Production of German -*n* Plurals in Aphasia: Effects of Dominance and Predictability

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Abstract

Background: In picture naming, both unimpaired and impaired speakers are usually better in naming singular than plural forms of the same noun, such as *cat/ cats.* This singular-advantage is especially present in the case of singular-dominant nouns (e.g., *table* has higher surface frequency compared to its corresponding plural *tables*). However, for plural-dominant items (e.g., eyes has a higher surface frequency compared to *eye*) such singular advantage disappears. Thus, the lexical representation/ processing of singular-dominant and plural-dominant nouns seem to differ but the exact underlying source for this dominance effect is still a matter of debate. While most of the available data stem from English experiments, less data are available from German.

Aim: This study examines the effect of plural dominance for the German –*n* plural, a plural form, which can be predictable or non-predictable on the basis of the ending of the singular word form and its grammatical gender. Hence, this study examines the role of dominance and predictability of plural production in aphasia. Our data will enrich the development of materials for the assessment of morpho-lexical impairments in aphasia.

Methods & Procedures: In a case-series design, five people with aphasia with severe word-finding difficulties participated in two picture naming tasks with single- and multiple-depictions of objects. Materials included nouns of the German –*n* plural type. Exp. 1 tested for effects of number and plural dominance in naming fully predictable –*n* plurals and their corresponding singulars. Exp. 2 tested for effects of number and predictability, using subsets of fully predictable and non-predictable –*n* plurals, and their corresponding singulars.

Results: Exp. 1 revealed a significant plural dominance effect in spoken picture naming across five German speakers with aphasia: a singular advantage was observed for singular-dominant nouns, but plural-dominant singular and plural nouns did not differ. Further, in Exp. 2, no effect of predictability for the German plural affix –*n* was found, but an overall singular advantage across both groups.

Conclusions: We interpret the dominance pattern of Exp.1 as manifestation in the links between concept and lemma level for singular- and plural-dominant nouns. Exp. 2, confirmed the singular advantage for singular-dominant nouns for both –*n* plural groups, indicating that both –*n* plural groups follow *one* plural production mechanism, however, we cannot be confident about the *type* of mechanism that caused the plural disadvantage in Exp. 2 as both full listing or decomposition at word form level are plausible explanations.

Introduction

The processing of inflected words, including plural nouns, can be specifically impaired in people with aphasia (PwA) (e.g., Miceli, Silveri, Romani, & Caramazza, 1989; Penke & Krause, 1999; 2002). For example, a task like picture naming frequently triggers plural errors.

Let us assume, an individual with aphasia is presented with the picture of *three zebras*, and responds "*zebra, three of them"*. This answer cannot be classified entirely as incorrect since concept, semantic content and even information of number is correctly captured. The difficulty seems to be in successfully merging the information onto one word form, or assigning the correct plural marker to the end of the word. Other observations are the use of a plural for a singular word form (e.g., *bricks* for *brick*), or the use of the singular for a plural form (e.g., *spider* for *spiders*), where the response is incorrect, and the availability of number information at concept or semantic level remains unclear.

That processing of plural forms can be impaired in spoken picture naming and different levels of language breakdown in aphasia can be affected has been demonstrated for English (e.g., Biedermann, Lorenz, Beyersmann, & Nickels, 2012; Biedermann, Beyersmann, Mason, & Nickels, 2013), however, for German it is more complex since the latter language has over five different plural forms, which are mostly irregular or ambiguous (e.g., Lorenz & Biedermann, 2015). Even though all papers to date carve out differences in functional grammatical breakdown amongst aphasic individuals that can result in plural errors, clarity has not been achieved about the representation of those different plural forms. Potential origins of plural breakdown can be due to impairment in the mapping from concepts to lexical semantics, lexical semantics itself, the mapping from lexical semantics to lexical syntax, or the lexical syntactic level itself (for a theoretical framework, see Levelt, Roelofs, & Meyer, 1999). A phonological impairment might be another origin for plural errors, either within the phonological word form lexicon, or at the phoneme level itself. In addition, in case of regular default plural nouns, such as the –*s* plural in English or German, plural errors might also result from a specific impairment in the application of an abstract morpho-syntactic rule (e.g., Clahsen, 1999; Lorenz & Biedermann, 2015). The aim of our study was to further explore the underlying functional sources of plural errors produced in aphasic picture naming in German in a case series design with plural tasks uniquely tailored for each processing level to be able to isolate level-specific plural representations or processes.

The German plural system

The German plural system consists of five plural forms (*-s, -n, -e, - er,* and a *zero* suffix), and if we consider the marking of plural through Umlaut (the altering of the stem vowel) three further plural forms can be identified. Plural subtypes are partially predicted by phonological properties of a word and its grammatical gender, but German plural forms are predominantly ambiguous (Table 1).

Table 1. Distribution of German plural types, including percentage values for types and tokens.

Plural type	***-s* (regular default)**	***-n* (predictable/ non-predictable)**	***-e* (irregular)**	***-er* (irregular)**	***-Ø* (irregular)**
%Types	4	48	27	4	17
%Tokens	2	45	21	3	29
Examples	Auto-s	Katze-n (fem, pred) Gabel-n (fem, non-pred) Riese-n (masc, non-pred) Bett-(e)n (neuter,	Fisch-e	Kind-er	Eimer -**-Ø**

non-pred)

Although *–s* is the regular default plural in German, it is the least frequent one. The *-n* plural is the most frequently used plural morpheme in German, which can be subdivided into two categories: the fully predictable *–n*, and the non-predictable *-n* ending (see Marcus, Brinkmann, Clahsen, Wiese, & Pinker, 1995; Sonnenstuhl & Huth, 2002; Penke & Krause, 2002).

Fully predictable vs. default form

Since *–s* is officially labelled as regular default plural form, the *–n* plural is labelled as subregular plural form as it is not the default form but is fully predictable on the basis of word form and grammatical gender (Penke & Krause, 2002). It is fully predictable for feminine nouns that end in schwa in the singular form (e.g., *die Blume-n*$_{fem,pred\_plural}$ [flowers]*)*.

Fully predictable vs. non-predictable –n plurals

There is a second *–n* plural that is not predictable when taking phonological word form and grammatical gender into account: the non-predictable *-n* plural. It is used with masculine and neuter nouns, and with feminine nouns not ending in schwa, hence its occurrence is non-predictable. For example, *Riese*$_{masc\_non\text{-}pred\_singular}$ [giant] and *Bett*$_{neuter\_non\text{-}pred\_singular}$ [bed] are both marked by *–(e)n (Riese-n*$_{masc\_non\text{-}pred\_plural}$*; Bett-en*$_{neuter,non\text{-}pred\_plural}$*),* whereas *Pilz*$_{masc,\_non\text{-}pred\_singular}$ [mushroom] and *Rind*$_{neuter,\_non\text{-}pred\_singular}$ [ox] are marked differently for plural (*Pilz-e*$_{masc,non\text{-}pred\_plural}$*; Rind-er*$_{neuter\_non\text{-}pred\_plural}$). Furthermore, there are feminine nouns, not ending in schwa which are also marked by *–en*, or by other plural affixes (e.g., Uhr$_{fem_non\text{-}pred_singular}$ [clock]-> Uhr-en$_{fem,non\text{-}pred_plural}$; Axt$_{fem_non\text{-}pred_singular}$ [axe] -> Äxt-e$_{fem,non\text{-}pred_plural}$).

Current Theories of Plural Processing

Full listing

The 'full listing assumption' predicts that all lexical entries, no matter how morphologically complex, are stored as full forms, for example, the singular of *cat* has a separate entry to its plural *cats* (e.g., Butterworth, 1983; for a network theory see Plaut & Gonnerman, 2000). The same prediction holds for the predictable and non-predictable German plural forms, e.g., *Blume-n*$_{fem\_pred}$, *Riese-n*$_{masc\_non\text{-}pred}$ [giants], *Fische*$_{masc\_non\text{-}pred}$, and *Kinder*$_{neuter\_non\text{-}pred}$ [children], and for the regular default form (e.g., *Auto-s*$_{regular\_default}$ [cars]), with separate entries for singular and plural. This assumption predicts stem errors (e.g., semantic word substitutions, circumlocutions, no responses), and no or less pure number errors (e.g., omissions, additions of the plural endings). Any observed plural errors might simply result from the substitution of a whole word form (e.g., the singular full form *Kind* is substituted with plural full form *Kinder or vice versa*).

Full decomposition

At the other end of the spectrum stands the assumption of decompositional processes that come into play as soon as a word is morphologically complex (e.g., *cats* is stored as stem + -*s*; Taft, 2004; Taft & Ardasinski, 2006; Pinker, 1999; Crepaldi, Rastle, Coltheart, & Nickels, 2010). While English irregular plural nouns consist of a stem change (e.g., *mouse* -> *mice*), German irregular plural nouns are mostly marked by a suffix (e.g., child/children: *Kind-er*), sometimes accompanied by an additional stem change (e.g., *Gans*$_{fem\_non\text{-}pred\_singular}$ [goose] -> *Gäns-e*$_{fem\_non\text{-}pred\_plural}$ [geese]). Cholin, Rapp, and Miozzo (2010) suggested a full-decomposition model of German inflection, assuming that all stems have combinatorial processes inherent, and can link up with any affix, hence the name of their model Stem-based Assembly Model (SAM). This model is based on production errors of a person with chronic aphasia. Under this full-decomposition assumption both predictable (i.e. regular) and non-predictable (i.e. irregular) plurals are decomposed. Note, however, that specific links between stems and affixes are necessary in this theory to allow for the correct selection of the target affix in case of ambiguous German plural forms. Both the full-form and the full-decomposition assumption fall under the term *single mechanism theories* as they only offer one process as underlying mechanism for plural marking (see also connectionist network accounts for a similar prediction).

Dual mechanism models

Pinker and Ullman (2002; see also Pinker & Prince, 1994; Ullman, 2001) put forward a model based on perception and production data addressing predominantly regular and irregular verb processing (past tense), hypothesising that forms generated by regular default rules are decompositionally stored, while all other forms are holistically stored (see also Miozzo, 2003; Ullman Pancheva, Love, Yee, Swinney, & Hickok, 2005). When this theory is applied to the German noun plural, decomposition is assumed for the regular default form (-*s*), exclusively, with holistic storage for all other forms (e.g., Clahsen, 1999; 2006). According to another account, however, fully predictable German plural forms are also generated by a rule-based process, such as one subtype of the German –*n* plural (feminine nouns, ending on schwa) (Penke & Krause, 2002; see also Wiese, 1996; Wunderlich, 1999). Thus, according to the latter predictable and non-predictable plural forms should be stored and processed differently. Non-predictable plural forms would be stored as full forms in the mental lexicon, whereas the predictable default form would be generated by a morpho-syntactic rule (e.g., Penke & Krause, 2002). Under this assumption, a dissociation in error patterns between predictable and non-predictable plural nouns can be anticipated.

Plural nouns in speech production: The Two-Stage Theory

A recent assumption put forward by Nickels, Biedermann, Fieder, and Schiller (2015) is based on the Two-Stage model from Levelt et al. (1999) as a framework for plural production processing. Nickels et al.'s assumption integrates full listing and decompositional aspects of spoken word production. However, as opposed to the dual route approach described above, differences in processing words holistically versus decompositionally are not due to representational constraints but rather due to different weightings of the links between representations.

The model contains three processing levels: a lexical concept and/ or semantic level, a lexical-syntactic level (also called 'lemma'), and a phonological word form level. The latter level is the location for the full listing and decomposed entry assumptions introduced earlier. However, according to Levelt et al.'s model, the processing of number (here plural) starts much earlier *prior* to the phonological word form level. At the lexical concept and / or the lexical-semantic level, information regarding quantity is selected (*more than one),* and at the lexical-syntactic level information such as word category (e.g. noun) and number (e.g. plural) is waiting to be chosen. After conceptual, lexical-semantic and lexical-syntactic information has been selected, phonological word form information can subsequently be accessed. According to Levelt et al. a fully listed plural word form (in case of non-predictable, irregular forms), and a decomposed plural word form (in case of a predictable, regular form) will be accessed. While Levelt et al. suggest only one lexical-syntactic entry for singular and plural, Nickels et al. (2015) suggest separate ones for singulars and plurals at lemma level. Since the account postulates a separate syntactic-lexical level - the lemma level, and a phonological-lexical word form level, it seems arbitrary whether the plural is stored decomposed, or fully listed at word form level as the connection strength between a singular lemma or plural lemma, and their word form(s) will predict the success of word retrieval including its plural marking (Nickels et al., 2015, p. 292).

Plural dominance

Data in accordance with the Nickels et al. assumption are studies that found a plural dominance effect in spoken production. Part of the evidence stems from several studies examining the role of plural dominance in aphasia during spoken word processing (e.g., Luzzatti, Mondini, & Semenza, 2001 for Italian; and Biedermann et al., 2012; Biedermann, et al., 2013 for English; and Lorenz & Biedermann, 2015 for German). For all languages, speakers with aphasia showed a different number error rate depending on the relative frequency of the plural form to its singular form. A plural form that occurs more frequently in the spoken or written language compared to its singular (i.e. plural-dominant items; e.g., cherries vs. cherry) is less error prone than a plural form that occurs less frequently in its spoken or written form compared to its singular (i.e. singular-dominant items; e.g., tables vs. table). However, taken together, these studies suggest that it is not the frequency of the plural form alone, but the *relative* frequency between the plural and its corresponding singular forms that modulates the accuracy of the spoken plural form. This pattern might suggest that full-listing storage and processing for plural-dominant plurals, and decompositional storage and processing for singular-dominant plurals. These findings thus challenge full-listing theories and decompositional theories, and are mostly compatible with the dual-route account, and the Nickels et al. account, the latter incorporating both full-form and decompositional plural processing at phonological word form level.

Figure 1 below illustrates all testable accounts discussed above about decomposition and full-listing at word form level, and singular and plural dominance between concept and lemma level.

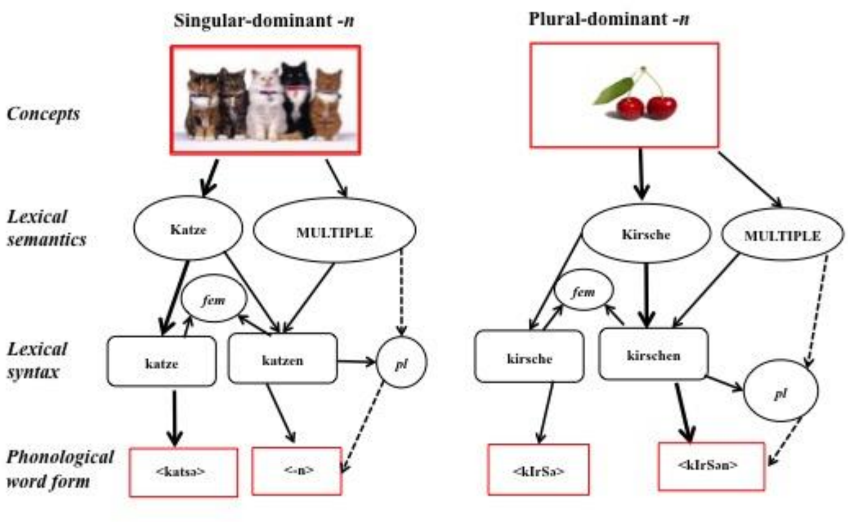

Figure 1: Possible theoretical framework for singular and plural dominance in a spoken word production model.

Research questions

Our present study has two goals. Our first goal is to re-examine the role of plural dominance during spoken word production in a more extensive cohort of German aphasic speakers. Previous evidence stems primarily from single-case studies based on English-speaking individuals with aphasia (Biedermann et al., 2012; Biedermann et al., 2013). Only one study to date has reported effects of plural dominance in two German individuals with aphasia (Lorenz & Biedermann, 2015), no pre- and post-lexical control tasks were administered in order to localise the dominance effect.

Our current study will attempt to firstly replicate the plural dominance pattern in picture naming in a larger case series with different materials, and secondly incorporate pre- and post-lexical control tasks that are able to disambiguate the dominance effect and its interpretation in a spoken word production model (Exp. 1). An additional goal (Exp. 2) was to further pinpoint at what processing step in spoken word production plural effects arise with focus on the predictable and non-predictable –*n* plural group.

Predictions Based on Current Empirical Evidence

German is a morphologically rich language with a more complex inflectional paradigm than English. For example, German offers the possibility to test overtly affixed forms for both regularly and irregularly inflected words (nouns and verbs), whereas in English irregular forms are generally built by a stem change without using an affix (e.g., *mouse* - *mice*; *go* - *went*). Therefore, type of representation and processing of German inflected words might be different from inflectional word processing in English (e.g., for German see Cholin et al., 2010; Lorenz & Biedermann, 2015; Penke & Krause, 2002; Smolka et al., 2013; for English see Miozzo, 2003; Ullman et al., 2005). To our knowledge, we are the first to examine plural dominance in a larger-scale case-series study with German PwA. If effects of plural dominance are indeed replicable across a whole series of patients with aphasia, this would provide particularly compelling evidence for the Nickels et al. assumption. This assumption incorporates functional reasons for number and dominance effects beyond the phonological word form level, considering concept and lemma level for plural representation, and softens the processing debate between the more traditional full listing and decompositional accounts at word form level.

Our second goal was to test if effects of dominance are additionally modulated by the predictability of German plural –*n* processing. In Experiment 2, singular-dominant predictable and non-predictable German –*n* plurals are contrasted.

Penke and Krause (2002) examined plural predictability in eight German patients with aphasia using a spoken number elicitation task. Four participants produced significantly less errors for predictable than non-predictable –*n* plurals, whereas four participants did not show a significant difference between predictable and unpredictable targets. Penke and Krause (2002) also reported a frequency effect in the non-predictable but not in the predictable subset, with a higher error rate for low-frequency than high-frequency targets. This finding was replicated in a visual lexical decision with 16 *healthy* participants, suggesting that predictable –*n* plurals are more likely to be processed decompositionally, whereas non-predictable –*n* plurals are more likely to be processed holistically, which is compatible with dual mechanism accounts.

A related study by Sonnenstuhl and Huth (2002) used visual lexical decision (Experiment 1) – a reception task- in healthy participants to study plural predictability in German. The authors investigated the effect of frequency on number processing, comparing six different types of plurals (the default –*s*, -*er*, and predictable and non-predicable –*n* plurals with two further sub-categories –*en_fem* and –*en_masc*). All plural forms, with the exception of the default –*s* plural, revealed a clear-cut frequency effect, *including* the predictable –*n* plurals *(-n_fem)*. This would be in line with full-listing of –*n* plurals in the German mental lexicon (e.g., Penke & Krause, 2002). However, Sonnenstuhl and Huth (2002) report conflicting results from a second cross-modal priming experiment (auditory prime followed by visual target). The auditory prime was either an identity prime (e.g., *Blume* preceding *Blume*), a plural prime (e.g., *Blumen* preceding *Blume*), or an unrelated control prime (e.g., *Wind* preceding *Blume*). In this experiment, the predictable –*n* plural showed only a marginal difference to the recognition time triggered by the identity prime, where as the remaining non-predictable –*n/-en* plural types showed a significantly longer recognition effect for the plural condition compared to the identity prime condition. While the results of Experiment 1 suggest that the predictable *–n* plural is processed holistically, which is clearly inconsistent with Penke and Krause's (2002) findings, the results of Experiment 2 indicate that the predictable *–n* plural is processed decompositionally compatible with Penke and Krause's (2002) data.

Our aim was to shed further light on these conflicting findings and re-examine plural predictability in a case-series study, including five German PwA. In particular, our goal was to test the interplay between plural predictability and plural dominance (Experiment 2). There are good reasons to assume that plural dominance may be modulated by plural predictability. Plural-dominant plurals are more likely to be processed holistically than singular-dominant plurals (e.g., Biedermann et al., 2012; 2013; Beyersmann, Dutton, Amer, Schiller, & Biedermann., 2015; Bertram, Schreuder, & Baayen., 2000; Burani & Laudanna, 1992; Hay, 2001; Laudanna & Burani, 1995; see Nickels et al., 2015 for a contrasting account), and therefore less likely to be affected by the predictability of the plural morpheme. Singular-dominant plurals however are more likely to be processed decompositionally, and are therefore more prone to be affected by the predictability of the plural morpheme. In our second experiment, we therefore focused on singular-dominant plurals, expecting significantly less errors in the predictable plural condition compared to the non-predictable plural condition.

Experiment 1: Spoken Picture Naming of Singular-Dominant and Plural-Dominant *-n* Plurals - A Case Series Study

Method & Materials

We selected 15 singular-dominant and 15 plural-dominant singular-plural pairs (e.g., *cat – cats* vs. *cherry-cherries*). Corresponding pictures were collected from Hemera (1997-2000) or Google Images. Singular-dominant plurals and plural-dominant plurals were matched on surface frequency (extracted from the CELEX database: Baayen, Piepenbrock, & van Rijn, 1993; Baayen, Piepenbrock & Guliker, 1995). This paradigm forced differences in surface frequency between singular and plural for both groups, and between both singular groups (Appendix A). Pictures all had at least 80% name agreement based on 16 unimpaired native German speakers. Target words were presented separately as single and multiple entities. Plurals were all predictable –*n* plurals, i.e. feminine nouns, ending on schwa, e.g., *Blume-n [flower-s]*.

Plural groups were further matched for number of letters, phoneme and syllable number, and phonological and orthographic neighbourhood (CELEX, Baayen et al, 1993). Naturally, number of phoneme and letter between singular vs. plural differed, but consistently for both the singular- and plural-dominant conditions. In addition, the sets were matched for visual complexity, age of acquisition and name agreement, based on information acquired from the above mentioned 16 unimpaired controls (see Appendix A).

Participants

Five PwA participated in the study, two female (MM, LR) and three male individuals (WN, SB, AK). All were native speakers of German and learned either English or Russian as a second language for around 5 years in school. All were in their 50s at the time of testing and suffered a stroke more than 2 years ago, classifying them as chronic. MM suffered an ischemic stroke in the left fronto-parietal area, LR in the left sub-cortical temporal area, WN in the left fronto-temporo-parietal area and SB an infarct in the media carotids artery. AK suffered an ischemic stroke in the left arteria cerebri media. All participants had normal or corrected-to-normal vision and hearing.

The prerequisite for participation in this study was a main deficit in accessing the phonological word form level, which typically presents in word finding difficulties, and the frequent occurrence of plural errors in spoken picture naming screening of single and multiple objects. Each participant gave his or her informed consent to take part in this study. Ethics were obtained and approved by the ethics committee of the Department of Psychology, Münster University[1].

Background Assessments. All participants presented with a main functional impairment of spoken word finding that primarily originated at the phonological word form level. However, each participant showed minor additional language impairments that differed across participants (e.g., mild semantic impairments). Differences and main language impairments were established by the following background assessments presented below. Assessment results are discussed for each participant.

The Aachener Aphasie Test (AAT, Huber, Poeck, Weniger, & Willmes, 1983) and subtests from LEMO[2] (Stadie, Cholewa & De Bleser, 2013) were used to assess language comprehension and production in our participants (see Table 2). While the AAT is a syndrome-oriented assessment and embeds both single word and in sentence level tasks, LEMO is a model-based assessment and includes tasks on single word production and comprehension (see Table 3). The Bogenhausener Semantik Untersuchung (BOSU, Glindemann, Klintwort, Ziegler, & Goldenberg, 2002) captures non-verbal semantic processing (e.g. colour recognition).

SB's and WN's speech was fluent, while MM, LR, and AK were non-fluent aphasic speakers. MM, LR, SB, and AK showed agrammatic speech production (e.g., simple sentence structure, and underrepresentation of verbs, inflectional endings and function words were often omitted, with only mildly impaired comprehension). WN's

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[1] Workplace of co-author A.Lorenz at the time of the study.
[2] LEMO = Lexikon modellorientiert [lexicon model-based]

aphasia was unclassifiable according to the AAT, showing moderate production and comprehension skills with only mild impairments (Table 2). In addition to her aphasia, MM suffered from apraxia of speech (for further information on MM, see Lorenz & Biedermann, 2015).

Table 2. AAT Background Assessment – Accuracy Scores (with % correct in Parentheses).

AAT Subtest	N	MM	SB	WN	LR	AK
Token Test[a]	50	16* (72)	20*(65)	13*(76)	45*(16)	25* (53)
Repetition	150	112*(51)	133*(76)	139* (84)	107*(47)	131*(73)
Written Naming	90	80* (89)	49*(51)	79* (87)	52* (53)	48* (51)
Spoken Naming	120	75* (48)	93*(66)	91* (64)	77*(49)	91* (64)
Spoken Comprehension	120	110 (97)	92*(70)	91* (68)	67* (35)	81* (53)

Note. [a]Scores are age-corrected. *Significantly impaired compared to healthy controls.

Non-verbal semantic processing was mainly preserved for all participants (Table 4) and lexical-semantic processing was preserved or only mildly impaired in MM, SB, WN, and LR, whereas AK showed moderately impaired lexical-semantic processing (see word-to-picture matching and synonymy judgement tasks, Table 3). Reading aloud of existing words was mildly to moderately impaired in the participants, whereas reading of non-words was more severely impaired in all participants except for WN. Furthermore, repetition of existing words was only mildly impaired but retrieval of the correct gender-marked determiner was severely impaired, especially for MM and LR (see Table 3, repetition of nouns with determiner).

All participants suffered from mild to moderate word-finding difficulties in spoken picture naming. These word-finding difficulties resulted from a predominantly post-semantic deficit in accessing lexical-phonological representations in speech production.

Table 3. LEMO Background Assessment – Accuracy Scores (with % correct in Parentheses).

LEMO Subtest	N	MM	SB	WN	LR	AK
Visual discrimination – nonword minimal pairs	72	70 (97)*	n/a	n/a	n/a	72 (100)
Auditory lexical decision	80	80 (100)	n/a	n/a	n/a	76 (95)
Visual lexical decision	80	75 (94)*	n/a	n/a	n/a	69* (86)
Repetition, nonwords	40	28* (70)	34* (85)	38* (95)	18* (45)	35* (88)
Repetition, words w. determiner	60	32* (53)	47* (78)	49* (82)	28* (47)	52* (87)
Reading aloud, nonwords	40	12* (30)	14* (35)	36* (90)	1* (3)	12* (30)
Reading aloud, reg. vs. irreg. words	60	37* (62)	34* (57)	51* (85)	31* (52)	41* (68)
Auditory word-picture matching	20	20 (100)	20 (100)	19 (95)	20 (100)	16* (80)
Visual word-picture matching	20	20 (100)	20 (100)	19 (95)	20 (100)	18* (90)
Auditory synonym judgement	40	37 (93)*	27* (68)	34* (65)	25* (63)	26* (65)
Visual synonym judgment	20	19 (95)	14* (70)	13* (65)	12* (60)	0 (stopped)

Note. *Significantly impaired compared to healthy controls (based on Lemo controls, n=41) (Stadie et al., 2013) *n/a* = not applicable.

Table 4. BOSU Background Assessment – Accuracy Scores (with % correct in Parentheses).

BOSU Subtest	**N**	**MM**	**SB**	**WN**	**LR**	**AK**
Matching of objects to situations	10	10 (100)	10 (100)	10 (100)	10 (100)	10 (100)
Sorting of objects according to main semantic features	10	10 (100)	10 (100)	10 (100)	9 (90)	9 (90)
Sorting of objects according to semantic category features	10	10 (100)	8 (80)	9 (90)	8 (80)	8 (80)
Sorting of written words according to semantic features	10	9* (90)	8* (80)	9* (90)	9* (90)	4* (40)
Sorting of objects according to colours	10	9* (90)	10 (100)	9* (90)	9* (90)	10 (100)

Note. *Impaired compared to healthy controls (BOSU, healthy control participants, n= 72)

Procedure

PwA were presented with single and multiple depictions of objects. The main task of interest concerned *spoken picture naming*. All singular-plural target pairs were also presented in two control tasks (*written word-picture verification* and *spoken repetition,* see below). Both control tasks contained the same stimuli sets used in the main picture naming task. In each session a set of items was presented for each modality, but with carefully quasi-randomised sets, so that no overlap of items occurred in corresponding sets within one session.

Main task: Spoken picture naming

Pictures were presented in the centre of a computer screen using SuperLab 4.5 (e.g., Haxby, Parasuraman, Lalonde, Abboud, 1993). Pictures were presented in a quasi-random order with targets from different sets and different number (singular and plural) intermixed (but no singular was presented with its plural partner within one session or vice versa). The experiment used two testing blocks, which were assessed in two different sessions, based on a Latin Square Design, which guaranteed counterbalance of singular and plural items between blocks. Participants were instructed to name the picture aloud. The investigator did not comment on the response accuracy until the very last testing session. The testing sessions were repeated, so that each item was tested twice within a three-month period. Analyses of naming responses were then based on the combined accuracy scores of the initial and the repeat testing sessions.

Control-task 1: Written word-picture verification

This task was designed to tap into conceptual/semantic processes. Participants were requested to either confirm or negate with *yes* or *no* if a picture and written word matched. Pictures were presented either with the correct word or a number distractor, e.g. a picture of one *flower* to the corresponding plural noun $\textit{Blumen}_{\textit{fem\_pred\_plural}}$ [flowers]. Stimuli were the same sets (1 & 2) as presented for the main task of spoken picture naming.

Control-task 2: Repetition

This task tapped into peripheral processes (sublexical and post-lexical) including auditory analysis of the stimulus, storage in a phonological buffer, and articulation of the (inflected) word. The participants repeated a voice recording of a word. Recordings were presented once only. Stimuli were the same sets 1 & 2 as presented for the main task of spoken picture naming. Items that used no plural as plural marking (zero plural) served as filler items for both control tasks. All testing sessions were audio-recorded and responses were checked and coded according to accuracy and error classification.

Scoring & coding of responses

All responses were documented. Additional reliability scorings were carried out from two separate interraters, both native German speakers. Only the first full response of the participant was coded for analysis. Scoring concerned two aspects of the response: (i) stem accuracy (e.g., *cat* in *cats*), and (ii) number morphology accuracy (singular or plural correctly/ incorrectly produced).

A stem was scored as 'correct' if the stem was produced, regardless of morphology accuracy (e.g., *cat* for *cats*, or *cats* for *cat* was scored as correct stem response). A response that resulted in a non-word that only differed in a single phoneme from the target word was still coded as correct as the stem was clearly identifiable (for a similar procedure, see Nickels & Howard, 1995).

Number was scored as 'correct' if the spoken word form was assigned with the correct plural marker, or no plural marker was assigned in case of singular. A number error was defined as follows:

(i) *Omission* of plural affix: A singular form was produced for a plural item (e.g., *Blume$_{singular}$* for *Blumen$_{plural}$* [flower for flowers])

(ii) *Addition* of plural affix: A plural form was produced for a singular item (e.g., *Blumen$_{plural}$* for *Blume$_{singular}$* [flowers for flower])

(iii) *Substitution* of plural affix: An incorrect morpheme was used for a plural word (e.g., *Insel**s*** (incorrect plural marking) for *Insel**n*** (correct plural marking [e.g., possible error in English island-er (incorrect) for island-s (correct)]).

Since our focus was the analysis of the correct number marking of singular and plural nouns in our participants' responses, all incorrect stem responses were excluded from the analysis, including their number errors (e.g., *cats* for *dog*). The remaining words including a correct stem response formed the basis for the following analysis: Each word was given a proportion score combining the scores from the initial presentation and the second presentation. For example, if the target word was *Blumen$_{fem,_pred_plural}$* [flowers] and it was correctly produced in the initial testing block, but produced with a number error in the repeat testing block, e.g., *Blume$_{fem,_pred_singular}$* [flower] instead of *Blumen$_{fem_pred_ plural}$*

[flowers], the score was based on two correct stems, and one correct number response, resulting in a proportion score of 0.5. However, if both stems were produced incorrectly (e.g., plant for flower), the entire singular-plural pair *'flower-flowers'* was excluded from the analysis. Therefore, the proportion score was only based on the 'number correct ' score, when the stem was produced correctly (for a similar procedure, see Biedermann et al., 2012; Biedermann et al., 2013). In addition, we report the proportion of pure number errors, when the stem was retrieved correctly compared to the proportion of stem errors.

Analyses

We carried out Wilcoxon comparisons and Fisher's exact tests. The Wilcoxon tests compared the production of number between singular and corresponding plural forms based on the proportion score, looking at the main effects of number and item type and its interaction within each participant. We used two subtests: A Wilcoxon Matched Pairs Test compared the proportion score for singular and plural word-forms, when singulars and plurals were matched. If the sets between singulars and plurals did not match up in pairs due to the exclusion of either the singular or plural partner caused by a stem error (e.g., $Insel_{fem\_non\text{-}pred\_singular}$ [Island] excluded due to stem error, but $Inseln_{fem\_non\text{-}pred\_plural}$ [Islands] retained), a Wilcoxon 2-Sample Test was used. Wilcoxon tests were carried out for each individual separately. We then compared plural groups directly (singular-dominant vs. plural-dominant), using a Fisher's Exact Test.

Results

Picture naming of singular-dominant and plural-dominant sets

Table 5 shows the proportion of correct responses in the picture naming task. Differences between healthy controls and individual aphasic participants are marked with an asterisk. Crawford & Garthwaite's modified t-test (2002) was used to establish differences.

Oral Naming	**N**	**Control Mean**	**MM**	**SB**	**WN**	**LR**	**AK**
Sg-Dom SG	15	14.43	11.5 * (76.7)	11.5 * (76.7)	14 (93.3)	13.5 (90)	12 (80)
Sg-Dom PL	15	13.25	6 *	9 *	8 *	4.5 *	8.5 *

Table 5. Predictable *–n for* singular- and plural-dominant oral naming - based on combined initial and repeat stem and number accuracy scores - % correct in parentheses.

			(40)	(60)	(53.3)	(30)	(56.7)
Pl-Dom SG	15	13.43	6 * (40)	9 * (60)	10.5 (70)	7.5 * (50)	8 * (53.3)
Pl-Dom PL	15	12.94	7.5 * (50)	10 (67.7)	8.5 (56.7)	7 * (46.7)	10.5 (70)

**p < .001; *p < .05 compared to control group using modified T-Test Crawford and Howell (2002).

In contrast to singular-dominant nouns, production of singular and plural nouns did not differ significantly for any of the participants in case of plural-dominant nouns.

Singular-dominant plural vs. singular. For all analyses, we are only reporting stem and number accuracy respectively number errors. Using a Wilcoxon Matched Pairs test (two-tailed), all aphasic participants showed a significant difference in accurately producing singular-dominant singulars compared to plurals. The singular was always produced with higher accuracy. Below, we report z scores with their p-values. Four participants showed a significant singular advantage over plural picture naming (MM: $z = 2.466$ $p = 0.014$; WN: $z = 2.866$ $p = 0.004$; LR: $z = 3.693$ $p < 0.001$; AK: $z = 3.373$, $p = 0.017$). SB was the only participant, who did not show a singular advantage for this group, although he showed a trend when considering his one-tailed p value ($z = 1.475$, $p = 0.070$).

Plural-dominant plural vs. singular. None of the participants showed a significant difference in number accuracy between the singulars and their corresponding plurals for the plural-dominant set. A Wilcoxon Matched Pairs test (two-tailed) was carried out and z scores together with their p values were taken as critical measure (MM: $z = 0.227$, $p = 0.821$; SB: $z = 0.499$, $p= 0.617$; WN: $z = -0.103$, $p = 1$; LR: $z = 0.794$, $p = 0.427$; AK: $z = 0.009$, $p = 0.993$).

A significant interaction between number (singular vs. plural) and dominance (singular-dominant vs. plural-dominant) (using a Wilcoxon 2-Sample test, two-tailed) was evident for WN (*z = 1.945, p = 0.052*) and LR (*z = 1.962, p = 0.05*) confirming more errors for singular dominant plurals than singulars, whereas singulars and plurals did not differ for plural dominant nouns. When considering one-tailed p values, AK also shows a marginally significant interaction (*z = 1.638, p = 0.051*). There was no difference between singular-dominant plurals and plural-dominant plurals using a Fisher Exact Test, indicating that plural errors occurred in both groups since accuracy dropped for both plural groups. However, we found a significant difference between singular-dominant singulars and plural-dominant singulars for one participant, and a trend for two further participants (Fisher's exact, two-tailed, MM: *p = 0.058; WN: p = 0.052; LR: p = 0.004*). Although singular errors showed a higher error rate in the plural-dominant condition (45.33%) compared to the singular-dominant condition (16.67%), singulars were overall less error-prone across all conditions across all patients (overall error rate - singular: 31% vs. plural: 47%).

Control task 1: Visual word-picture verification. Table 6 summarises results for the conceptual/semantic control task. SB, who only showed a marginally significant singular-dominant effect in picture naming, showed a significant difference in visual word-picture matching with an advantage for singular-dominant singular targets compared to their plurals (Wilcoxon Matched Pairs, two-tailed: *z = 2.551; p = 0.011*). No such difference was found in his performance for the plural-dominant set. No significant differences between singular and plural groups – regardless if singular- or plural-dominant- were observed for the remaining four participants (MM, WN, LR, and AK).

Table 6: Predictable –*n* singular- and plural-dominant visual word-picture-verification raw scores.

WPV	N	Control Mean	MM	SB	WN	LR	AK
Sg-Dom SG	15	14.86	14.5	14.5	14.5	9.5 *	9.5 *
Sg-Dom PL	15	14.96	13 *	11 *	15	11 *	9.5 *
Pl-Dom SG	15	14.96	11 *	12 *	14 *	8.5 *	8.5 *
Pl-Dom PL	15	14.85	12.5 *	11 *	15	7 *	9 *

**p < .001; *p < .05 compared to control group using modified T-Test Crawford and Howell (2002).

Control task 2: Repetition. Table 7 summarises raw scores for the post-lexical control tasks. No significant processing differences were observed between singular and plural processing at post-lexical level for any participant.

Table 7. Predictable *–n* singular- and plural-dominant repetition raw scores.

Repetition	N	Control Mean	MM	SB	WN	LR	AK
Sg-Dom SG	15	15	12 *	13 *	15	13 *	13 *
Sg-Dom PL	15	15	12 *	12 *	15	13 *	13 *
Pl-Dom SG	15	15	15	14 *	15	15	14 *
Pl-Dom PL	15	15	12 *	15	14 *	15	14 *

**p < .001; *p < .05 compared to control group using modified T-Test Crawford and Howell (2002).

Discussion

The spoken picture naming results of Experiment 1 revealed clear effects of dominance on the production of singular and plural nouns in five German patients with aphasia. This pattern was not replicated in the two control tasks, which allows us to rule out a conceptual or post-lexical locus of the observed dominance effect. All patients made more errors producing singular-dominant plurals than singular-dominant singulars (with SB showing only a trend in the one-tailed test), whereas no differences were found between plural-dominant singulars and plurals. This finding replicates a pattern previously reported for English aphasic word production (Biedermann et al., 2012; 2013) as well as preliminary German data on the *–n plural* reported by Lorenz and Biedermann (2015) for two participants. Our data suggest that singular-dominant plurals are processed decompositionally at the word-form level, whereas plural-dominant plurals are processed holistically. Alternatively, the pattern might result from different activation strengths of connections between concept and lemma level for singular-dominant and plural-dominant targets (Nickels et al., 2015) regardless of representation at word form level (see also Lorenz & Biedermann, 2015).

Since our first experiment unambiguously replicated the effect of plural dominance within our new set of predictable German –*n* plurals across five PwA, and also could uniquely demonstrated with two pre- and post-lexical tasks using the same stimuli sets from the picture naming task that the dominance effect was truly lexical, we conducted our second experiment, to test if plural predictability does modulate the processing of singular-dominant plurals. This would be in line with dual-route accounts, assuming different types of representation and processing at the word-form level for fully predictable versus non-predictable German –*n* plurals (e.g., Penke & Krause, 2002).

Experiment 2: Picture naming of predictable and non-predictable –*n* plurals for singular-dominant nouns

Materials

As in Experiment 1, target stimuli were German -*n* plurals, all highly pictureable nouns, presented in separate testing sessions as a single or multiple depiction in a spoken picture naming task. They either belonged to the predictable –*n* group set (Set 1) or to the non-predictable–*n* group set (Set 2). The same singular and plural items were used in two further control tasks: visual picture-word verification, and repetition.

Set 1: The *predictable -n plural set* consisted of 13 x 2 (n=26) singular-plural pairs. The use of the plural marker -*n* for this subset is fully predictable as the -*n* suffix is assigned to nouns that are feminine in gender, but only if the singular form ends in schwa (e.g., *die Katze*$_{fem\_pred\_singular}$ [cat] vs. *die Katze –n*$_{fem\_pred\_plural}$ [cats]). All stimuli pairs were presented again in repeated testing session within a three-month time frame after the initial testing sessions had been fully completed. The repeat sessions served to increase power of the small item set. When including the repeated testing presentations, the total of data points for the predictable –*n* group included 52 items.

Set 2: The *non-predictable –n plural set* consisted of *9 x 2 (n*=18) singular-plural pairs. The use of the plural marker for this subset is not predictable as the –*n* suffix can be assigned to nouns that can either be neuter, feminine or masculine; end in any other phoneme than Schwa for feminine, neuter or masculine nouns in their singular form (e.g., *das Bett*$_{neuter\_non\text{-}pred\_singular}$ [bed] vs *die Bett-(e)n* $_{neuter\_non\text{-}pred\_plural}$ [beds]; *der Riese* $_{masc\_non\text{-}pred\_singular}$ [giant] vs. *die Riesen* $_{masc\_non\text{-}pred\_plural}$ [giants]). As for Set 1, all non-predictable stimuli pairs were presented again in repeat testing sessions within a period of three months after the initial testing sessions had been completed to increase item power, providing overall 36 data points for the non-predictable -*n* group.

Both plural sets and both singular sets (all of them singular-dominant) were matched list-wise on stem- and surface frequency, number of letters, number of phonemes, number of syllables, phonological neighbourhood, and orthographic neighbourhood (Appendix B) extracted from CELEX (Baayen et al., 1993). Visual complexity and name agreement were matched in order to reduce confounds of the picture materials on language performance. Both variables were obtained from 16 German healthy controls ranging in age from 19 to 25 years with a mean age of 21. Variables were also matched between singular and plural sets within the predictable and non-predictable group, with the exception for letter and phoneme length. All pictures were colour photographs and sourced from Google Images or Hemera (1997-2000). Name agreement was at least 80% as obtained from the 16 controls (Appendix B). As in Experiment 1, we used a set of 14 x 2 (n=28) zero suffix items as a filler group (not considered for analysis). Analyses were based on combined scores of initial and repeat sessions (as explained in the ‘Scoring & Coding Responses’ section below).

Procedure

Procedure for Experiment 2 was identical to Experiment 1, with the initial testing being repeated after 3 months. Scoring and coding of correct and incorrect responses, as well as analysis steps were identical to Experiment 1.

Results

Picture naming accuracy for Set 1 (predictable -n plural)

Across all participants, plural accuracy was worse than singular accuracy, although AK showed only a trend towards significance (MM: Wilcoxon 2-Sample: $z = 3.588$, $p < 0.001$; SB: Wilcoxon 2-Sample: $z = 3.522$, $p < 0.001$; WN: Wilcoxon Matched Pairs: $z = 2.222$, $p = 0.026$; LR: Wilcoxon 2-Sample: $z = 2.744$, $p = 0.006$; AK: Wilcoxon 2-Sample: $z = 1.750$, $p = 0.08$; all two-tailed). Table 8 indicates differences when compared to the healthy control group, using modified t-tests (two-tailed) as suggested by Crawford and Garthwaite (2002).

Picture naming accuracy for Set 2 (non-predictable -n plural)

In two participants, plural accuracy was worse than singular accuracy (WN: Wilcoxon Matched Pairs, two-tailed: $z = 2.222$, $p = 0.026$, and AK: Wilcoxon 2-Sample: $z = 2.429$, $p = 0.015$). Despite the absence of a significant plural disadvantage for the remaining three participants, a numerical plural disadvantage is evident for all participants.

Oral Naming	N	Control Mean	MM	SB	WN	LR	AK
SG pred.	13	12.25	9 * (69.2)	10.5 (80.8)	12.5 (96.2)	10 * (76.9)	11.5 (88.5)
PL pred.	13	11.69	3 * (23.1)	4 * (30.8)	9 (69.2)	2 * (15.4)	9.5 (73.1)
SG non-	9	8.56	6 *	6.5 *	7.5	5.5 *	6 *

Comparing predictable with non-predictable –n item sets in picture naming

A Fisher's Exact test (two-tailed) confirmed the overall predictable vs. non-predictable -*n* analysis. All participants, except SB, showed greater difficulties with producing the plural than the singular form, regardless if the plural belonged to the predictable or non-predictable –*n* category (p >.1) (Table 8). Only SB and MM produced fewer number errors for the non-predictable -*n* set than the predictable -*n* set (Fisher Exact, SB: p = 0.035, MM: p = 0.080).

A significant interaction between the predictable and non-predictable -*n* groups overall, including both singular and plural was only observed in SB's naming performance, using a Wilcoxon 2-Sample, two-tailed (z = 2.342, p=0.019), resulting from significantly stronger number effects with predictable than non-predictable –*n* plurals.

pred.			(66.7)	(72.2)	(83.3)	(61.1)	(66.7)
PL non-pred.	9	8.31	4 * (44.4)	5 * (55.6)	4.5 * (50)	3 * (33.3)	5 * (55.6)

**p < .001; *p < .05 compared to control group using modified T-Test Crawford and Howell (2002).

Table 8. Predictable and non-predictable –*n* oral naming – based on the average initial and repeat testing for stem and number accuracy scores - % correct in parentheses.

Types of plural errors

To shed further light on the representation and processing of the German –*n* plural, the main error types in spoken picture naming were analysed for both predictable and non-predictable -*n* plural sets. Table 9 gives the raw number of different error types (pure number error, semantic error, no response, other errors) and percentage correct of responses in relation to all responses given (including stem errors and number errors) during the spoken picture naming task for predictable and non-predictable subsets. Number errors were produced mostly in response to plural targets, omitting the plural affix, thus resulting in correct retrieval of the singular form (e.g., WN for target: Geigen$_{fem_pred_plural}$ - > response: Geige$_{fem_pred_singular}$). Only one affix substitution error was observed: WN substituted –*n* with –*s*, resulting in a non-existing form (WN for target: Zwiebeln$_{fem_non\text{-}pred_plural}$ -> response: Zwiebel-s*$_{fem\_violated\_plural}$). A few number errors (i.e., pluralisations) occurred with singular targets (e.g., LR for target: Waage$_{fem_pred_singular}$ -> response: Waagen$_{fem_pred_plural}$; or for target Insel$_{fem__non\text{-}pred_singular}$ -> response: Inseln$_{fem_non\text{-}pred_plural}$). Participants mainly produced pure number errors in spoken picture naming (50-66.7 %). The main stem error type consisted of ‘semantic paraphasias’, followed by ‘no responses’, with all other errors types, including ‘phonological paraphasia’ and ‘neologisms’ only produced very occasionally (see raw scores in Table 9). Semantic word substitutions occurred less frequently than number errors (4.2-33.3 %, see Table 9).

Table 9. Spoken picture naming of single and multiple object pictures: raw number scores of error types for singular and plural targets in predictable and non- predictable sets - with % correct in parentheses.

Oral Naming	N	MM	SB	WN	LR	AK
Pure Number Errors						
SG pred.	26	1 (12.25)	0 (0)	0 (0)	2 (33.3)	0 (0)
PL pred.	26	15 (75)	14 (77.8)	7 (87.5)	9 (40.9)	5 (71.4)
SG non-pred.	18	1 (16.7)	1 (20)	1 (33.3)	4 (57.1)	0 (0)
PL non-pred.	18	5 (50)	3 (37.5)	6 (66.7)	10 (83.3)	8 (100)
Semantic Paraphasias						
SG pred.	26	0 (0)	3 (60)	1 (100)	4 (66.7)	0 (0)
PL pred.	26	3 (15)	2 (11.1)	1 (12.5)	7 (31.8)	1 (14.3)
SG non-pred.	18	1 (16.7)	2 (40)	2 (66.7)	1 (14.3)	0 (0)
PL non-pred.	18	2 (20)	0 (0)	3 (33.3)	0 (0)	0 (0)
No Response						
SG pred.	26	3 (37.5)	0 (0)	0 (0)	0 (0)	2 (66.7)
PL pred.	26	1 (5)	1 (5.6)	0 (0)	1 (4.5)	1 (14.3)
SG non-pred.	18	2 (33.3)	2 (40)	0 (0)	0 (0)	6 (100)
PL non-pred.	18	1 (10)	5 (62.5)	0 (0)	2 (16.7)	0 (0)
Other Errors (include circumlocutions, phonological paraphasias, neologisms)						
SG pred.	26	4 (50)	2 (40)	0 (0)	0 (0)	1 (33.3)
PL pred.	26	1 (5)	1 (5.6)	0 (0)	5 (22.7)	0 (0)
SG non-pred.	18	2 (33.3)	0 (0)	0 (0)	2 (28.6)	0 (0)
PL non-pred.	18	2 (20)	0 (0)	0 (0)	0 (0)	0 (0)

Control task 1: Visual word-picture verification.

All participants were mildly impaired in this task compared to the language-unimpaired controls (based on Crawford & Garthwaite, 2002), however, no number difference was observed. Errors consisted mainly of false positive responses, for example, for the picture-word pair ‘Hexe’ - ‘Hexen’ a ‘yes’ response was given, followed by a self-correction, “ja, aber viele, also ich glaube nein” [*yes, but I think many, so I think no’]*. Since most of the participants self-corrected in this task, it can be assumed that the task was understood, however, our scoring scheme only considered the first response, so self-correction are not reflected in the presented analysis. No specific difference was observed for predictable and non-predictable –*n* plurals, but more importantly, none of the five speakers with aphasia showed a *processing difference* between singulars and plurals when verifying a singular or plural picture to a written singular or plural word (Table 10). Thus, no plural disadvantage, as observed for the spoken picture naming task was confirmed, providing evidence that the observed plural disadvantage was not driven by conceptual-semantic processes.

Table 10. Predictable and non-predictable –*n* visual word-picture-verification raw scores.

WPV	n	Control Mean	MM	SB	WN	LR	AK
SG pred.	13	13	8 *	10 *	11 *	6.5 *	7 *
PL pred.	13	13	9 *	9.5 *	13	7.5 *	7.5 *
SG non-pred.	9	8. 8	6 *	7.5 *	8 *	6 *	4.5 *
PL non-pred.	9	9	6.5 *	6.5 *	7 *	4.5 *	5 *

**p < .001; *p < .05 compared to control group using modified T-Test Crawford and Howell (2002).

Control task 2: Repetition.

No specific problems with producing plural nouns as compared to singular nouns were observed in the repetition task for any of the participants for both the predictable and non-predictable –*n* singular and plural subsets (Table 11). Thus, a post-lexical phonological deficit or an articulatory deficit could be ruled out as a reason for the plural disadvantage in the spoken picture naming tasks.

Table 11. Predictable and non-predictable -*n* repetition raw scores.

Repetition	n	Control Mean	MM	SB	WN	LR	AK
SG pred.	13	13	12 *	9 *	13	10 *	8 *
PL pred.	13	13	9 *	8 *	13	7 *	9 *
SG non-pred.	9	9	6 *	6 *	9	8 *	9
PL non-pred.	9	9	3 *	8 *	9	6 *	8 *

**p < .001; *p < .05 compared to control group using modified T-Test Crawford and Howell (2002).

Discussion

Four out of five speakers showed a significant plural disadvantage for predictable -*n* plural production in picture naming. For the non-predictable –*n* set, a significant plural disadvantage was obtained for only two participants. Overall (with the exception of SB), PwA made more plural than singular errors regardless of predictability. Thus, plural errors were also produced with non-predictable –*n* plurals, in addition to predictable –*n* plurals. This suggests a similar underlying functional source of plural errors produced in response to predictable and non-predictable targets, and, thus, speaks against the modified dual-mechanism account for the German –*n* plural (Penke & Krause, 2002). However, it remains unclear whether full-listing or decomposition is the underlying mechanism.

Additionally, based on the results of the pre-and post-lexical control tasks (visual word-picture-verification, and repetition) which both did not reveal a plural disadvantage pattern for any of the subsets, we infer (together with the background assessment) that the impairment in spoken plural production was predominantly caused by either a breakdown at lemma or the phonological word form level for all five participants with aphasia.

General Discussion

The production of German plural nouns was examined in five PwA (three non-fluent, and two fluent) who encountered problems in accessing lexical entries for spoken production that originated from a primarily post-semantic deficit but with maintained post-lexical processes. The presented study examined effects of plural dominance (Experiment 1), and plural predictability (Experiment 2) for the predictable and non-predictable German –*n* plural using a spoken picture naming task, and two control conditions: a written word-picture verification and a repetition task (all testing the same item sets same materials as the naming task).

The key finding of Experiment 1 is an effect of plural dominance in spoken picture naming (singular-dominant singular and plural items show a singular advantage, while plural-dominant singular and plural items show no difference), which we replicated across five German PwA, however, the effect was absent for repetition and word picture verification. Our findings support the pattern found in Lorenz and Biedermann (2015) while fine-tuning the locus of the dominance effect by introducing pre- and post-lexical control tasks. Our data suggest that the effect occurs post-concept and prior to the access of the phonological word form (as explained in detail below). Further this paper adds evidence to studies that have previously reported an effect of dominance in English, Dutch and Italian within *both* unimpaired and impaired participants (e.g., English: Biedermann et al., 2012; 2013; Dutch: Beyersmann et al., 2015; Italian: Luzzatti, Mondini, & Semenza, 2001).

The results of Experiment 2 indicate that spoken picture naming accuracy and error types were comparable for predictable and non-predictable –*n* plurals. Thus, the processing of singular-dominant –*n* plurals does not seem to be modulated by plural predictability. Importantly however, Experiment 2 revealed a significant plural disadvantage across all PwA, which is consistent with the pattern observed in Experiment 1 for singular-dominant nouns. Even though the non-predictable group showed a disadvantage in only two PwA but a trend for all participants (which might be due to the relatively small item group compared to the predictable plural group), the plural disadvantage was evident for all five participants for the predictable group.

We discuss Experiment 1 and 2 results in the context of current word production models below.

How can our Findings Advance Theoretical Frameworks of Spoken Word Production?

Overall, result patterns of Experiment 1 and 2 demonstrate that number processes and representations go beyond the level of the phonological word form (Levelt et al., 1999). The observed pattern does not result from a pure surface frequency effect, hence, the number effect observed for singular-dominant nouns, i.e. better naming of singular compared to plural nouns (Experiment 1 and 2) seems to be unlikely to originate at the word form level (Jescheniak & Levelt, 1994) because the opposite effect, i.e. better naming of plural compared to singular forms, was not obtained for plural-dominant nouns (see also Lorenz & Biedermann, 2015).

The present findings are consistent with Nickels et al.'s (2015) theoretical framework, suggesting that the effect is located in the links between semantic concepts and lemmas. This assumption returns to the original idea of Levelt et al. (1999) suggesting two separate (holistic) entries for singular and plural at lexical-syntactic (lemma) level -not only for the plural-dominant case,- and one concept node that can activate either a multiple or single feature diacritic. Critically, Nickels et al. argue that differences in processing of singular- and plural-dominant plurals are based on differences in activation strengths of the links between the lexical-concept and the lexical-syntactic (lemma) level for either multiple or single concepts and their singular and plural lemmas. Singular-dominant items have as a default state stronger links between the ‘single’ concept and singular lemma, while plural-dominant items have stronger affiliations between the ‘multiple’ concept and plural lemma.

Interestingly, one participant, SB, showed a sensitivity for dominance in the word-picture verification task, e.g. revealing a marginally significant advantage in the visual word-picture matching task for singular-dominant singular targets compared to their plurals, a difference that was absent for the plural-dominant singular and plural group. Because this pattern was observed in a receptive task, it points to the interpretation that dominance can manifest partially at the semantic-conceptual level. Note, however, that our background assessments did reveal only mild lexical-semantic deficits for SB (see Table 3 and 4). Alternatively, the pattern might have resulted from a specific deficit at the *modality-independent* lemma level for SB, resulting in similar lexical processing deficits of singular-dominant plurals in comprehension and production (Levelt et al., 1999). Furthermore, we cannot fully exclude that SB's pattern resulted from an orthographic input lexicon impairment (word-form level) – in this case dominance would also affect comprehension (as has been shown for visual lexical decision in healthy speakers, for example in Baayen, Dijkstra, & Schreuder, 1997).

Experiment 2 also showed a number effect for a set of singular-dominant *-n* plurals (hence, a replication of Exp.1 results for singular-dominant items occurred) regardless of whether the plurals belonged to a predictable or non-predictable condition. Even though the number effect was more pronounced in the predictable group, for both groups, the singular was processed more accurately compared to its corresponding plural. Thus, predictable and non-predictable German –*n* plurals seem to be lexically stored and retrieved in a similar way. In our view, this pattern fits well with the Nickels et al. account (Nickels et al., 2015), assuming that –in the case of singular-dominant nouns- number errors in picture naming often result from deficient access to holistic plural representations at the lemma level. This explanation is in opposition with the assumption of the stem-based assembly model (SAM; Cholin et al., 2010) which assumes decomposition for all morphological complex forms at the word-form level. Note, that almost no affix substitution errors (except for one affix error where the default *–s* plural marker replaced a non-predictable *–n* plural: Zwiebel-*s* for Zwiebel-*n*) were observed in our study (see also Lorenz & Biedermann, 2015). Therefore, it is more likely that the number errors observed here resulted from substitutions of inflected full forms, or fully listed lemmas (replacing the plural full form with the corresponding singular noun).

Overall, less stem errors and more number errors were observed for the participants, hence this pattern might have resulted from the substitution of a plural by the corresponding singular (and vice versa), a substitution error easily done since form and semantics mostly overlap. What this pattern clearly shows, however, is that a processing difference at word form level for the different *–n* plural groups (e.g., predictable *-n* plurals are decomposed, and non-predictable *–n* plurals are fully listed) does *not* hold.

To sum up, while our data point to full listing storage of the German *–n* plural in the production lexicon, further evidence is needed to support this strong hypothesis since we did not take into account varying frequency within a singular or plural- dominance group, it might well be possible that low-frequency singular- and plural-dominant plural items might be stored decompositionally (see also Gimenes, Brysbaert, & New, 2016). However, that the occurrence of number errors in the naming of German *–n* plurals is modulated by dominance due to different activation strengths of singular-dominant and plural-dominant plural lemmas (Nickels et al., 2015) was clearly demonstrated across Exp. 1 and 2 in our study. Note, however, that this conclusion does not generalise to all German plural nouns, and we are only making inferences about the *–n* plurals. Even though our data shows a trend towards full listing for both *–n* plurals, rule-based processing still needs to be accommodated in a speech production theory. Previous findings support the notion of decomposition for the regular German default plural *–s*, exclusively (e.g., Clahsen, 1999;

Lorenz & Biedermann, 2015; but see Penke & Krause, 2002). Overall, our data demonstrates the complexity of number representation throughout the production system from concept to word form level.

Conclusions

This paper highlights that information of 'grammatical number' (plural) is stored in more than one place within our spoken word production system: plural and singular nouns differ in their representation at both conceptual, lemma and word-form level. The results of our case-series study with five PwA point to the important role of activation strength of the links between concept and lemma level in order to explain dominance effects during spoken word production, whereas no difference in processing was detected for plural predictability. Hence, our German case series data are compatible with the 'concept-lemma' link explanation for the dominance effect (e.g. Nickels et al., 2015), with relative flexibility for representation at word form level (compatible with both full-listing and decomposition). Data from Exp. 2 excludes a Dual-Mechanism for both –*n* plurals and a trend towards the full-listing assumption at word form level.

This study emphasises the importance to extend the debate about morphological processing (plural processing) to all levels involved in spoken word production: concept, lemma and word form level.

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Appendices

Appendix A

Matching sets using t-test (unequal variance, 2-tailed)										
***P*-values for Dominant Condition**										
	Surface freq.	**Stem freq.**	**Let-ters**	**Pho-nemes**	**Syl-lables**	**Orth. Neigh-bor-hood**	**Phon. Neigh-bor-hood**	**Name Agree-ment**	**Vis. Com-plexity**	**Age of Acqui-sition**
Mean sing-dom. singular	1.792	1.138	5.4	4.467	2.133	5.6	8.933	0.965	2.291	2.533
SD sing-dom. singular	0.553	0.522	1.12	0.743	0.352	4.323	6.408	0.053	0.711	0.743
Mean sing-dom. plural	1.257	1.138	6.4	5.533	2.133	6.333	10	0.937	2.515	2.533
SD sing-dom. plural	0.458	0.522	1.12	0.915	0.352	5.300	7.071	0.058	0.681	0.743
Mean plural-dom. singular	0.908	0.660	5.47	4.73	2.067	3.867	6.2	0.957	2.186	2.667
SD plural-dom. singular	0.468	0.406	1.06	0.594	0.258	3.357	6.247	0.040	0.654	0.816
Mean plural-dom. plural	1.449	0.660	6.47	5.73	2.07	4.07	6.73	0.922	2.390	2.67
SD plural-dom. plural	0.391	0.406	1.06	0.594	0.258	3.43	7.14	0.061	0.604	0.816
Singular-dominant versus Plural-dominant	**2.8E-05**	**0.005**	0.6	0.243	0.5212	0.176	0.202	0.586	0.733	0.745
Plural-dominant singular versus Plural-dominant plural	**0.001**	1	**0.03**	**3E-05**	1	0.792	0.747	**0.039**	0.525	1
Singular-dominant singular versus Singular-dominant plural	**0.007**	1	**0.02**	**0.002**	1	0.681	0.668	0.167	0.386	1
Singular-dominant singular vs. plural-dominant singular	**0.001**	**0.012**	0.855	0.217	0.334	0.295	0.294	0.686	0.632	0.582
Singular-dominant plural vs. plural-dominant plural	0.254	**0.013**	0.855	0.384	0.573	0.060	0.267	0.436	0.651	0.582

Appendix B

Matching sets using t-test (unequal variance, 2-tailed)

p* values for comparison of predictable versus non-predictable –*n

	Surface freq.	Stem freq.	Let-ters	Pho-nemes	Syl-lables	Orth. Neigh-bor-hood	Phon. Neigh-bor-hood	Name Agree-ment	Vis. Com-plexity	Age of Acqui-sition
Mean singular pred. –n	1.239	0.817	5.85	5.308	2.308	4.692	7.692	0.947	2.49	4.385
SD singular pred. –n	0.498	0.365	1.57	1.494	0.480	4.571	7.443	0.063	0.500	1.502
Mean plural pred. –n	1.245	0.817	6.850	6.308	2.308	4.692	7.769	0.906	2.652	4.385
SD plural pred. –n	0.440	0.365	1.570	1.494	0.480	4.250	7.661	0.055	0.365	1.502
Mean singular non-pred. –n	1.158	0.798	5.67	5.111	2	1.889	2.667	0.946	2.497	3.889
SD singular non-pred. –ns	0.699	0.570	0.87	0.601	0	2.619	3.354	0.066	0.517	1.054
Mean plural non-pred. –n	1.312	0.798	6.67	6.111	2	3.333	4	0.916	2.617	3.889
SD plural non-pred. –n	0.494	0.570	0.87	0.600	0	2.291	2.828	0.067	0.773	1.054
Pred. vs. non-pred. overall	0.965	0.894	0.678	0.623	0.008	0.073	0.022	0.837	0.929	0.224
Pred. singular vs. plural	0.972	0.997	0.118	0.101	n/a[a]	0.074	n/a	**0.004**	n/a	0.131
Non-pred. singular vs. plural	0.596	1	**0.026**	**0.003**	n/a	0.231	0.375	0.352	0.704	1
Pred. vs. non-pred. –*n* singular	0.754	0.927	0.76	0.71	0.071	0.114	0.074	0.961	0.976	0.404
Pred. vs. Non-pred. –*n* plural	0.742	0.927	0.76	0.71	0.071	0.394	0.176	0.721	0.886	0.404

Notes. a) not applicable since values for singular and plural group are identical.