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Activation of syntax in lexical production in healthy speakers and in aphasia

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Abstract

Theories of spoken word production agree that semantic and phonological representations are activated in spoken word production. There is less agreement concerning the role of syntax. In this study we investigated noun syntax activation in English bare noun naming, using mass and count nouns.

Fourteen healthy controls and thirteen speakers with aphasia took part. Participants named mass and count nouns, and completed a related noun syntax judgement task. We analysed speakers’ noun syntax knowledge when naming accurately, and when making errors in production.

Healthy speakers’ noun syntax judgement was accurate for words they named correctly, but this did not correlate with naming accuracy. Speakers with aphasia varied in their noun syntax judgement, and this also did not correlate with naming accuracy. Healthy speakers' syntax for semantic errors was less accurate, as was that for speakers with aphasia. For phonological errors half the participants with aphasia could access syntax, half could not, indicating two types of phonological error. Individual differences were found in no responses. Finally, we found no effect of frequency for any of the above.

The lack of a relationship between syntax and naming accuracy suggests that syntax is available, but access is not obligatory. This finding supports theories incorporating non-obligatory syntactic processing, which is independent of phonological access. The semantic error data are best explained within such a theory where there is damage to phonological access and hence to independent syntax. For the aphasia group we identify two types of phonological error, one implicating syntax and phonology, and one implicating phonology only, again supporting independent access to these systems. Overall the data support a model with in which syntax is independent of phonology, and activation of syntax operates flexibly dependent on task demands and integrity of other processing routines.

Keywords: aphasia, anomia, semantic error, noun syntax

1. INTRODUCTION

1.1 Theories of spoken word production

The degree to which speakers access syntactic information while producing spoken words remains a focus of debate in psycholinguistics, in particular whether syntax is co-activated when a word is produced in isolation. In spoken production an activated semantic representation maps onto the relevant phonological code. There seems little debate around this, and several lines of enquiry converge on this universal finding. A number of theories propose that spoken word production involves primarily just these two levels (Caramazza, 1997; Ellis and Young, 1996; Patterson and Shewell, 1987), and the focus in most studies of anomia and rehabilitation lies squarely in these two domains (e.g. Howard et al., 1985; Wisenburn and Mahoney, 2009).

The finding of syntactic class constraints in error production (Dell et al., 1997; Fay and Cutler, 1977; Garrett, 1975) led to the proposal that syntactic information is integrated into the lexicon. ERP investigations of the time-frame of lexical access have found evidence of syntactic activation prior to phonological access (e.g. vanTurennout et al., 1997), which Levelt et al. (1999) incorporated into their WEAVER ++ model as the lemma level, and which mediates between semantics and phonology. Word-specific lemma nodes give access to syntactic properties. In similar vein, but motivated by speech error data, Dell et al. (1997) proposed a 'word' level lying between semantics and phonology. Interactive activation between the levels explains grammatical class constraints in error production, as syntactic activation at the word level ensures that competitors sharing grammatical class receive greater activation.

A number of authors have described the lemma stratum as a network of word-specific lemma nodes which connect to abstract word-independent combinatorial nodes, corresponding to the word's syntactic properties (e.g. Branigan and Pickering, 2004; Pickering and Branigan, 1998; Rowland et al., 2012). For nouns this consists of grammatical class, grammatical gender, mass or count status, and pluralisation forms. According to the theory, nouns sharing syntactic properties such as grammatical gender will access the same gender node. This all assumes lexical representation of syntax, and that sentences are constructed from activated lexical representations. Hence such theories have been termed 'lexicalist' accounts (e.g. Vigliocco et al., 2011).

A strong argument against a purely lexicalist account of sentence production is presented in a recent review of the literature by Vigliocco and colleagues (Vigliocco et al., 2011). They concluded that this view of syntactic representation was not upheld by findings across a range of methodological approaches. They report the general finding of activation of syntax only when this is explicitly required, such as explicit marking of gender, number, or case on nouns. When words are produced in isolation there is no compelling evidence of syntactic activation. This view is instantiated in Caramazza's (1997) influential Independent Network (IN) model, which argues for the independence of syntax from semantic and word form information.

1.2 Evidence concerning the activation of syntax

1.2.1 Grammatical class and gender in healthy speakers– picture-word interference

Effects have been investigated primarily with healthy speakers, using grammatical class or gender as the primes. Evidence for the activation of syntax in production has been found across a range of studies and languages, primarily when the task in question involved explicit engagement of morpho-syntactic information, for example in gender marking of adjectives or determiners. Effects have been found for grammatical class (e.g. Pechmann & Zerbst, 2002; Pechmann et al., 2004) and for grammatical gender (e.g. Akhutina et al., 1999; LaHeij et al., 1998; Schriefers, 1993; Schriefers and Teruel, 2000; Starreveld and La Heij, 2004; Vigliocco et al., 2002). Pechmann et al., (2004, p724) conclude that 'activation of grammar depends on engagement of syntactic processes'.

The counter-evidence, proposing activation of syntax in bare noun production comes from studies in French, Italian, Spanish, Russian and English. Melinger and Koenig (2007) primed grammatically ambiguous English words, such as 'convict', with either a noun or a verb, finding priming according to word class. Janssen et al. (2010) found an effect of grammatical category in their bare noun condition. Alario et al. (2004) found gender priming of bare nouns in French. Cubelli et al. (2005) found gender interference for bare nouns in Italian, Akhutina et al. (2001) found gender priming effects in Russian, and Paolieri et al. (2011) found gender interference in naming bare nouns in Italian. Finally, in English, Gregory et al. (2012) primed production of mass and count nouns with congruent determiners. So, across a range of languages, there is evidence of activation of syntactic information, even when this is not explicitly required for the production task, lending support to the claim that syntax is represented lexically.

1.2.2 Tip of the tongue states in healthy speakers

Vigliocco et al. (1997) found 84% accuracy in gender judgements in Italian speakers in ToT. In a similar study in English, Vigliocco et al. (1999) examined speakers' knowledge of mass and count syntax of nouns they could not name, finding above chance performance. Biedermann et al. (2008) found a dissociation between access to syntax and phonology in English and German speakers. Caramazza and Miozzo (1997), and Miozzo and Caramazza (1997) found similar results to Vigliocco et al. (1997). Crucially however the latter did not find a correlation between access to syntactic knowledge and access to phonological knowledge, concluding that the two forms of knowledge dissociated. Gollan and Silverberg (2001) found that healthy speakers were at chance on gender judgements when in ToT. As for gender priming, there are conflicting sets of evidence in this domain.

1.2.3 Evidence from anomia

The third form of evidence concerning syntactic knowledge in spoken word production comes from studies of speakers with aphasia, in Italian, English, French, Spanish and German. Typically, participants with anomia are asked to judge the grammatical properties of words they cannot produce. Dante (Badecker et al., 1995) was able to select the grammatical gender of the Italian targets at levels significantly above chance. GM (Henaff-Gonon et al., 1989) showed a similar pattern in French. Other similar findings are reported by Avila et al. (2001), Bachoud-Lévi and Dupoux (2003), Macoir and Béland (2004), and Scarnà and Ellis (2002). Akhutina et al. (2001) investigated gender priming in Russian speakers with aphasia, finding effects on bare noun naming latencies. Vigliocco et al. (1999) report the English speaker patient MS who was able to judge syntactic properties of mass and count nouns when unable to name these. Herbert and Best (2010) cued participant MH with determiners and found effects on mass and count nouns, and on error distribution across mass and count.

1.3 Syntactic knowledge and errors in production

1.3.1 Error types and classification

Speech errors differ in being either words or non-words, and in the degree to which they are related semantically and/or phonologically to the target. In addition to these errors of commission, there are also errors of omission, where no attempt at a response is made. Analysis of errors and the activation of syntax in error production can illuminate the mechanisms of processing further.

1.3.2 Semantic errors

Semantic errors are largely syntactically constrained (e.g. Garrett, 1975) hence the claim that they arise at the lemma level. Frequency effects governing semantic error production in aphasia (e.g. Bormann et al., 2008a; Dell et al., 1997; Kittredge et al., 2008) also support the notion that a lexical level malfunction underlies semantic errors.

The syntactic information that speakers have about the target, and the syntactic relationship between the target and the error, have both been examined. Paganelli et al. (2003) found that healthy speakers' targets and errors shared grammatical gender at levels above chance. Abd-el-Jawad and Abu Salim (1987) found that Jordanian Arabic targets and errors shared number, case, and grammatical gender. Marx (1999) found that healthy speakers' German targets and errors shared grammatical gender, similarly Arnaud (1999) in French. In aphasia similar findings have emerged. Most speakers produce nouns in place of nouns (e.g. Dell et al., 1997; Dell et al., 2004), indicating a lexically driven phenomenon. Kulke and Blanken (2001) found that gender was preserved in around 60% of paraphasias in German aphasic speech.

Counter evidence comes from e.g. Friedmann and Biran (2003), who found no evidence of preservation of grammatical gender in aphasic errors in Hebrew, which they explained in terms of the specific nature of the determiner phrase in Hebrew. In his seminal article outlining the IN theory, Caramazza (1997) cites findings from speakers with aphasia who present with semantic errors in one modality only, a finding which poses problems for the claim that a modality neutral lemma is the source of semantic errors.

1.3.3 Phonologically related errors

In healthy speakers phonological errors are more rare than lexical selection errors. In aphasia such errors are common, although incidence varies across speakers. The accepted view is that such errors arise in phonological encoding, after lexical selection has been completed. Few studies have analysed the degree to which syntactic information is available in the production of these errors. Berg (1992) found that German speakers with aphasia produced errors which preserved the target's gender at levels above chance. Dell et al. (1997) explain this finding in terms of activation of phonological competitors at the phoneme level, feeding back to the word level. Words which also share syntactic properties with the target will receive a boost. Hence those sharing both phonological and grammatical features will be highly activated. Still fewer studies have looked at syntactic information in the production of non-word phonologically related errors. As they are non-words they have no grammatical properties, so their class or gender cannot be assessed. As these errors are extremely frequent however, more so than formal errors, they warrant attention.

1.3.4 Failure to respond or omissions

More attention has been given to errors of commission than those of omission. Healthy speakers make few errors of omission in naming tasks, but for people with aphasia they are frequent, and for some speakers they account for most of their errors. As no response is provided it is difficult to determine the source of these errors. Evidence regarding syntactic activation when omitting a response may shed light however on the processing stage reached, and hence where the block arises. As for semantic errors, the fact that frequency of the target predicts the occurrence of omissions has been taken as evidence that the source is failure of lexical retrieval (Bormann et al., 2008a; Kittredge et al., 2008).

1.4 Mass and count nouns

Most of the studies investigating syntactic activation in production have been performed in languages carrying grammatical gender. This is a fixed property of a noun and hence provides a clear window onto processing. English does not carry gender but, like many other languages, does mark mass or count status explicitly and systematically in syntax. Count nouns such as cat frequently occur with determiners such as 'a', whereas mass nouns such as milk frequently occur with determiners such as 'some'. A few studies have capitalized upon this difference to investigate noun syntax in English (Gregory et al., 2012; Herbert and Best, 2005; Herbert and Best, 2010; Vigliocco et al., 1999).

One criticism of this methodology is that the count and mass distinction is not only syntactic but also semantic, as count nouns refer mainly to discrete entities, such as everyday objects, whereas mass nouns refer to, amongst other things, most substances. Subsequent processing in experiments involving mass and count nouns may as a result be semantically based. Such experiments investigating syntax via mass and count nouns need therefore to ensure that task completion is not semantically driven.

1.5 Summary and rationale for the study

The evidence marshaled above signals that there is a strong body of support for an independent level of processing, instantiating lexical syntactic information. Lemmas are word-dependent and modality neutral, and they provide access to word-independent nodes containing specific syntactic properties, such as word class, grammatical gender, and mass and count status. In a strongly lexicalist account access to this is obligatory in production. In other accounts e.g. the Independent Network (Caramazza, 1997), syntax is activated independently, in parallel, and activation is non-obligatory, unless required by specific task demands.

To address this debate we investigated noun syntax knowledge in English in healthy speakers and in those with aphasia, through a determiner judgement task with mass and count nouns. We analysed speakers' noun syntax knowledge for words named accurately and for different error types, in order to contribute to the arguments concerning the degree to which noun syntax information is activated in bare noun naming, and to arguments concerning the source of different errors in the processing routine. To ensure that we could isolate processing anomalies to lexical or phonological routines, and that contamination from semantic disturbance was not a contributory factor, we included only speakers with aphasia with good semantic processing.

2. PARTICIPANTS

2.1 Participant details

Thirteen people with aphasia and fourteen healthy controls took part. The people with aphasia had each sustained a single left hemisphere CVA at least one year prior to their participation. Three were female, and their mean age was 63, with a range of 41 to 83 years. They all had significant word-finding difficulties, and relatively good comprehension, such that they were able to follow task instructions. Six had fluent spoken language and seven non-fluent. None of the participants had marked loss of intelligibility of speech, and all had good hearing and vision. None had any other significant neurological or psychiatric history, and no history of speech or language difficulties prior to their stroke. Fluency was determined using the criteria established by Goodglass and Kaplan (1983). Details for participants with aphasia are shown in table 1. Aphasia classification was based on performance on language tests shown in table 2, and based on Davis' (1993) classification.

Table 1 here

The fourteen controls had no relevant neurological or psychiatric history, no history of speech or language difficulties, no history of neurological disorder, and all had normal hearing and normal or corrected to normal vision. Six were female, and their mean age was 67 (range 43 to 80 years). Ten were educated at school only, and four had undertaken higher education.

The participants with aphasia were recruited via local communication support groups. The controls were recruited from social clubs. All gave informed consent to participate. Ethical approval for the study was obtained from the North Sheffield NHS Local Research Ethics Committee and the Department of Human Communication Sciences Research Ethics Committee at the University of Sheffield. Participants attended assessment sessions at the Department, in their own homes, or at another appropriate venue of their choice, over a period of eight weeks (speakers with aphasia) and two weeks (controls).

2.2 Assessment of aphasia

The participants with aphasia were all tested using standard clinical tests of language and cognition. Aphasia syndrome and fluency are shown in table 1. Details of the various tests and participants' scores are shown in table 2.

Table 2 here

Participants presented with a range of aphasia syndromes. All had some degree of anomia as shown on CAT picture naming (Comprehensive Aphasia Test: Swinburn et al., 2005). None of the participants had visual perceptual difficulties. Participants presented with scores on tests of semantic processing which were within the normal range for at least two tests. All were within normal limits for spoken word to picture matching. In terms of phonological output, seven participants retained relatively good phonological output as shown by scores above 90% on word repetition, whereas six showed marked impairments.

2. 3. Noun syntax in production

In order to investigate the nature of the relationship between noun production and noun syntax knowledge, all the participants were assessed on the same novel test, which involved picture naming, combined with a related syntax judgement test. The same test was used with participant MH described by Herbert and Best (2010).

2.3.1 Determiner processing

2.3.1.1. Methods

As the syntax component of the syntax judgement test relied on processing of a particular set of function words, a function word lexical decision task was used as a screening test to assess word recognition in the people with aphasia. This test consisted of six function words, including A, AN, and SOME, which were used in the noun syntax judgement test (details to follow) and six non-words, which were derived by changing one letter in each real word. Participants were presented with the list in written format. They were asked to say yes or no to each item. A score of 10 or greater was judged to be above chance performance, but we stipulated 100% performance on this in order for participants to proceed.

2.3.1.2. Results

All 13 speakers with aphasia scored 100% on the lexical decision task. This indicates that for these speakers with aphasia word recognition of the function words used in this task, and hence in the following experiment, is intact.

2.3.2 Picture naming and syntactic judgement task

2.3.2.1 Materials

The picture materials depicted two types of nouns, 40 count nouns and 40 mass nouns. The nouns were common objects or substances. The two sets were matched for key psycholinguistic variables (table 3). All were single nouns, and none were compounds or superordinate terms. Some nouns depicted animate entities such as vegetables, but none were living things. Each noun was depicted by a digital photograph. Name agreement for the photographs had been established with 15 healthy younger control speakers, aged 33-60, of whom eight were female (87% or greater agreement).

Table 3 here

2.3.2.2 Design

The nouns were sorted into four lists of twenty words, 10 mass and 10 count in each list. Items were quasi-randomised in each list to ensure that semantically or phonologically related items were at least three items apart, and no more than three items in either the count or mass category occurred consecutively. Participants were exposed to one of 24 possible orders of the four lists, randomly selected. Healthy controls completed all four lists in one session, whereas participants with aphasia completed one list per session over four consecutive sessions, each a week apart.

2.3.2.3 Procedure

The noun naming and syntax judgement experiment was presented on a computer software program designed for the study by Dr Mike Coleman of University College London. The experiment involved two stages for each item: naming, followed by syntax judgement. In the naming stage a photograph appeared in the middle of the screen and remained there for 20 seconds or until a response had been given. Participants were instructed to name the picture as quickly as they could, using the single best word for that picture. After the naming attempt was completed the experimenter moved the program on to the second stage. Here, the same picture appeared in the centre of the screen reduced in size. At the same time the words A and SOME appeared top left and right of the screen in 36 bold font. At the same time as the written words appeared, the spoken form was also presented to the participant via headphones. The written words remained on screen for ten seconds, or until a response had been given within that time. Participants were instructed to select the determiner which correctly paired with the noun by pressing a keyboard button on the left or the right. The position of the determiners was varied, to ensure that no three consecutive correct selections were positioned on the same side, and no determiner appeared on the same side in three consecutive trials. After the participant's attempt at determiner selection for that item was completed the researcher moved the program on to the next item.

The program recorded the spoken naming responses in audio-files. The response accuracy of the syntax judgement task was recorded via the button press. All naming responses were transcribed in situ, then checked against the audio-recordings after the assessment was complete. Each response was then coded for its relationship to the target.

2.3.2.4 Response coding

The criteria used to code responses are based on those described by Dell et al. (1997) (see box). Following this methodology, the first CV or VC response containing an unreduced vowel was coded. A response was counted as correct if it exactly matched the target picture name. Preceding determiners or adjectives were accepted with a correct response, so the responses *a book* for the target *book* or *green grass* for the target *grass* were considered correct.

The reliability of the coding was checked by a second researcher who independently coded 10% of the naming attempts, including a sample taken from each of the 14 participants with aphasia. Comparison of codings showed overall agreement of 96%. Syntax judgement responses were scored correct or incorrect. All responses produced after 10 seconds were scored as incorrect. All failures to make a decision were also scored as incorrect. The resulting data consisted of naming responses and concomitant syntax judgement for each participant for all 80 words.

Lexical errors
Semantic: the response is a synonym, category coordinate, category superordinate, category subordinate or associate of the target
Formal: the response is phonologically similar to the target, i.e. the target and response starts and ends with the same phoneme, has a common phoneme in another syllable or word position or has more than one common phoneme in any position. Proper nouns and

plural morphemes do not contribute to phonological similarity
Mixed: the response meets the criteria for both semantic and formal errors
Unrelated: the response meets neither semantic nor formal errors and is not visually related to the target

Sublexical errors

Phonologically related non-word: criteria as for Formal but resulting in a non-word
Semantically related or semantically and phonologically related non-word: e.g. response 'babbit' for target 'squirrel'
Unrelated non-word: no relationship to the target and not a real word

Other

Description: the response is a multiword utterance or single adjective or adverb that characterizes the target object or explains its function or purpose.
No response: no spoken production apart from comments such as 'Oh what's the word'.
Miscellaneous: e.g. named a part of the target object such as response 'sleeve' for target 'jumper'.

3. Results

3.1 The relationship between naming accuracy and syntactic knowledge

3.1.1 Healthy controls

Table 4 shows overall naming accuracy, and, for those items which were named correctly, the proportion of them for which the syntax judgement was correct. Controls made few errors in naming, and each picture was named correctly by at least 12 of the 14. All participants responded at levels significantly above chance in their syntax judgement of correctly named words. These data suggest that controls were able to easily access related syntax when they named an item. None of the controls showed a difference between mass and count naming, or mass and count syntax judgement.

Table 4 here

3.1.2 Speakers with aphasia

Table 5 shows the data from speakers with aphasia for overall naming accuracy, and, for those items which they named correctly, the proportion for which the syntax judgement was correct, along with z scores derived from the normal data for both tasks, and results of binomial tests used to analyse the relationship between the syntax scores and chance. Details of each participant's syndrome and fluency are also included. Participants are ordered by naming accuracy.

All performed significantly worse than controls. All participants were also significantly impaired on the noun syntax test in comparison to the controls, and there were marked variations in performance across the group. Three participants' syntax scores did not differ significantly from chance. Details of individual response patterns are in Appendix A.

Table 5 here

The combined data for the whole group showed a small advantage in naming count nouns (321 count nouns vs. 292 mass nouns) but this was not significant (Wilcoxon $z=0.84$, $df=12$, two tailed $p=0.4008$). Four people showed significant differences in naming accuracy between count and mass nouns. EB and PT showed an advantage for mass nouns (two tailed Fisher Exact: EB $p=0.0018$; PT $p=0.04$) and two showed an advantage for count nouns (two tailed Fisher Exact: GE $p=0.0025$; KC $p=0.03$).

Syntax accuracy was better for count nouns than for mass nouns (Wilcoxon $z=2.25$, $df=12$, $p=0.0243$). Five participants showed a significant advantage for count noun syntax judgements (two tailed Fisher Exact: KC $p=0.04$; MC $p=0.04$; NH $p<0.001$; RP $p=0.04$; SH $p=0.06$). Note that MC and NH were at chance overall on this test, thus the difference reflects a response bias wherein they selected 'a' in most cases, regardless of the status of the noun. When participants whose overall judgement was at chance were removed there was no difference between mass and count (Wilcoxon $z=0.89$, $df=9$, $p=0.37$).

Ten of the thirteen speakers with aphasia performed above chance on the syntax test. Of these, five were fluent and five non-fluent speakers. Of those who were at chance on the noun syntax test one was fluent, and two were non-fluent. Thus we found no evidence linking noun syntax knowledge to fluency or aphasia syndrome.

Comparison of the controls with the speakers with aphasia revealed significant differences between the groups for naming accuracy (t=9.268, df=25, p<0.001), and for syntax (t=6.936, df=25, p<0.001).

3.1.3 Correlations between naming and syntax judgement scores

In order to further explore the relationship between syntax knowledge and naming accuracy, specifically do the two co-vary or are they independent, we used correlations to examine naming scores and syntax accuracy scores. We found no relationship between syntax accuracy and naming accuracy for controls (Pearson's R=-0.198, df=12, p=0.496), or for the people with aphasia (Pearson's R=-0.33, df=11, p=0.277).

3.1.4 Interim discussion

The data indicate that successful naming in healthy controls is accompanied by successful access to noun syntax knowledge. At issue is whether bare noun naming requires access to syntax. Correlational analyses found no relationship between accuracy and access to noun syntax. It is feasible therefore that healthy speakers *can* access syntax, but that they do not need to do so in order to produce a noun.

The data from speakers with aphasia reveal differences between speakers in terms of access to lexical syntax information. This is not related to aphasia syndrome or fluency. Like the control group, the lack of a relationship between naming accuracy and access to lexical syntax in speakers with aphasia supports the contention that syntax may be activated, but that bare noun naming can proceed without this.

3.2. Error responses

3.2.1. Controls

3.2.1.1. Syntax knowledge for errors

Healthy controls produced 63 errors, 49 of which were semantic errors, 13 mixed semantic and phonological errors, and one was an unrelated word. Table 6 shows the distribution of the two main error types, and syntax judgement scores for each type. The controls' noun syntax judgements to semantic errors were above chance, but this was significantly impaired in comparison to when they named items correctly (Wilcoxon z=2.73, df=13, p=0.0032). When they made mixed errors their syntax judgements were 100% accurate.

The data show that in the case of lexical selection errors, access to syntax is significantly impaired in comparison with access in accurate naming. This suggests that disturbances to lexical selection processing also implicate syntactic mechanisms. The retained access to syntax for the mixed errors is at odds with this claim, unless interactive processing is invoked (see Discussion).

Table 6 here

3.2.1.2. Mass and count status of errors

If syntax is activated in semantic error production, targets and errors should share mass or count status, as the latter forms one of the (hypothetical) primitives of noun syntax. Figure 1 shows the mass and count status of the two main error types according to target's status.

Figure 1 here

The data show a difference between mass and count nouns. The majority of errors to count noun targets were count nouns, either singular or plural, for both semantic and mixed errors. Only one error was a mass noun. The errors to mass targets included both mass and count nouns.

Syntax accuracy did not differ however for count versus mass semantic errors (Wilcoxon matched pairs z=0.27, df=7, p=0.79). This demonstrates that the impaired syntax judgements to semantic errors were not due to correct selection of syntax for the error word, i.e. producing a count noun in place of a mass noun target, e.g. *leek* for target *garlic*, then selecting the correct syntax for the error - participants made equal numbers of errors when the target and error shared mass or count status, e.g. in selecting determiner 'some' when producing a count noun in place of a count noun.

3.2.2. Speakers with aphasia and errors

3.2.2.1 Syntax knowledge for errors

The speakers with aphasia produced a total of 427 errors. There were three predominant error types: lexical semantic errors, non-lexical phonologically related errors, and no responses. These three categories made up 71% of the total errors. The distribution of errors for the 13 participants as a group is shown in table 7.

Table 7 here

Syntactic accuracy for the three main types of error is shown in table 8. As a group the participants with aphasia were at chance on syntax judgement when they produced semantically related errors. They performed above chance when producing non-lexical phonologically related errors and no responses.

Table 8 here

Table 9 shows the breakdown of semantic errors by count or mass target, and the proportion of syntax judgements in each class. There were significantly more semantic errors to mass targets than to count targets (Wilcoxon matched pairs z=2.06, df=12, two tailed p=0.0389). Syntax accuracy was slightly better for count noun targets although this was not significant (Wilcoxon matched pairs z=1.37, df=12, two tailed p=0.1698).

We also coded semantic errors as either coordinate or associative errors to identify any differences between mass and count nouns. We found no difference here, with 0.90 count noun errors and 0.87 mass noun errors being coordinates of the target.

Table 9 here

To control for the impact of the group who were at chance on syntax judgements we re-analysed the data excluding the participants whose syntax judgements were at chance for accurately named. These data are shown in table 10. Analyses from this point forward relate to those ten only, as the remaining three were also at chance on syntax for errors.

Table 10 here

Removal of the group who were at chance did not alter the overall findings. Participants who performed well for correctly named items showed differences in syntactic knowledge for the three error categories. The combined data showed good knowledge of syntax for phonologically related errors and for no responses, and more impaired knowledge for semantically related errors.

There were more semantic errors to mass than to count targets (41 vs 52) but this was not significant (Wilcoxon matched pairs $z=1.3$, $df=9$, two tailed $p=0.1922$). There was no difference in syntax accuracy across the two sets (Wilcoxon matched pairs $z=0.92$, $df=9$, two tailed $p=0.3590$).

Individuals' syntax scores for correctly named and for each error type are shown in Table 11. Comparing syntax accuracy between accurately named and each different error type, there was a significant difference between accurately named and semantic errors (Wilcoxon $z=2.75$, $df=9$, two tailed $p=0.0059$), but not between accurately named and phonological paraphasias (Wilcoxon $z=0.21$, $df=7$, two tailed $p=0.8336$), or between accurately named and no responses (Wilcoxon $z=1.07$; $df=8$, two tailed $p=0.2863$).

Table 11 here

The semantic error data show that nine of the ten participants accessed syntax more accurately when they named items correctly, than when they made a semantic error. Only JMM showed the opposite pattern. The individual data therefore support the group analysis.

Of the eight participants who made phonological paraphasias, four showed better access to syntax when they made phonological paraphasias, and four showed better access to syntax when they named accurately. KC, RP GE, and JMM had significantly better access to syntax for phonological paraphasias than for accurately named (Wilcoxon $z=1.64$, $df=3$, $p=0.05$). PT, WS, JM and EB showed the reverse (Wilcoxon $z=1.66$, $df=3$, $p=0.05$)

Of interest is that the first group showed good phonological access in production (word repetition scores: mean=0.90, st dev= 0.11, range=0.74-0.97). The second group presented with a phonological deficit in production, as demonstrated by their poor word repetition (mean=0.53, st dev= 0.14, range=0.39-0.66).

Eight participants produced no responses. JMM and RP produced the majority of these errors (60 of the 96 errors), and both showed high levels of syntactic accuracy for the failed target words. The other participants produced between 1 and 16 errors, and binomial tests for these participants revealed performance at chance.

The findings for semantic errors for the participants with aphasia are in tune with those from the healthy controls. They indicate that lexical selection errors also implicate syntactic processing. The data for phonological paraphasias identify two subgroups, with different sources of phonological disruption. One group has access to syntax, one does not. The data for no responses show individual differences.

3.2.2.2. Mass and count status of semantic errors

Figure 2 shows the mass and count status of the semantic errors according to target's status. For mass nouns we include a category 'unclassifiable' which included brand names such as Heinz, which are not categorisable by mass or count status. The data mirror the data from controls in that most errors to count nouns are count nouns, whereas for mass nouns a considerable number of errors are count nouns.

Figure 2 here

3.2.2.3 Summary

The error data reveal that control participants make predominantly lexical semantic errors. They are more likely to produce count nouns than mass nouns as errors. Syntax judgement is accurate at levels lower than for accurately named items, indicating that syntactic processes are disrupted. Syntax judgement for mixed errors was within the normal range for accurately named. This suggests a difference in processing between these two error types.

The participants with aphasia produced semantic errors, non-words which are phonologically related to the target, or failures to respond. Syntax judgement for semantic errors is at chance for both count noun targets and mass noun targets. The analysis of the semantic error data revealed the same pattern as found for controls, in that speakers with aphasia were more likely to produce count nouns than mass nouns as errors. Access to syntax for phonological paraphasias was either spared or impaired, and this related to overall phonological integrity. For no responses two individuals produced the majority of the errors and had good access to syntax. The other participants did not produce this error type often so their data are hard to interpret.

3.2.3 Effect of variables on performance

In this final section we analysed the impact of variables, including word frequency, on naming accuracy, syntax judgement, and errors. The analyses were completed for the two groups independently. For all analyses we examined the relationships between the dependent variable and name agreement, mass count status, imageability, frequency, age of acquisition, number of phonemes, and number of syllables, via correlations. Significant variables were then entered into the regression analysis.

3.2.3.1 Controls

None of the variables correlated significantly with naming accuracy, semantic error production, or syntax judgement. Frequency did not correlate with accuracy (Pearson's $R=0.139$, $df=78$, $p=0.218$), with semantic errors (Pearson's $R=-0.145$, $df=78$, $p=0.199$), or with syntax judgments (Pearson's $R=0.154$, $df=78$, $p=0.174$).

3.2.3.2 People with aphasia

Details of the regression analyses are in Appendix B. Name agreement and age of acquisition were significant predictors of naming accuracy. Mass count status and number of syllables predicted phonological errors. Age of acquisition predicted no responses.

No variables correlated with semantic error production, and only mass count status correlated with syntax judgment (Pearson's $R=0.346$, $df=78$, $p=0.002$): people with aphasia were significantly better at syntax judgement for count nouns than for mass nouns overall (all responses) (Wilcoxon $z=2.49$, $df=12$, $p=0.0129$) (but see 3.1.2 above).

3.2.5.3 Summary

We found no evidence of frequency effects on any of the dependent variables examined. For controls there were no effects of any variables on any outcomes. For the speakers with aphasia age of acquisition predicted accuracy and no responses. Mass count status and syllables predicted phonological errors.

4. DISCUSSION

In this study we examined the role of noun syntax in accurate spoken word production, and in error production, in healthy speakers and people with aphasia. We used one experiment to conduct this investigation, which assessed lexical retrieval, and concomitant access to lexical syntax.

4.1 Main findings

4.1.1 Accuracy and syntax knowledge

When naming accurately healthy speakers can usually access syntax. This was the case in the vast majority of trials. Syntax accuracy did not correlate with naming accuracy however, suggesting that naming can also proceed without access to syntax. No psycholinguistic variables predicted controls' naming accuracy or their syntax accuracy.

People with aphasia showed impairments in naming and in noun syntax. They differed individually in terms of their ability to access syntax knowledge, and, like the controls, their access to noun syntax did not correlate with naming accuracy. Name agreement and age of acquisition predicted naming accuracy, and mass count status predicted syntax accuracy, with more accurate syntax judgements to count than to mass nouns overall.

4.1.2 Errors and syntax knowledge

Healthy speakers produced predominantly semantic errors, and their knowledge of syntax for their errors was impaired in comparison to that for their accurately named words. They made equal numbers of errors to mass and to count targets, although more of the errors produced were count nouns. Syntax accuracy was similar across mass and count targets. Healthy participants also produced a small number of mixed errors, for which their syntax judgement was intact. No variables predicted semantic error production.

The participants with aphasia produced three main error types: semantic errors, phonological paraphasias, and no response. Like the healthy participants, the aphasia group's syntactic knowledge for semantic errors was impaired in comparison to that for accurately named words, they made equal numbers of errors to mass and to count targets, and the errors produced were predominantly count nouns. Syntax accuracy was similar across mass and count targets when response bias was excluded. No variables predicted semantic error production.

Syntax accuracy for phonological errors was similar to that for accurately named words. Individual analyses showed that this was due to four participants who had good syntax knowledge. The other four participants who produced these errors had impaired knowledge of syntax. The first group had good output phonology, and the second group impaired output phonology. Mass count status and number of syllables predicted phonological errors, with more phonological errors occurring on longer words, and more to count noun than to mass noun targets.

Syntax knowledge to no responses was similar to that for accurately named. Individual differences pertained however, and overall group effects were due largely to the impact of two individuals with good syntax knowledge. The other six speakers produced few errors in this category and/or showed impaired syntax. Age of acquisition predicted the occurrence of failure to respond.

4.2 Mechanisms underlying processing

4.2.1 Theories of spoken word production

Two stage accounts incorporating one route, from semantic or conceptual representations, to a word or lemma level, then to phonological representations involve necessary activation of a word-dependent node at the intermediate level word or lemma level (e.g. Dell et al., 1997; Levelt et al., 1999; Rapp and Goldrick, 2000). From here word-independent syntactic nodes can be accessed. In phrase or sentence production this access is deemed obligatory, whereas in bare noun production it is not (Levelt et al., 1999: 14). This allows the theory to explain gender congruency effects in production of phrases, and the absence of such effects in production of bare nouns (e.g. Schriefers 1993).

An alternative account, outlined by Caramazza (1997) and termed the Independent Network (IN) proposes three linked subsystems: a lexical semantic network, a syntactic network, and phonological (or orthographic) lexemes. There is some equivocation in the account of this theory regarding the degree to which activation of syntax is dependent upon prior activation of phonological lexemes (see Caramazza, 1997: 195). The crucial point here however is that the theory does not insist upon prior activation of syntax in order for activation of phonological forms to be realized, and indeed states that this may not be the case in many circumstances: 'the phonological and orthographic content of the lexeme nodes may, under special circumstances (e.g. TOT states, brain damage) become available independently of their grammatical features.' This theory thereby uncouples phonological access from syntactic access, and provides a more flexible processing account. Under certain circumstances syntax is activated, in particular where combinatorial demands are present, and in other circumstances it need not be, the prime example from the neuropsychological literature being bare noun naming.

4.2.2 Explanations of the accuracy data

The biggest challenge to the two stage account from our data concerns the finding of no necessary syntactic activation in accurate production, in both our groups of participants. The two-stage model accounts for our findings as follows. In accurate bare noun naming the lemma node of the target word is activated. As the task does not involve explicit engagement of syntax, activation of related syntax nodes, such as mass/count information, is not required, hence processing can proceed without it. Lexical syntax is accessible via the lemma nodes under certain specific task demands only. This is the position adopted by a range of authors (e.g. Schriefers, 1993). The explanation demands a lemma node that must be accessed in order for phonology to be accessed, but whose role in bare noun production is redundant, as no further processing proceeds from this. Caramazza (1997: 188) identified this difficulty in the theory, describing the lemma as 'a contentless way-station'.

The IN theory offers an alternative explanation of the findings. The lack of a relationship between naming accuracy and syntax knowledge demands a flexible system, where syntax *can* be accessed when it is needed, but where access to phonology can proceed without this. The IN theory provides this flexibility. Speakers can under certain circumstances access syntax via the syntactic network, but they can also proceed without this. The data suggest that in healthy speakers and many speakers with aphasia spoken production usually activates the syntactic network, but that for some speakers with aphasia access to the syntactic network is not routinely achieved. For bare noun naming this does not necessarily mean less successful production (see e.g. participant AV).

The speakers with aphasia judged the syntax of count nouns significantly better than that of mass nouns however, so access was not equal. Neither theory accounts for this difference, although both might propose frequency of use as a factor, with the more usual condition being easier to access. Of the lexical variables investigated, none had an impact on healthy speakers' naming or syntax. In aphasia age of acquisition predicted naming but did not predict syntax. This finding argues for the independence of the lexical production of nouns from the syntax of nouns, but does not discriminate between the two main theories[1].

The IN account can also explain the finding of activation of syntax in bare noun naming found in research using the picture-word interference paradigm (e.g. Alario et al., 2004; Cubelli et al., 2005; Janssen et al., 2010). In the same gender condition, the relevant shared gender node in the syntactic network receives activation from both the word and the picture name, hence facilitation occurs; and in the incongruent gender condition two gender nodes are activated, that of the word and that of the picture name, resulting in slower reaction times while the competition between the two is resolved.

4.2.3 Semantic error production

Two stage accounts explain semantic errors as the mis-selection of lemma or word nodes (Levelt et al., 1999: 35). This is the case for healthy speakers and arguably for the speakers with aphasia included in this study. As we excluded speakers with semantically derived semantic errors our data address one type of semantic error only. The grammatical class constraint operating over lexical selection errors (e.g. Dell et al., 1997; Fay and Cutler, 1977;

[1] This study did not focus on the impact of variables on output. As such there was likely insufficient power in the data to make strong claims about any apparently significant findings. We are therefore wary about forming strong conclusions from these data.

Garrett, 1975) demonstrates the operation of a syntactic component in such errors. This account of semantic errors explains only one finding in our data – the general finding that nouns replaced nouns. If syntactic processes are operating over such errors it is not clear why syntax judgements should then be impaired, unless one invokes the caveat already mentioned in relation to accurate naming, whereby syntax is not activated unless explicitly required. If this is the case it begs the question why grammatical class information is available but other syntactic information is not. Moreover, the lack of a frequency effect for naming or syntax judgements calls into question the level of processing involved in such errors. As such our data provide certain challenges to the two-stage account.

Caramazza and Hillis (1991: 112) proposed a response blocking mechanism at the phonological level to explain semantic errors. Incorporating this into the IN account we explain our findings as follows. Activation cascades from semantics to syntax and from semantics to lexemes. As ours is a bare noun task the links between semantics and lexemes are critical, whereas syntax is arguably not, and activation of the lexeme is not dependent on the syntactic network. There is insufficient activation to lead to selection of the target phonological lexeme. After further processing from semantics to lexemes the phonological lexeme of a neighbour is then selected in its place. By this stage it is feasible that processing in the syntactic network is out of step with the activation of the lexeme. As a result of this, syntax is not readily accessible, leading to errors in syntax judgement.

A second line of enquiry with semantic errors looked at the mass count status of the targets and their errors. The syntactic constraint hypothesis (e.g. Dell et al., 1997) was proposed to explain the finding that errors retain grammatical class and grammatical gender of the target. We found evidence of noun status constraining errors for count nouns only. In a two stage model account of bare noun production lemma nodes are activated but syntactic nodes are not, hence mass and count status does not govern semantic errors. Similarly in the IN account, syntax is not activated fully. The finding of more count nouns than mass nouns in the errors is then explained by the fact that there are more count nouns in the lexicon, hence a larger pool of potential errors. This is similar to the semantic neighbourhood proposal put forward by Blanken et al. (2002) and Bormann et al. (2008b).

Finally in this section we consider mixed errors. Healthy speakers were 100% accurate in syntax judgement for mixed errors, unlike for semantic errors. According to Dell et al. (1997) mixed errors reflect activation of both semantic and phonological levels, with competitors that share both these features with the target receiving most activation. Both theories would need to invoke interactive activation to explain our data. The data consist of 13 events however so more data are needed before strong conclusions can be drawn.

4.6 Phonological errors – speakers with aphasia

In the first type of phonological error there is good syntactic knowledge. We propose that there is successful activation of the lexeme and of syntax. Subsequently phonological encoding goes awry. Both theories offer similar accounts of the processing involved. These data are similar to reports of speakers with anomia who know the syntactic features of words they cannot name (e.g. Avila et al., 2001; Badecker et al., 1995), and support the notion of serial access to independent syntax and phonology. It is not clear from either account why syntax is more accurate than for accurately named in this group.

For the second type of error syntax is also impaired, and the explanation provided by both theories is weak. They both invoke impaired syntactic and impaired phonological processes, but both have previously explained semantic errors with reference to impaired syntax. So by this account mixed semantic and phonological errors should arise. It may be that interactive activation provides a better explanation, allowing activation to spread back from phonology to syntax, and with phonological level damage then impacting on syntax (see e.g. Dell et al., 1997: 823).

The key finding here is of two groups of speakers who produce phonological errors, but who have different profiles in spoken production, and whose access to syntax differs. This differentiation allows for more fine-grained assessment and diagnosis of the deficit in anomia.

4.7 Failure to respond

The last error category is failure to respond. Dell et al. (2004) investigated three possible explanations of this phenomenon, finding support for a lexical threshold account. According to this, no single word unit reaches a sufficient level of activation to be selected for production. The implications of this for access to lexical syntax are that no access should occur if no word unit or lemma is selected.

We found some evidence of knowledge of lexical syntax for such errors in our group analysis, with scores significantly above chance. Analysis of individual data indicated that this finding was largely due to two speakers who showed high levels of accuracy, indicating an impairment arising after access to syntax has occurred. This explanation is equally plausible via the two-stage or the IN account. The other participants produced few errors so their data are difficult to interpret. Age of acquisition predicted the occurrence of no responses, hence locating this error type within lexical selection processes. Analysis of this error type may therefore aid in more specific diagnosis of word finding impairments, discriminating those with intact from those with impaired syntax, and hence refining the diagnosis.

4.8 Study design

The task used in this study involved conscious explicit processing of grammatical information, where speakers had time to consider the possible combinations of words presented to them. Goodglass (2000) refers to the workings of procedural and declarative memory in relation to grammatical gender, where procedural memory governs automatic use, and declarative involves metalinguistic knowledge. For some speakers tasks involving automatic implicit processes are easier than those involving controlled explicit processing (e.g. Biran and Friedmann, 2012; Heim, 2008; Bates et al., 2001; Scarnà and Ellis, 2002). Further research investigating naming in speakers with aphasia using more implicit methods such as priming is warranted.

A final point concerns the use of mass and count nouns. Unlike grammatical gender there are no restrictions governing the combinatorial potential of these noun types. A noun deemed count or mass occurs more frequently with certain determiners than others, but can occur with any determiner. There are no rules, but there are probabilities. As such speakers may not be accessing syntactic rules per se, but are ruled by frequency of co-occurrence. Again, more studies using a range of different methods are needed.

4.9 Summary

The research presented here argues for a flexible system of spoken production, with access to syntax operating in parallel with direct phonological access. Such a system was initially outlined by Caramazza (1997). For bare noun production the links between semantics and phonological lexemes are heavily implicated. Access to syntactic knowledge is potentially available, although not necessary. Thus speakers may produce bare nouns without any (apparent) access to lexical syntax. Evidence for the separate workings of syntax and phonology comes from the dissociation between speakers who can name with syntax and those who can name without syntax. The error data reported here provide new evidence concerning the source of semantic errors, and the processing achieved in both phonological errors and no responses.

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Table 1. Demographic details of speakers with aphasia

Initials	Age (years)	Gender	Months post-onset	Age on leaving educatio n	Fluency	Aphasia syndrome
AV	48	F	60	16	NF	Transcortical motor
EB	63	F	276	15	NF	Broca's
GE	81	M	26	14	F	Anomic
JM	68	M	25	16	NF	Broca's
JMM	41	M	58	20	NF	Transcortical motor
KC	83	M	24	14	F	Anomic
MC	57	M	162	16	NF	Broca's
NH	67	M	36	23	F	Anomic
PT	60	F	48	18	F	Conduction
RP	56	M	49	16	F	Anomic
RW	63	M	104	15	NF	Transcortical motor
SH	61	M	66	15	NF	Transcortical motor
WS	75	M	21	16	F	Conduction

F: Fluent; NF: Non-fluent

Table 2. Language and cognitive tests

	N =	AV	EB	GE	JM	JM M	KC	MC	NH	PT	RP	RW	SH	WS	Normal control range
Picture naming test CAT	24	0.92	0.42	0.75	0.63	0.75	0.79	0.75	0.79	0.38	0.79	0.92	0.92	0.38	
Spoken word to picture matching (CAT)	30	0.90	0.93	0.93	0.90	0.97	0.97	0.87	1.00	0.93	1.00	0.90	0.87	0.87	0.83-1.00
Written word to picture matching (CAT)	30	0.90	0.97	1.00	0.93	1.00	0.93	0.90	0.97	1.00	1.00	1.00	0.97	0.97	0.90-1.00
Pyramids and Palm Trees (three pictures)	52	0.98	0.90	0.94	0.94	1.00	0.98	0.92	0.92	1.00	0.96	0.98	0.88	1.00	0.94-1.00
Auditory sentence comprehension (CAT)	16	0.56	0.75	0.75	0.81	0.69	0.94	0.75	0.81	0.56	0.94	0.56	0.63	0.75	
Repetition words	182	0.98	0.43	0.74	0.66	0.97	0.95	0.55	0.97	0.63	0.95	0.98	0.98	0.39	
Repetition non words	26	0.81	0.19	0.35	0.50	0.81	0.54	0.54	0.92	0.12	0.96	0.92	0.92	0.04	
Read aloud words	182	0.79	0.34	0.88	0.66	0.37	0.89	0.54	0.97	0.36	0.97	0.93	1.00	0.63	
Read aloud non-words	26	0.04	0.00	0.50	0.35	0.00	0.19	0.00	0.69	0.00	0.81	0.12	0.54	0.54	
Digit span		3.0	1.6	3.5	4.5	2.5	4.7	2.3	5.5	2.1	3.9	4.7	4.9	2.5	
BORB picture judgement easy	32	1.00	0.88	0.97	0.88	0.97	0.94	0.91	0.91	1.00	0.97	1.00	0.81	0.94	0.88-1.00
BORB picture judgement hard	32	0.84	0.81	0.94	0.94	0.88	0.78	0.84	0.66	0.81	0.81	0.81	0.78	0.91	0.69-1.00

Key to table 2: CAT Comprehensive Test of aphasia (Swinburn et al., 2005); Pyramids and Palm Trees (Patterson andHoward, 1992); Repetition, reading aloud, and digit psan: David Howard, personal communication; BORB: Birmingham Object Recognition Battery (Riddoch and Humphreys, 1992)

Table 3. Mean values of psycholinguistic variables for count and mass noun sets

N=40	Name agree	Conc	Imag	Celex log freq	Famil	Age of acq	Letter s	Phons	Sylls
Count	0.96	595	590	1.45	551	263	5.03	4.05	1.53
Mass	0.95	592	587	1.44	558	264	5.03	3.98	1.50
T	0.156	0.509	0.392	0.127	0.559	0.089	0.000	0.251	0.165
p=	0.876	0.612	0.696	0.899	0.551	0.930	1.00	0.802	0.870

Key: Name agree: name agreement from 15 healthy younger controls; Conc: concreteness; Imag: imageability; Celex log freq: word frequency, Celex database; Famil: familiarity; Age of acq: age of acquisition; letters: number of letters; phone: number of phonemes; sylls: number of syllables. Values for frequency, familiarity, concreteness, and imageability are derived from the Medical Research Council Psycholinguistic Database (Coltheart, 1981). Values for age of acquisition are from the same source plus data generated by the authors using Gilhooly and Logie's (1980) methods.

Table 4 Naming and syntax accuracy for controls

Controls n=14	Proportion named correctly	Proportion syntax accuracy
Mean	0.94	0.99
StDev	0.03	0.01
Min	0.91	0.96
Max	1.00	1.00

Table 5 Naming and syntax accuracy for speakers with aphasia

	Syndrome	Fluency	Proportion named correctly	Z-score for naming	Proportion syntax correct	Z score for syntax	Binomial p value for syntax
AV	TM	NF	0.78	-6	0.55	-44	0.5258
KC	AA	F	0.76	-6	0.89	-10	0.0000***
MC	BA	NF	0.69	-8	0.49	-50	1.0000
SH	TM	NF	0.69	-8	0.65	-34	0.0300*
NH	AA	F	0.66	-9	0.51	-48	1.0000
RW	TM	NF	0.66	-9	0.70	-29	0.0055**
JM	BA	NF	0.61	-11	0.78	-21	0.0001***
PT	CA	F	0.60	-11	0.90	-9	0.0000***
EB	BA	NF	0.54	-13	0.77	-22	0.0006***
WS	CA	F	0.46	-16	0.84	-15	0.0002***
JMM	TM	NF	0.44	-17	0.74	-25	0.0139*
GE	AA	F	0.36	-19	0.71	-27	0.0241*
RP	AA	F	0.36	-19	0.83	-16	0.0005***

Aphasia syndromes: AA anomic aphasia; BA Broca's aphasia; CA Conduction aphasia; TM transcortical motor aphasia. F: fluent; NF: non-fluent. Values of p: *** p≤0.001; **p≤0.01; *p≤0.05.

Table 6. Controls' error responses and syntax judgement

	Number of errors	Proportion syntax accuracy	Binomial
Semantic errors			
Count target	23	0.70	0.09
Mass target	26	0.65	0.1686
Total	**49**	**0.67**	**0.0213***
Mixed semantic and phonological errors			
Count target	9	1.00	0.0039*
Mass target	4	1.00	0.1250
Total	**13**	**1.00**	**0.0002*****

Values of p: *** p≤0.001; **p≤0.01; *p≤0.05.

Table 7. Distribution of error types for 13 speakers with aphasia

Error type	Number of errors	Proportion of total errors	Number of speakers
Main error categories			
Lexical semantically related	119	0.28	13
Non-words phonologically related	63	0.15	10
No response	118	0.28	11
Other error categories			
Lexical formal	19	0.04	4
Lexical mixed semantic and formal	27	0.02	8
Unrelated	8	0.02	5
Non-words sem and phon related	7	0.02	5
Non words unrelated	14	0.03	6
Description of the target	41	0.10	12
Miscellaneous	11	0.03	9

Table 8. Syntactic knowledge for errors of 13 participants with aphasia

Error type	Number of errors	Syntactic accuracy	Binomial
Lexical semantically related	119	0.55	0.3594
Non-words phonologically related	68	0.70	0.0022**
No response	115	0.64	0.0041**

Values of p: *** p≤0.001; **p≤0.01; *p≤0.05

Table 9. Semantic error responses and syntax judgement for 13 speakers with aphasia

	Number of errors	Proportion syntax accuracy	Binomial
Count target	50	0.58	0.3222
Mass target	69	0.52	0.8099
Total	119	0.55	0.3594

Values of p: *** p≤0.001; **p≤0.01; *p≤0.05.

Table 10 Syntactic knowledge for errors for group of 10 with access to syntax

Error type	Number of errors	Syntactic accuracy	Binomial
Lexical semantically related	93	0.60	0.0614
Non-words phonologically related	56	0.71	0.0018**
No response	96	0.71	0.0001***

Values of p: *** p≤0.001; **p≤0.01; *p≤0.05

Table 11 Syntactic knowledge for 10 participants for correctly named and three error categories

	Correctly named	Semantic errors	Phonological paraphasias	No response
KC	0.89	0.79	1.00	-
RP	0.83	0.60	0.86	0.83
GE	0.72	0.42	0.90	0.25
JMM	0.71	0.75	1.00	0.75
PT	0.90	0.71	0.63	0.75
WS	0.84	0.71	0.75	0.50
JM	0.78	0.70	0.00	1.00
EB	0.77	0.50	0.50	-
RW	0.7	0.56	-	0.31
SH	0.65	0.47	-	0.33

Missing values = no errors in that category.

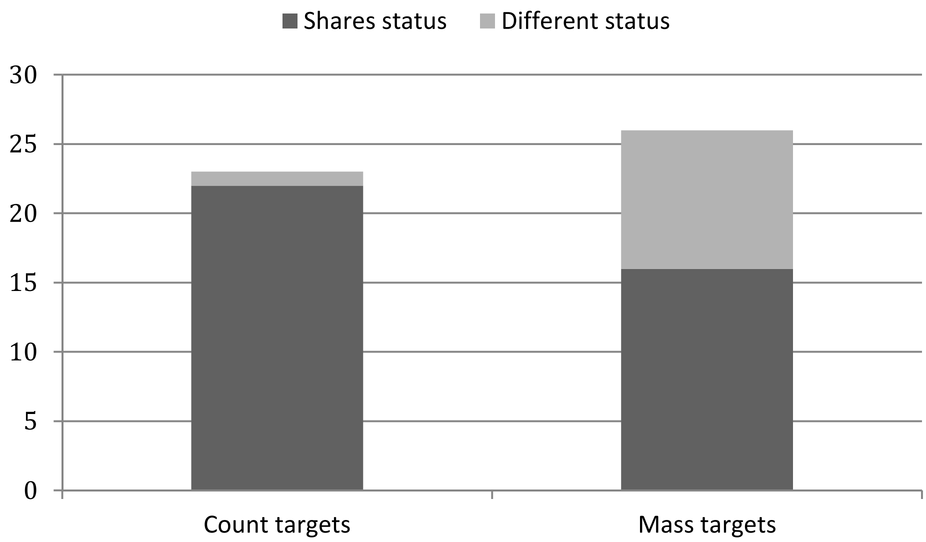

Figure 1 Distribution of semantic errors by mass and count: healthy controls

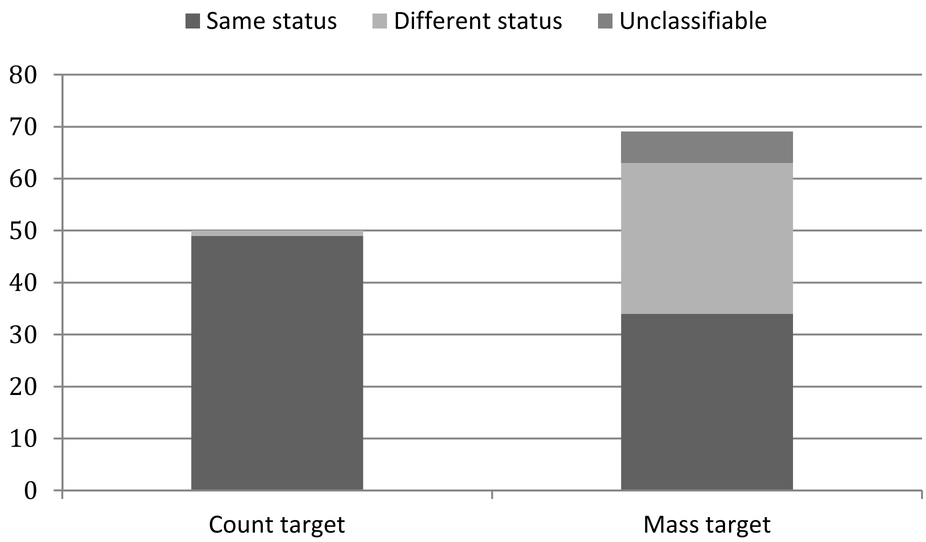

Figure 2 Distribution of semantic errors by mass and count: participants with aphasia

Appendix A. Distribution of responses for participants with aphasia

	Lexical errors					Non-lexical errors			Other		
	Correct	Semantic error	Formal	Mixed	Unrelated	Phonological related	Phonological to semantic	Unrelated	Desc	NR	Other
AV	0.78	0.11	0.00	0.03	0.00	0.04	0.00	0.01	0.00	0.04	0.00
EB	0.54	0.13	0.05	0.05	0.00	0.18	0.01	0.00	0.01	0.04	0.00
GE	0.36	0.15	0.01	0.01	0.03	0.10	0.01	0.04	0.20	0.05	0.04
JM	0.63	0.15	0.00	0.05	0.04	0.04	0.01	0.06	0.01	0.01	0.00
JMM	0.48	0.13	0.00	0.03	0.00	0.01	0.00	0.00	0.04	0.30	0.03
KC	0.76	0.16	0.00	0.01	0.00	0.01	0.00	0.00	0.03	0.00	0.03
MC	0.69	0.14	0.00	0.03	0.00	0.05	0.01	0.01	0.06	0.00	0.01
NH	0.66	0.08	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.24	0.00
PT	0.60	0.09	0.05	0.03	0.01	0.10	0.00	0.01	0.04	0.05	0.03
RP	0.36	0.05	0.01	0.01	0.00	0.09	0.00	0.01	0.01	0.45	0.00
RW	0.66	0.08	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.20	0.01
SH	0.69	0.16	0.00	0.05	0.00	0.00	0.00	0.00	0.03	0.08	0.00
WS	0.46	0.08	0.11	0.00	0.01	0.18	0.04	0.03	0.08	0.03	0.00

Appendix B

Regression analyses: people with aphasia

	Naming accuracy	Phonological errors	No responses
Model			
F	11.059	3.354	9.508
df	5,74	4,71	3,76
p	0.001	0.014	0.001
R squared	0.428	0.159	0.273
Variables			
Name agreement Beta	0.293	-	-
Name agreement p	0.002	-	-
Mass count Beta	-	0.252	-
Mass count p	-	0.025	-
Imageability Beta	0.177	-	0.128
Imageability p	0.07	-	0.216
Age of acquisition Beta	0.418	0.084	0.387
Age of acquisition p	0.001	0.519	0.001
Frequency Beta	0.039	0.067	0.139
Frequency p	0.714	0.596	0.224
Syllables Beta	-	0.222	-
Syllables p	-	0.05	-
Phonemes Beta	0.141	-	-
Phonemes p	0.147	-	-

- = factor not entered into equation