analysed the data of the aphasic speakers, using logistic mixed-effects regression modeling. Regression modeling is a flexible approach that does not require a completely balanced design to assess the influence of various predictors of interest on the dependent variable. As our dependent variable is binary (1: correct, 0: incorrect), we analysed the data using logistic regression. In logistic regression, the dependent variable is transformed to the logit scale by taking the logarithm of the odds of the probability of success versus the probability of failure. This transformation ensures that the dependent variable is unbounded. Of course, another consequence of this transformation is that the estimates of the predictors need to be interpreted with respect to the logit scale. A logit of 0 corresponds to a probability of answering correctly of 50%. An estimate of 0 is therefore uninformative (just like in normal regression). Positive estimates indicate that the probability of giving a correct answer is higher than 50%, while a negative estimate indicates the opposite (and thus indicates that the probability of incorrectly answering the question is higher than 50%). More information about logistic regression is provided by Agresti (2007).

In our study, there are multiple answers associated with each participant. As some participants will be more likely to answer questions correctly than others, we need to take this participant-related structural variability into account. Similarly, multiple participants respond to questions; some questions may be easier than others and this variability needs to be brought into the model. An adequate approach for this purpose is mixed-effects regression (Pinheiro & Bates 2000; Baayen et al. 2008; Baayen 2008) that distinguishes fixed-effect factors (factors for which the levels are exhausted in the data, such as gender) and random-effect factors (for which the levels are sampled from a much larger population of levels, such as participant and question). By including so-called random intercepts, the model is able to take into account the fact that some items are easier than others and some participants are better than others. Of course, the influence of the different predictors may also vary. For example, for one participant a certain type of test may be easier than for another. This variability can be included in the model by taking into account so-called random slopes (in this case, a by-subject random slope for the effect of test). By including random slopes and intercepts, type-I errors are prevented (Baayen, 2008). To determine if random intercepts or slopes were required, we compared the Akaike Information Criterion (AIC; Akaike 1974). An AIC decrease of at least 2 supports the more complex model compared to the simpler model. This approach is in line with the one used by Groenewold et al. (2014).

To conduct our analysis, we used R (version 3.1.2) and the package lme4 (Bates et al. 2014).

Results

In Figure 4, the results on the 4 tests are displayed graphically.

[Figure 4 about here]

In Table 3, the results of the statistical analysis are given.

[Table 3 about here]

The Table shows the fixed-effects structure of the model. The random-effects structure (not shown) of the model consisted of random intercepts for item and subject, as well as by-subject random slopes for test and word frequency. These random intercepts and slopes were necessary as they reduced the AIC by at least 2.

The goodness of fit of the final model (see Table 3) may be evaluated using the index of concordance C (e.g., Harrell 2001). Values of C higher than 0.8 may be regarded as indicative of a successful classifier. Therefore, our model performed well with a C of 0.9.

The interpretation of the model is as follows. Higher age of acquisition (across all four tests) results in lower performance (shown in line 2 of the table). This means that verbs and nouns that are learned early are easier to retrieve than those that are learned later. There is a similar effect of imageability (shown in line 3 of the table): retrieval of both nouns and verbs, across all four tests, is influenced by imageability: the more concrete a verb or a noun is (i.e. having a lower imageability score), the easier it is to produce the word. Lemma frequency and test type interact (i.e., the effect of word frequency varies per test). Lines 4 to 6 show that for the average lemma frequency (since lemma frequency is centered), retrieval of nouns (object naming) is significantly easier than retrieval of verbs on the action-naming test. This effect is independent of the effect of age of acquisition and imageability. Lines 7 to 10 of Table 3 show that word frequency does not influence the retrieval of verbs, nor the production of verbs in isolation, nor their usage (in finite or non-finite nouns) in a sentence context. Lemma frequency only influences object naming. Higher frequency words are easier to retrieve, even while controlling for imageability. Instead of lemma frequency, we also fitted a model using lexeme frequency (the two correlated highly: $r = 0.93$, $p < 0.05$). However, the model fit of this model appeared to be worse (an AIC increase of 6). Consequently, we used lemma frequency as our predictor representing word frequency.

Discussion

The research question was whether noun and verb retrieval in well-controlled test conditions are influenced by word frequency when AoA and imageability (and other factors that showed to influence verb retrieval) are taken into consideration. As in many other studies (e.g., Kittredge et al., 2011), AoA, imageability and frequency affected the retrieval of nouns on an object-naming task. The results on an action naming task as well as on the tests for filling in infinitives and finite verbs failed to show a similar frequency effect on verb retrieval, just like in several other studies (e.g., Kemmerer and Tranel, 2000; Luzzatti et al., 2002).

In the next sections, the results will be interpreted in relation to the model sketched in the Introduction.

Imageability

Imageability plays a role at the level of the concept and the lemma: lemmas of high imageability concepts are easier to retrieve than lemmas that belong to less imageable concepts. The results of the analysis show that retrieval of nouns and verbs in aphasia is influenced by imageability. The lower the imageability, the harder it is to activate the lexical information. Notice that this does not mean that verbs are harder because their imageability is lower than that of nouns, as suggested by Bird et al. (2001). Verbs and nouns were rated separately by two different groups of people and the imageability for the items on the object and action-naming test was similar. The reported imageability effect means that retrieval of nouns belonging to concepts that are harder to imagine are more difficult to retrieve; the same holds for verbs.

Word class

Word class plays a role at the level of lemma retrieval and grammatical encoding. The data show that retrieval of verbs on all three verb-tests is more difficult than the retrieval of nouns. This is in line with many other studies (e.g., Jonkers and Bastiaanse, 2007; Kambanaros and Van Steenbrugge, 2006). The reason is that the grammatical encoder must encode all lemma information and the more information there is, the lower the performance of an IWA will be. This has been shown for agrammatic speakers (e.g., Bastiaanse and Van Zonneveld, 2004; Kim and Thompson, 2004) as well as for fluent aphasic speakers. In the latter group, verb retrieval diminishes when more complex grammatical encoding is demanded (Bastiaanse, 2011). Interestingly, verb frequency plays a role at this level: in spontaneous speech the verbs that are inflected for tense and agreement are of lower frequency than those of NBDs, whereas this is not the case for other verb forms. However, Bastiaanse (2011) did not control for AoA and imageability.

From the current findings we conclude that verbs are harder to retrieve than nouns for aphasic speakers, because they contain more grammatical information that needs to be encoded.

Word frequency and Age of Acquisition

Both word frequency and AoA play a role at the level of the lexeme. When the word was acquired (AoA) and how often it has been retrieved (word frequency) determines the ease with which lexemes can be accessed. The data showed that word frequency and

Age of Acquisition affect the retrieval of nouns on an object-naming task in aphasia. However, as Kittredge et al., (2010) argue, these two factors are not only related to the lexeme, but probably to the whole string concept – lemma – lexeme, since they are always activated in combination. Also, it is not entirely clear what people do when they rate AoA: do they rate when they acquired the word or when they acquired the concept? Of course, these two are very hard to divide, especially for laymen who participate in such a survey.

As mentioned in the Introduction, there is an ongoing discussion on the independence of the factors AoA and word frequency. It is clear that these are related (see Nickels and Howard, 1995; Brysbaert and Ellis, this issue). In the study of Nickels and Howard (1995) and in the current study similar regression analyses were done to measure the effects of AoA and word frequency independently. Nickels and Howard (1995) report an effect of AoA, but not of word frequency, on an object-naming test, whereas we find an AoA as well as a word frequency effect on a similar test. The reason of this difference may be language related (Nickels and Howard: English; current study: Dutch) or it may be due to the fact that we used frequencies of spoken language whereas Nickels and Howard used a written language corpus.

AoA did influence verb retrieval on all 3 tests. This means that AoA is quite a robust factor that overrules the effect of word class in aphasic word retrieval. This does not hold for frequency: frequency does not affect the retrieval of verbs, as has been shown before (e.g., Kemmerer and Tranel, 2000; Luzzatti et al., 2002). A similar result was reported for frequency of grammatical construction in agrammatic aphasia: the frequency with which grammatical constructions are used in a language is not related to the ease with which agrammatic speakers can produce them (Bastiaanse et al., 2009; but see Gahl and Menn, this issue). What verbs and grammatical constructions have in common, is that they, unlike nouns, vary in their grammatical complexity and this complexity rather than frequency determines the ease with which they are produced: complex constructions are hard for aphasic speakers, just like complex verb lemmas.

An interesting finding is that lemma frequency is a slightly better predictor than lexeme frequency. This is in line with the findings of Kittredge et al. (2011). However, there is only a significant influence of frequency for nouns. For nouns there is little variation between lemmas and lexemes: in Dutch there are two lexemes for each noun (singular and plural) that are morphologically and phonologically closely related. For verbs, however, there are many more lexemes per lemma. There are the finite verbs that are inflected for tense, person and number and the non-finite infinitives and participles. This results in at least 6 different lexemes for each verb. Apart from that, many high-frequency verbs have an irregular form in past tense and past participle. However, there is no influence of either the lemma or the lexeme frequency on the production of infinitives or finite verbs.

Conclusion

We evaluated the influence of word frequency on the retrieval of nouns and verbs, using several tasks. Logistic mixed-effects regression modeling showed that performance of individuals with aphasia is influenced by age of acquisition and imageability. The effect of frequency only shows up for noun retrieval. Noun retrieval is better preserved than verb retrieval and the latter is not influenced by frequency. It is suggested that the complexity of the verb lemma is responsible for the poor performance on the verbs tasks and that this determines the lack of frequency effects.

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Appendix

The percentages correct. lemma and lexeme frequencies and Age of Acquisition (AoA) and Imageability ratings for the individual items of the tests for action naming and object naming and filling in infinitives and filling in finite verbs.

Action naming

Dutch	English	%correct	lemma frequency	lexeme frequency	AoA	imageability
aaien	to stroke	58	1.36	0.78	1.47	1.64
aansteken	to light	52	1.78	1.18	2.58	2.32
boren	to drill	86	1.88	1.59	2.37	1.68
breien	to knit	86	1.71	1.46	2.58	1.45
drinken	to drink	78	3.15	2.85	1.11	1.14
eten	to eat	70	3.61	3.31	1.00	1.27
fietsen	to bike	80	2.95	2.74	1.68	1.18
fluiten (met fluitje)	to [blow a] whistle	68	2.16	1.76	1.95	1.82
föhnen	to dry hair	76	0.48	0.00	3.32	1.45
fotograferen	to photograph	58	1.70	1.38	3.11	1.36
hockeyen	to play hockey	44	1.11	0.78	3.21	1.32
kammen	to comb	76	1.53	0.60	1.74	1.59
knipogen	to wink	54	1.40	0.48	2.89	1.50
knippen	to cut [scissors]	74	2.37	2.02	1.74	1.41
koken	to cook	82	2.80	2.56	1.84	1.41
koppen	to play the ball with the head	76	1.97	1.30	2.74	2.14
lassen	to weld	64	0.78	0.30	3.53	1.73
lezen	to read	86	3.74	3.36	1.68	1.27
lijmen	to glue	68	1.15	0.70	1.79	2.09
melken	to milk	70	1.43	1.28	2.26	1.36
plukken	to pick [flowers]	58	2.05	1.67	3.11	1.91
puzzelen	to jigsaw	72	1.20	1.08	1.89	1.64
roeien	to row	74	1.82	1.66	2.79	1.32
schaatsen	to skate	82	1.88	1.84	2.00	1.36

scheren	to shave	76	1.81	1.48	2.42	1.41
schermen	to fence	66	1.30	1.11	3.63	1.59
schieten	to shoot	68	2.93	2.17	2.21	1.55
schilderen	to paint	80	2.48	2.14	2.47	1.27
schommelen	to swing	60	1.59	0.95	1.68	1.27
skiën	to ski	60	2.03	1.96	2.89	1.27
slapen	to sleep	92	3.26	3.02	1.05	1.23
slijpen	to sharpen	52	1.45	1.00	2.58	2.50
snijden	to cut	56	2.43	1.88	2.00	1.45
snorkelen	to snorkel	76	0.78	0.78	3.32	1.41
sproeien	to spray	66	1.08	0.90	2.58	1.95
stempelen	to stamp	62	1.18	1.00	2.32	1.95
steppen	to scooter	64	0.70	0.48	2.11	1.55
stofzuigen	to vacuum	82	1.70	1.59	2.32	1.18
strijken	to iron	82	2.11	1.72	2.53	1.41
tanken	to get gas	76	1.66	1.43	3.05	1.5
tappen	to draft beer	68	1.32	1.00	3.74	1.86
trouwen	to marry	72	2.91	2.37	2.05	1.64
varen	to sail	38	2.34	1.90	1.84	1.68
vlechten	to braid	56	1.11	0.00	2.21	1.82
vliegeren	to kite	76	0.85	0.70	2.05	1.41
vouwen	to fold	50	1.79	1.28	1.95	2.50
zagen	to saw	80	2.00	1.81	2.00	1.32
zingen	to sing	76	2.96	2.61	1.53	1.82
zitten	to sit	66	4.38	3.61	1.11	1.27
zwemmen	to swim	74	2.65	2.51	1.68	1.18

Object naming

Dutch	English	%correct	Lemma frequency	Lexeme frequency	AoA	Imageability
appel	apple	96	2.21	1.70	1.20	1.07
auto	car	96	3.44	3.36	1.10	1.07
baby	baby	92	2.45	2.26	1.10	1.13
ballon	balloon	84	1.68	1.23	1.30	1.20
bed	bed	96	3.11	3.08	1.10	1.07
bel	bell	90	2.21	2.05	1.30	1.20
berg	mountain	82	2.59	2.26	1.50	1.13
boek	book	96	3.63	3.37	1.40	1.07
brandblusser	fire extinguisher	61	0.70	0.48	2.80	1.80
brood	bread	96	2.74	2.58	1.10	1.07
drumstel	drums	69	0.90	0.90	2.50	1.20
emmer	bucket	88	1.99	1.77	1.40	1.10
fiets	bike	96	3.01	2.94	1.20	1.07
garde	whisk	53	1.28	1.28	2.90	1.20
hand	hand	98	3.49	3.28	1.10	1.07

handboeien	handcuffs	82	0.70	0.70	2.60	1.30
hark	rake	78	1.26	1.00	2.00	1.20
hockeystick	hockey stick	73	0.48	0.30	3.20	1.20
horloge	watch	86	1.81	1.81	2.20	1.13
kam	comb	94	1.32	1.26	1.20	1.07
koe	cow	98	2.55	2.13	1.00	1.00
konijn	rabbit	94	2.17	1.95	1.00	1.00
lucifer	match	75	1.32	0.90	2.10	1.07
mes	knife	96	2.17	2.01	1.30	1.00
microfoon	microphone	69	2.23	2.15	2.90	1.27
naaimachine	sewing machine	71	1.28	1.18	3.00	1.27
neus	nose	90	2.65	2.62	1.00	1.13
oog	eye	94	3.30	2.74	1.00	1.13
paard	horse	94	2.64	2.39	1.30	1.10
pan	pan	84	2.32	2.02	1.70	1.13
pleister	bandaid	73	1.36	1.20	1.30	1.13
schaar	scissors	86	1.69	1.56	1.70	1.00
schep	shovel	75	1.56	0.90	1.20	1.07
schilderij	painting	78	2.46	2.16	2.40	1.53
schoen	shoe	92	2.60	1.79	1.10	1.07
schommel	swing	69	1.11	1.00	1.40	1.27
sjaal	shawl	90	1.76	1.54	1.70	1.20
slee	sledge	71	1.61	1.53	1.20	1.00
snor	moustache	88	1.60	1.49	1.80	1.20
sok	sock	88	2.04	0.95	1.10	1.13
stoel	chair	88	2.81	2.60	1.20	1.13
stofzuiger	vacuum cleaner	82	1.62	1.56	2.40	1.20
taart	cake	84	1.91	1.79	1.30	1.07
tent	tent	88	3.07	2.69	1.60	1.20
trampoline	trampoline	45	0.30	0.30	3.00	1.20
tuinslang	hose	69	0.48	0.30	2.30	1.33
verrekijker	binocular	71	1.11	1.08	2.20	1.30
vlieger	kite	69	1.56	1.46	1.50	1.07
zaag	saw	88	1.28	1.15	1.90	1.13
zwembad	swimming pool	82	2.30	2.24	1.80	1.07

Filling in infinitives

Dutch	English	%correct	lemma frequency	lexeme frequency	AoA	Imageability
badmintonnen	to play badminton	61	0.78	0.70	3.05	1.32
bedelen	to beg	75	1.51	1.08	3.05	2.14
bidden	to pray	88	2.22	2.00	1.95	1.64
blaffen	to bark	84	1.72	1.18	1.50	2.30
fluiten	to whistle	75	2.16	1.76	1.95	1.82

inschenken	to pour	59	1.54	1.40	2.47	1.59
kneden	to knead	71	0.95	0.60	2.05	2.14
marcheren	to march	80	1.62	0.78	3.32	1.95
mediteren	to meditate	33	1.34	1.23	4.30	3.50
opblazen	to inflate	82	1.69	1.04	2.37	2.20
ophangen	to hang	73	2.40	2.16	2.20	2.09
schillen	to peel	78	1.64	1.43	2.47	1.73
schoffelen	to hoe	57	1.15	0.85	3.21	1.91
smeren	to butter	76	1.82	1.45	1.84	2.09
spelen	to play	78	3.60	3.10	1.05	2.00
surfen	to surf	53	1.79	1.72	3.05	1.36
tellen	to count	76	2.79	2.30	1.47	2.45
vangen	to catch	84	2.51	2.16	1.47	2.09
vegen	to sweep	75	2.18	1.56	1.95	1.41
vijlen	to file	59	0.60	0.48	3.26	2.09

Filling in finite verbs

Dutch	English	%correct	lemma frequency	lexeme frequency	AoA	Imageability
duikt	dives	79	2.24	1.51	2.42	1.27
harkt	rakes	76	1.08	0.00	2.11	1.50
kijkt	watches	67	4.16	3.09	1.00	2.45
knuffelt	hugs	65	1.43	0.60	1.58	1.82
kruipt	crawls	69	2.45	1.90	1.32	1.59
kust	kisses	84	2.26	0.85	1.68	1.27
likt	licks	71	1.68	1.28	1.74	1.45
luistert	listens	65	3.14	2.21	1.47	3.20
perst	squeeze	59	0.00	0.00	2.79	2.73
roert	stirs	69	1.61	0.30	1.95	1.55
schreeuwt	shouts	65	2.40	1.62	1.74	2.14
springt	jumps	71	2.73	2.11	1.37	1.59
strikt	ties	60	0.95	0.00	1.95	2.05
tennist	plays tennis	51	1.92	0.70	2.74	1.27
toetert	honks	63	1.11	0.30	2.00	2.09
trekt	pulls	79	3.36	2.72	1.84	1.82
verbindt	bandages	59	2.46	1.41	3.00	2.77
vliegt	flies	65	2.84	2.10	1.58	1.36
zeeft	sieves	39	1.08	0.00	2.32	2.32
zweet	sweats	47	1.82	0.90	2.53	1.95

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Notes

[1]There is a larger frequency corpus for spoken Dutch (SUBTLEX-NL, based on subtitles; 40M words), but this could not been used for the current study, since at the lexeme level, it does not distinguish the plural present finite and the infinitive which have the same form in Dutch and we only used infinitives. However, there is a high correlation between both corpora for both the lemmas (from 0.87 to 0.93, p<0.000) and the lexemes (from 0.88 to 0.93, p<0.000) we used.

[2]We are aware that for both AoA and imageability the balance female - male is far from ideal. This is due to the fact that there are only a few male students in Linguistics. However, it has been shown that AoA ratings of men and women do not differ (Moors, De Houwer, Hermans, Wanmaker, Van Schie, Van Harmelen, De Schryver, De Winne and Brysbaert, 2013). Unfortunately, the large AoA corpus of Moors et al. (2013) became available after we developed our tests and many of our items (33%) are not included in their corpus. However, for the words that do occur in both lists, the AoA is highly correlated (varying from 0.77 (p<0.000) for Object Naming to 0.97 (p<0.000) for Filling in Infinitives). Imageability ratings are not influenced by gender either (Friendly, Franklin, Hoffman and Rubin, 1982).

[2] One verb was used in both Action Naming Test and Filling in Infinitives Test: the Dutch verb *fluiten.* The meaning is both *to whistle* (non-instrumental) and *to blow a whistle* (instrumental). *To blow a whistle* was used in the Action Naming Test; *to whistle* was used in the Filling in Infinitives Test.

[3] We did not make a distinction between obligatory and pseudo-transitive verbs as has been done by, for example, Kim and Thompson (2000) since obligatory two-place action verbs hardly exist in Dutch.

Legends to the Figures

Figure 1: Language production model based on the model for speech production by Levelt (1989).

Figure 2: Examples of the tests for Action Naming (left: *to bike*) and Object Naming (right: *a bike*). Art work by Victor Xandri Antolin. © University of Groningen.

Figure 3: Examples of the tests for Filling in Infinitives (left: *whistle*) and Filling in Finite Verbs (right: *listens*). Art work by Victor Xandri Antolin. © University of Groningen.

Figure 4: Graphical representation of the test performance (percentages on the Y-axis) of the non-brain-damaged speakers (NBDs) and the aphasic speakers.

Table 1: Mean (sd for frequency; median for age of acquisition and imageability) and ranges on the tests for Action Naming, Object Naming, Filling in Infinitives and Filling in Finite Verbs.

	lemma frequency	lexeme frequency	age of acquisition	imageability
Action Naming	1.94 (0.85)	1.56 (0.88)	2.28 (2.21)	1.57 (1.45)
	0.48-4.38	0.00-3.61	1.0-3.7	1.3-2.5
Filling in	1.80 (0.71)	1.45 (0.83)	2.40 (2.29)	1.99 (2.05)
Infinitives	0.60-3.60	0.48-3.10	1.1-4.3	1.3-3.5
Filling in finite	2.04 (0.97)	1.18 (0.95)	1.96 (1.90)	1.91 (1.82)
verbs	0.00-4.16	0.00-3.09	1.0-3.0	1.3-3.2
Object Naming	1.92 (0.81)	1.74 (0.86)	1.69 (1.40)	1.16 (1.13)
	0.30-3.63	0.30-3.37	1.0-3.2	1.0-1.8

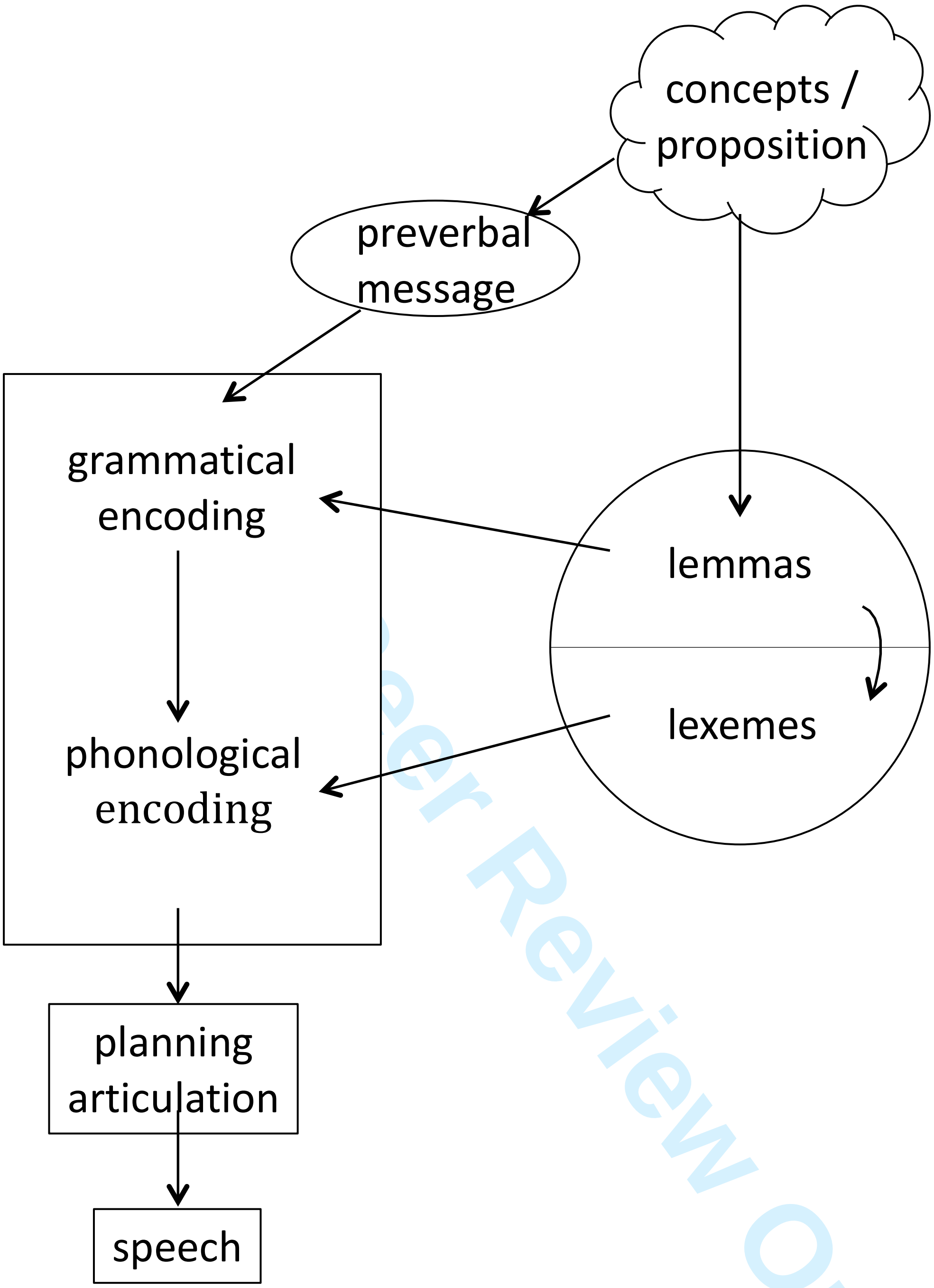
Tabel 2: Demographics of the 54 aphasic individuals.

Gender	30 male
Handedness	53 right-handed
Mean age[1] (sd)	55,52 (12.90)
Aphasia type	
Broca	15
anomic	7
Wernicke	3
global	2
mixed	19
rest	8

[1]Mean age (sd) has been calculated over 53 aphasic speakers; 1 age was missing from the files.

Table 3: The best-fitting logistic mixed-effects regression model predicting the correctness of a question.

	Estimate	Standard error	*p*-value
Intercept	1.49169	0.27945	< .001***
Age of Acquisition (centered)	-0.42685	0.12667	< .001***
Imageability (centered)	-0.66813	0.18669	< .001***
Filling in infinitives vs. Action naming	0.30184	0.23262	.194
Filling in finite verbs vs. Action naming	-0.39210	0.25848	.129
Object naming vs. Action naming	0.69460	0.21920	.002**
Frequency (centered), for Action naming	0.01416	0.14824	.924
Frequency (centered), for Filling in infinitives	0.31583	0.26220	.228
Frequency (centered), for Filling in finite verbs	0.17774	0.18407	.334
Frequency (centered), for Object naming	1.02789	0.16670	< .001***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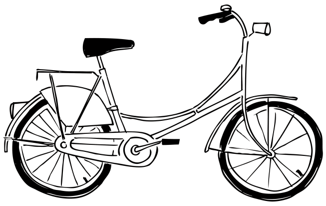
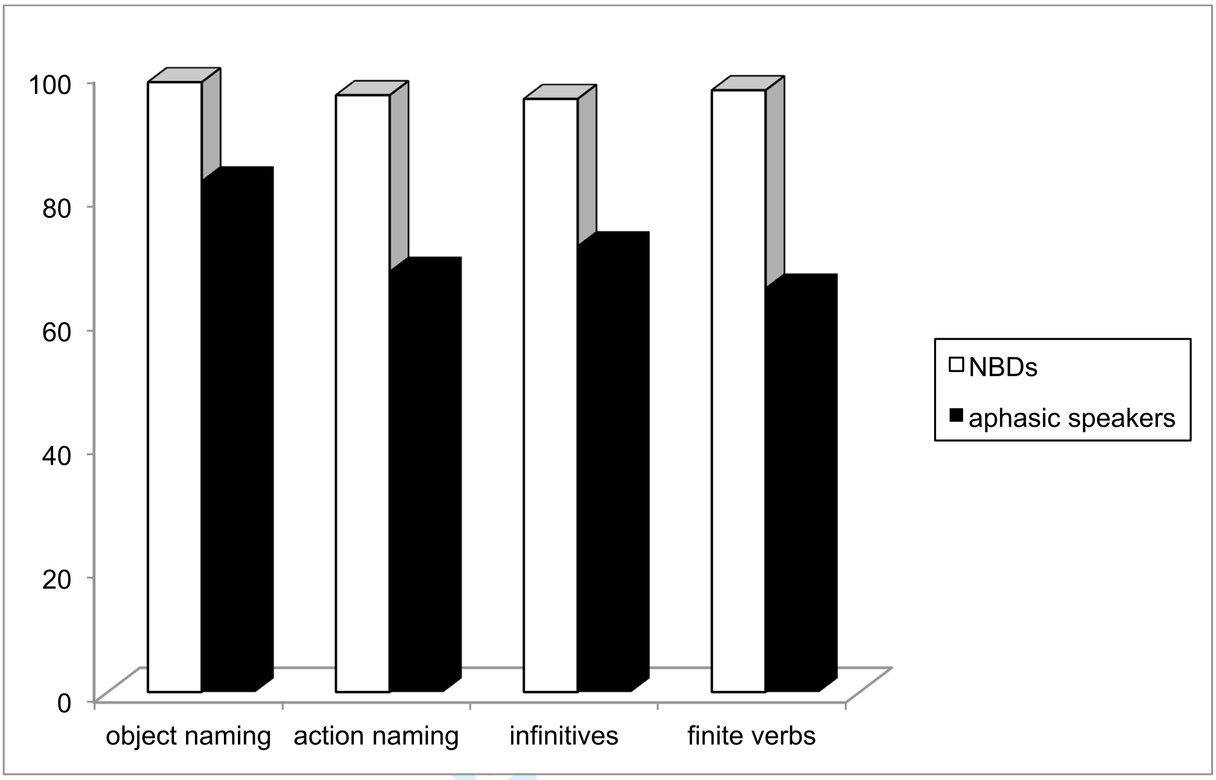


The boy likes to … in the street

Every morning the boy … to the bird


100
80
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object naming
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infinitives
finite verbs
NBDs
aphasic speakers