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# Production of morphologically derived words in the semantic variant of primary progressive aphasia: preserved decomposition and composition but impaired validation

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**ABSTRACT**
Although there is growing interest in inflectional morphology in semantic variant primary progressive aphasia (svPPA), derivational morphology has rarely been studied in this population. This study reports the performance of N.G., a 72-year-old-woman with svPPA in a verb production task designed to entail morphological processing (composition, decomposition) and self-appraisal of her productions. N.G. demonstrated an over-reliance on morphological processing and failures in her appraisal of root/affix combinations that resulted in the production of morphological paraphasias and neologisms. Her performance in lexical decision of verbs and pseudo-verbs points to the involvement of semantic impairment in these difficulties.

**KEYWORDS**
Semantic variant of primary progressive aphasia; mor-phology; derivation; verb production; lexical decision

The semantic variant of primary progressive aphasia (svPPA) (or semantic dementia (SD)) is characterized by anomia in confrontation naming and single-word comprehension deficit (Gorno Tempini et al., 2011; Neary et al., 1998). However, recent studies draw attention to impairments that go beyond those core manifestations. More specifically, these studies show the presence of impairments in tasks considered to put little or no reliance on semantic processing, such as lexical decision, object decision, and verb inflection (e.g., Jefferies, Rogers, Hopper, & Lambon Ralph, 2010; Patterson et al., 2006; Rogers, Lambon Ralph, Hodges, & Patterson, 2004).

Among these tasks, verb inflection is probably the most studied. Morphological inflection has a grammatical/syntactic purpose. It marks information of a grammatical nature (tense, aspect, number, etc.) by the adjunction of an affix (or bound morpheme) to a base word (the root). In fact, inflection creates different *forms* of a given word to carry different grammatical information. Studies found impaired inflection of irregular verbs in individuals with svPPA (e.g., Benedet et al., 2006; Jefferies et al., 2010; Patterson, Lambon Ralph, Hodges, & McClelland, 2001; Patterson et al., 2006; Wilson et al., 2014). Because they are more idiosyncratic, irregular verbs depend more on semantic processing to support the association between the present and past tense forms (Patterson et al., 2006).

Inflectional morphology is distinct from derivational morphology, which creates different *lexical entries* by the adjunction of a suffix or prefix to a base word. Derivation can induce grammatical category changes (e.g., "to sing" (verb) – "singer" (noun)) and considerable meaning changes between the base and the derived form (e.g., morphological antonyms such as "fold" and "unfold"). There is no consensus on the processes involved in the production of derived words. The claim that derived words could be formed "online" by the concatenation of a base and an affix in ways similar to inflected words is controversial and varies greatly among authors (e.g., Badecker & Caramazza, 2001; Clahsen, Sonnenstuhl, & Blevins, 2003; Janssen, Roelofs, & Levelt, 2002; Levelt, Roelofs, & Meyer, 1999). According to a dominant view (Janssen et al., 2002; Levelt et al., 1999), compared to inflection, derivation is unpredictable in both meaning (some derived words lack semantic transparency in relation to their base) and existence (some forms are unattested), which makes it likely that derived words are "listed" in the lexicon and not formed compositionally. However, other models (e.g., Augmented Addressed Morphology) support the role of composition in the production of derived words (Laudanna, Cermele, & Caramazza, 1997). Evidence for the role of composition can also be found in studies that report the production of "illegal combinations of morphemes" (e.g., *poorless) in individuals with aphasia (e.g., Badecker & Caramazza, 2001; Semenza, Butterworth, Panzeri, & Ferreri, 1990). According to some authors (Badecker & Caramazza, 2001), the production of such errors suggests the impairment of mechanisms devoted to morphological composition (and/or decomposition) and not to the use of a "back-up system" that is only used when whole word retrieval fails, as suggested by other authors (e.g., Semenza et al., 1990).

Despite the fact that it holds a central role in the creation of new lexical entries that have their own specific meaning, derivational morphology has not been extensively studied in svPPA or SD. In their study, Meteyard and Patterson (2009) analyzed derivational errors in samples of connected speech in eight participants with SD. They showed that, overall, participants made more complex (e.g., "unusually" for "unusual") than simple (e.g., "normal" for "normally") errors. Other authors also assessed the production and comprehension of derived words in controlled contexts. Benedet et al. (2006) reported the case of I.L.J., a Spanish-speaking man with SD, who was tested on two occasions (T1 and T2) with a battery of morphological tests of production and comprehension. He was impaired in the production of morphologically complex words and his performance declined further at T2. The test battery included inflectional and derivational items but the authors did not report the results for each separately. The most extensive study of derivational morphology in central semantic impairment was published by Kavé, Heinik, and Biran in 2012. The authors report the longitudinal case study of S.H.S., a Hebrew-French bilingual man with svPPA. They present the results for several tasks of production and comprehension of derivational morphology. The production tasks required S.H.S. to produce the names of baby animals and to name professions to their definition. In both tasks, some names could be produced by morphological composition and some had to be retrieved from the mental lexicon. S.H.S. was unimpaired on the production of morphological diminutives of animal names in the first two testing sessions but was impaired at T3. However, he was at floor level in all three testing sessions on the production of lexicalized baby animal names from the name of the adult animal (e.g., cow → calf). His performance in naming morphological professions fluctuated over time and was impaired at both T1 and T3. The production of lexicalized profession names was also more impaired than the production of morphologically derived names in the three testing sessions. Interestingly, when asked to retrieve lexicalized profession names, S.H.S. made several of what the authors called "regularization errors," that is, he used a word presented in the definition and added one of the agentive suffixes of Hebrew to produce the name (e.g., someone who repairs pipes: piper (instead of plumber)). According to the authors, the production of such regularization errors suggests the preservation of morphological rules in S.H.S. The study of derivational morphology in svPPA has several implications for the comprehension of the various language manifestations that can be caused by central semantic impairment. It contributes to refine our expectations about the scope and type of language difficulties that are expected in this disease.

The goal of the present study was to assess the production of derived words in N.G., a French-speaking woman with svPPA. The main experimental task consisted of producing a verb semantically related to an inducing noun. This task was completed by a semantic matching task designed to assess the influence of the nouns' semantic preservation over verb production. Finally, the study presents a lexical decision task of morphologically complex nonwords conducted after the main experiment in order to specify the nature of the validating processes involved in the production of morphologically complex words in N.G.

## Methods

### *Case presentation*

N.G. is a 72-year-old right-handed woman who received a diagnosis of semantic dementia (Neary et al., 1998) in 2010. Her profile at the time of diagnosis also met the criteria for svPPA (Gorno-Tempini et al., 2011). N.G. is a native speaker of Quebec French and has 12 years of education. She worked as a secretary before her marriage and continued to do some secretarial work in her husband's company. To this day, she is still autonomous in her activities of daily living. The testing described in the present study took place in early 2012.

### *Assessment of language and cognition*

N.G.'s conversational speech was fluent, well-articulated and grammatically correct but was marked by word-finding difficulties (e.g., pauses, comments on her inability to find words). Her performance on language and neuropsychological tests is presented in Table 1.

Her performance in confrontation naming (Macoir, Beaudoin, & Bluteau, 2008) was impaired, as was her performance in confrontation naming of action videos (Routhier, 2014). Unconstrained, orthographic and semantic verbal fluency were below the norm (Joanette, Ska, & Côté, 2004). Her performance on three different tasks of semantic matching (Pyramids and Palm Trees Test (Howard & Patterson, 1992);

Table 1. Language and neuropsychological evaluation.

| Test | | N.G. |
|---|---|---|
| TDQ-60 (60) | | 38* |
| Action naming from videos (102) | | 66* |
| Verbal fluency: MEC | Unconstrained | 40* |
| | Orthographic: letter P | 9* |
| | Semantic: clothing | 16* |
| PPTT (52) | | 39* |
| Semantic similarity judgment (40) | | 31* |
| KDT (52) | | 38* |
| Reading | Irregular words (60) | 40* |
| | Regular words (60) | 57 |
| | Nonwords (60) | 49 |
| MoCA | | 24* |
| DMS-48 | Immediate recognition (48) | 42* |
| | Delayed recognition (48) | 41* |
| Digit span | Forward | 6 |
| | Backward | 6 |
| TMT | A – digits only (sec.) | 36 |
| | B – digit/letter alternance (sec.) | 99 |
| PENO | Praxis – arbitrary gestures (35) | 28* |
| | Praxis – pantomimes (35) | 26* |
| BORB | Line-length judgment (30) | 21* |
| | Object decision – hard (32) | 20* |
| | Object decision – easy (32) | 26* |

Notes: TDQ-60, Test de Dénomination de Québec; MEC, Protocole Montréal d'Évaluation de la Communication; PPTT, Pyramids and Palm Trees Test, picture-picture condition; KDT, Kissing and Dancing Test, picture-picture condition; MoCA, Montreal Cognitive Assessment; DMS48, delayed-matching-to-sample task; Digit span, Longest span; TMT, Trail-Making Test; PENO, Protocole d'Évaluation Neuropsychologique Optimal; BORB, Birmingham Object Recognition Battery.
*Impaired performance.

written word matching (Macoir, 2009); action picture matching: Kissing and Dancing Test (Bak & Hodges, 2003)) was characteristic of central semantic impairments. N.G. also had difficulties reading irregular words and made more regularization errors than the control subjects (Wilson et al., 2012), a pattern compatible with surface dyslexia.

N.G.'s score on the Montreal Cognitive Assessment (MoCA: Nasreddine et al., 2005) was below the suggested cut-off score for normality. Compared with the normal controls, her performance for nonverbal episodic memory was impaired (Barbeau et al., 2004). Her performances for attention and mental flexibility (Trail Making Test: Reitan & Wolfson, 1993) and short-term and working memory (digit span: Wechsler, 1987) were within the limits of normality. Her performance for imitation of arbitrary gestures and execution of gestures to command was slightly impaired (Joanette et al., 1995). N.G.'s performance on the length match task indicated mild visual-spatial impairment while her performance for object decision (Birmingham Object Recognition Battery: Riddoch & Humphreys, 1993) was suggestive of associative agnosia.

### Control group

N.G. was compared to a control group composed of five women without neurological impairment matched for age ($M$ = 71.4; $SD$ = 1.52; $t$ modified, two-tailed, α = 0.05: 0.36, $p$ = .74) and years of education ($M$ = 12; $SD$ = 1; $t$ modified, two-tailed, α = 0.05: 0, $p$ = 1) (Crawford & Howell, 1998). All the control group participants had a normal cognitive performance (all scores above or equal to 26) on the MoCA test (Nasreddine et al., 2005).

### Experimental tasks

#### Verb production task

In the verb production task, participants were shown an agent noun and were instructed to produce a verb semantically related to that noun. Stimuli were 72 agent nouns (names of people/animals doing something to something/someone) ending in *–eur* or its allomorph *–ateur*, a frequent and productive morpheme to form agentive nouns in French (Lehmann & Martin-Berthet, 2003). These 72 nouns were equally divided into four lists of 18 nouns controlled for token frequency (Lexique database: New, Pallier, Ferrand, & Matos, 2001). Average frequency was equivalent between lists (Friedman test: $\chi^2$ = 1.659, $p$ = .646). For lists 1, 2, and 3, the production of semantically related verbs could be assisted by operations of derivational morphology, while morphology could not assist the production in list 4.

The first list (Transparent List) contained nouns ending in *–eur* and having a phonologically and semantically transparent relationship to a verb. This list included nouns that could produce a verb by stripping the *–eur* morpheme and adding a verb-ending suffix (mostly, *–er* but also *–ir* for two items) (e.g., *chanteur* (singer): *chanter* (to sing); *coureur* (runner): *courir* (to run)). Of course, verbs that were related to the nouns solely on a semantic basis were also considered correct answers (e.g., for *chanteur* (singer): *vocaliser* (to vocalize), *fredonner* (to hum), etc.).

The second list (Allomorph *–ateur* List) consisted of nouns that are formed with *–ateur*, the allomorph of *–eur*. With these nouns, it was possible to produce a verb by stripping the *–ateur* ending and adding a verb-ending suffix (e.g., *fondateur* (founder): *fonder* (to found)) or by retrieving a verb that was related to the noun solely on a semantic basis (e.g., for *fondateur: créer* (to create)). It is worth noting that *–ateur* is less frequent than *–eur* based on their respective number of occurrences, and on the cumulative frequencies and average frequencies of words formed with these morphemes (New et al., 2001). For this reason, and because the item list made the *–eur* morpheme very salient, it was assumed that these words could eventually cause decomposition errors, leaving "*at*" attached to the stem (e.g., **fondater*).

The third list (Root Allomorphy List) consisted of nouns that were morphologically related to a verb, but through root allomorphy (e.g., *correcteur* (corrector): *corriger* (to correct)). Notwithstanding the rather unpredictable nature of this allomorphy, the relationship between two words that present a root allomorphy is not solely semantic and lexical in nature. For instance, Marslen-Wilson and Zhou (1999) showed that pairs of allomorphic words (sanity/sane) prime each other as much as non-allomorphic pairs (happiness/happy), and more than pairs that are only phonologically related (tinsel/tin). This effect was explained by the morphological relationship shared by the allomorphic words. For these nouns, affix stripping of the *–eur* morpheme could support verb production but via access to the root's lexical representation. In fact, activating a root at the lexical entry level allows access to its allomorph either because each allomorph has its own representation (e.g., Burani & Laudanna, 1992) or because allomorphs share a common, abstract representation (e.g., Marslen-Wilson & Zhou, 1999). Either way, retrieving a noun's root gives access to the related verb's root, to which a verb-ending affix can be added. However, if the participant keeps the noun's root "unchanged" and adds a verbal ending affix, it will result in the production of a morphological paraphasia (e.g., for *correcteur*: **correcter*). As was the case for lists 1 and 2, every noun had several solely semantic possible correct answers (e.g., for *correcteur* (corrector): *vérifier* (to verify)).

Finally, the fourth list (No Related Verb List) included nouns for which a transparently related verb does not exist, that is, is not used by native Quebec French speakers and is not attested in the most widely consulted French dictionary (Le Nouveau Petit Robert, 2001). For example, there is no verb **sénater* that would be related to *sénateur* (senator). For this type of noun, the participants had to rely on semantic relationships to produce a verb (e.g., from *sénateur: voter* (to vote), *légiférer* (to legislate), etc.). In this case, affix stripping and use of the noun's root as the basis for verb production would result in the production of a neologistic verb (e.g., *sénateur*: **sénater*). It was assumed that in the rather formal context of experimental testing, normal speakers would be reluctant to produce unattested forms and that they should occur rarely. N.G., on the other

hand, has less semantic resources at her disposal and might have to rely on derivational processes to a greater extent. Accordingly, she might produce more unattested forms than controls. The stimuli are reported in the Appendix.

*Procedure.* The nouns were presented in semi-random order (no more than two consecutive nouns from the same list) on a computer screen and were read by the experimenter at the same time. The participants were instructed to produce a verb semantically related to the noun. At no time were the participants told that there were items for which it was possible to produce a verb by morphological derivation and items for which it was not possible. The participants were told that there was more than one possible correct answer and they completed 10 practice items before beginning the task. During this practice phase, they were given feedback on the accuracy of answers (no correction provided) and were also asked, when necessary, to produce as precise a verb as possible and to avoid "light verbs" (to do, to go, etc.). No feedback was provided while they completed the experimental items.

### Comprehension task

To assess the influence of the preservation of the agent nouns' semantic representations on verb production, participants performed a task in which they were asked to match each agent noun used in the production task to another agent noun on the basis of semantic relationship. Each agent noun was presented above two other agent nouns, that is, a target and a distractor. For example, *envahisseur* (invader) was presented with *conquérant* (conqueror) – the target – and *adversaire* (adversary) – the distractor. The three lists of agent nouns (those used in verb production, the targets, and the distractors) were matched for frequency (New et al., 2001).

*Procedure.* Items were presented in semi-random order with no more than two consecutive nouns from the same experimental list in a row. The order of presentation of targets and distractors was counterbalanced between items so that there was the same number items for which the target was presented on the left side and the right side of the screen. The items were presented in written form on a computer screen and were read by the experimenter at the same time. The participants could either point to or say the word that was most semantically related to the word presented on top.

## Results

### Verb production task

Items were analyzed for the number of correct verbs produced and the types of verb produced.

### Verb production accuracy

For this analysis, answers were categorized as correct or incorrect. Results are shown in Table 2. Incorrect answers included neologistic verbs (e.g., the unattested form **orater*, produced starting from *orateur* (speaker)), morphological paraphasias resulting from the addition of a verb ending to a nominal root (e.g., **rédacter*, produced starting from *rédacteur* (editor, writer)), lexical/formal errors (e.g., *prédire* (to predict)) produced starting from *prédicateur* (preacher)), and nonanswers.

Table 2. Verb production task.

| | | Control group | | |
|---|---|---|---|---|
| | N.G. | *M* | *SD* | Range |
| Transparent List (18) | 18 | 18 | 0 | – |
| Allomorph–ateur List (18) | 18 | 18 | 0 | – |
| Root Allomorphy List (18) | 11** | 17.2 | 0.84 | 16–18 |
| No Related Verb List (18) | 7** | 15.6 | 1.52 | 14–18 |
| Total (72) | 54* | 68.8 | 2.05 | 67–72 |

Notes: *Statistically significant difference at $p < .05$; **statistically significant difference at $p < .0125$.

The difference between N.G. and the control group was tested using Crawford's modified test of mean comparison (Crawford & Howell, 1998). First, the total results out of 72 were compared using a 0.05 level of significance, two-tailed modified *t*-test. The difference between N.G. and the controls was significant (*t* modified: −6.592; $p = .003$). The results for each of the four lists were analyzed using Crawford's modified test with a Bonferroni corrected level of significance of 0.0125 (0.05 divided by four). Only the differences for the Root Allomorphy List (list 3) and the No Related Verb List (list 4) were tested since all the participants (including N.G.) performed at ceiling level on the two other lists. The two comparisons yielded significant differences (Root Allomorphy List: $t = -6.765$; $p = .002$; No Related Verb List: $t = -5.177$; $p = .007$).

### Type of answers

All the participants had perfect performances for lists 1 and 2 and produced a majority of morphologically related verbs. In fact, N.G. produced only morphologically related verbs for these two lists. In the control group, the production of verbs that were solely semantically related to the noun was rare. However, there were some semantic productions such as *peindre* (to paint) starting from *créateur* (creator). The production of solely semantically related verbs in lists 1 and 2 ranged from 0/36 (two participants) to 8/36 (one participant) (average: 2.2/36 or 6.11% of verbs).

N.G.'s performance for the Root Allomorphy List (list 3) was significantly lower than in the control group. Of the seven errors she produced in this list, five can be analyzed as morphological paraphasias. The remaining two errors were lexical/formal errors (*promettre* (to promise) produced starting from *promoteur* (sponsor); *imiter* (imitate) produced starting from *amateur* (fan, as in sports fan). The control subjects did not produce any morphological paraphasias and the majority of their responses were the morphologically related verbs associated with each noun. They also produced more solely semantically related verbs than in lists 1 and 2 (range: 1/18–6/18; average: 3.8/18 or 21.11% of verbs).

Table 3. Distribution of correct productions in the production task in relation to correct noun comprehension.

| | Production | | |
|---|---|---|---|
| Comprehension | Error | Correct | Total |
| Error | 9 | 11 | 20 |
| Correct | 9 | 43 | 52 |
| Total | 18 | 54 | 72 |

In list 4 (No Related Verb List), N.G.'s performance was also lower than in the control group. Of 11 productions categorized as incorrect, 9 can be analyzed as neologisms/unattested verbs. This type of production was rare in the control group (0: two participants; 1: two participants; 3: one participant). In every case, neologisms produced by the controls were also produced by N.G. Her remaining two errors were a nonresponse and a lexical/formal error (*prédire* (to predict) produced starting from *prédicateur* (preacher)).

### *Comprehension task*

N.G.'s total score on the comprehension task was lower than the average score of the control group (*t* modified, two-tailed, α = 0.05: −6.592; $p = .003$). The results for each of the four lists were analyzed using Crawford's modified test with a Bonferroni corrected level of significance of 0.0125. The only difference that was statistically significant was in the No Related Verb List (list 4) (*t* modified, two-tailed: −5.164; $p = .007$; all other differences > 0.05), which was also associated with poor performance on the production task.

The correspondence between N.G.'s performance on the comprehension task and the production task was tested with an exact McNemar's test on SPSS (SPSS Inc., 2008). Table 3 shows the distribution of correctly/incorrectly produced verbs according to the performance on the comprehension task. The results show that there was no statistically significant difference in the proportion of correct productions for agents nouns for which she had preserved or impaired semantic knowledge ($p = .824$).

## Discussion

N.G.'s performance on the production task varied according to the type of inducing noun. She obtained perfect scores on the first and second list, which consisted of nouns that were morphologically related to verbs in a transparent way. However, she had more difficulty producing verbs correctly when the morphological relationship was less transparent (due to root allomorphy) or simply nonexistent (no attested verb related to the noun).

Even though it could be argued that the production task could be completed without involving morphological processing, that is, by resorting to lexical/semantic knowledge only, several aspects of the participants' performance indicate that morphological processing did in fact take place during the completion of this task. The most convincing aspect of the performance is probably the production by N.G. of verb-like morphological paraphasias with nominal roots starting from the nouns in list 3, and the production of unattested verbs starting from the nouns in list 4. N.G. extracted a "root-like component" from these nouns to serve as the base for verb production and added a very frequent and productive verb ending (*–er*) to these "roots," which shows that morphological decomposition and composition were at play (in N.G., at least) during the completion of this task. In fact, given their morphological structure, it seems unlikely that N.G.'s errors are simply mixed phonological/semantic paraphasias.

Morphological paraphasias were not produced by the controls and unattested verbs were rare in that group. We cannot exclude the possibility that morphological operations had little or no involvement in their performance. Nevertheless, morphologically related verbs constituted the majority of their production, especially when the relationship between the noun and verb was most transparent (i.e., in lists 1 and 2, but less so in list 3). Overall, the internal structure of the stimuli, the repetition of this structure throughout the lists, and the nature of the production task make it likely that morphological operations supported the productions of at least some of the verbs from lists 1–3 in all the participants.

In line with the results of Kavé et al. (2012), the results for lists 1 and 2 show that basic aspects of morphological derivation are preserved in N.G. Using these morphological abilities, N.G. was able to correctly produce verbs that were semantically related to the nouns, despite her central semantic impairment. N.G.'s correct productions show that she always stripped the ending morpheme correctly to extract the root. The nouns in *–ateur* did not cause segmentation errors that would have resulted in keeping the "*at*" part attached to the root (e.g., starting from *fondateur* (founder): **fondater*). Her productions were always verbs and she did not commit grammatical category errors, such as producing the noun *fondation* (foundation) instead of the verb *fonder* (to found) starting from *fondateur* (founder).

Our results are also in line with those of Kavé et al. (2012) reporting the production of "regularization errors" in their Hebrew-speaking participant, S.H.S. When faced with the production of lexicalized (nonmorphological) profession names, S.H.S. often produced neologisms based on a word given in the definition to which he added an agentive ending. Kavé et al. (2012) limit their interpretation of these productions to stating that they show "[. . .] that S.H.S.'s morphological skills were relatively preserved." While we do not wish to deny that morphological paraphasias and neologisms demonstrate morphological knowledge preservation in some way, we feel that the substantial number of such errors produced by N.G. (and not the control group) warrants further investigation and interpretation.

The analysis of the correspondence between the comprehension and the production task showed that the semantic preservation of the noun given as input for verb production did not guarantee the successful production of a verb, and vice versa. Therefore, it seems that the

type of semantic knowledge involved in the successful production of the verb does not only concern N.G.'s capacity to access the semantic features of the nouns given as input. We suggest that semantic knowledge is involved in the validation of the verb to be produced.

As shown by her production of morphological paraphasias and unattested verbs, N.G. seems to demonstrate overreliance on morphological operations in the production task. While morphological operations could be used for nouns in lists 1 and 2 that have a morphologically transparent relationship to a verb, nouns in lists 3 and 4 lead the participants along a sort of "morphological garden-path." In fact, the identification of a root is a "rewarding" method for the nouns that have a transparent relationship to a verb, and it can, to some extent, support the production of verbs with an allomorphic root, provided that activation of the nominal root at the lexical level gives access to the verbal root (Burani & Laudanna, 1992; Marslen-Wilson & Zhou, 1999). For nouns for which there is no attested verb, the identification of a (pseudo-)root is misleading. The only way to avoid the production of morphological pseudo-words, whether they are morphological paraphasias formed with a nominal root or unattested forms, is to apply a form of validation judgment before their production. Accordingly, studies on lexical decision of morphologically complex words can shed some light on the interpretation of these errors.

Pseudo-words composed of existing morphemes cause more errors and are associated with longer latencies in lexical decision (e.g., Burani, Dovetto, Thornton, & Laudanna, 1997; Taft & Forster, 1975). Studies show that nonwords formed of existing morphemes can give rise to lexical activation, and therefore might be harder to reject in lexical decision, that is, to categorize as nonwords. The influence of morphological structure on lexical access is also demonstrated by studies that support morpheme-based (or decompositional) access to words' lexical representations (Rastle & Davis, 2008; Rastle, Davis, & New, 2004). By using a masked-priming paradigm, these studies show that words are automatically decomposed into constituting morphemes, even if they are not morphologically complex (as in "corner," which is not formed of "corn" and "–er"). Up to recently, this process was considered automatic and blind to semantic relatedness since priming was observed between nonsemantically related, pseudo-morphological pairs, like "corner" and "corn." However, a meta-analysis has shown a small but significant advantage for real morphological pairs in priming (Feldman, O'Connor, & Moscoso del Prado Martín, 2009). This advantage would be related to a final stage of lexical access in which the combination of the two morphemes is validated semantically. This stage would be necessary to determine the well-formedness of a morpheme combination.

Such a stage of morphological validation has been described by several authors under different names (licensing: Burani, Dovetto, Spuntarelli, & Thornton, 1999; recombination: Fruchter & Marantz, 2015; Taft, 2004; unification: Hagoort, 2005; Levy, Hagoort, & Démonet, 2014). Support for a stage of morpheme assembly validation also comes from behavioral and MEG/EEG results. Morphologically complex pseudo-words that are "semantically interpretable" or "transparent" are associated with longer response latencies and higher error rates (Burani et al., 1999; Wurm, 2000). MEG/EEG studies show that the time course of morphologically complex word processing is coherent with a semantically related, final validation stage (Bölte, Schulz, & Dobel, 2010; Fruchter & Marantz, 2015; Lavric, Elchlepp, & Rastle, 2012; Levy et al., 2014; Whiting, Marslen-Wilson, & Shtyrov, 2013). One study found evidence of semantic processing for morphologically complex pseudo-words that varied in interpretability and morphological well-formedness (Bölte et al., 2010). Other MEG/EEG studies show that the rapid and blind segmentation of "pseudomorphological" words (such as "corner") is followed by a phase of semantic processing in which the appropriateness of initial segmentation is evaluated (in visual word processing: Lavric et al., 2012; in auditory word processing: Whiting et al., 2013). Semantic processing would therefore have a "corrective" effect over the automatic decomposition triggered by morphological structure (Lavric et al., 2012). The validation (or "unification") of truly morphological words is also faster and more accurate compared to the unification of pseudo-morphological words (Levy et al., 2014). Lastly, this final stage of morpheme processing would be supported by its time-based association with surface frequency and semantic well-formedness effects (Fruchter & Marantz, 2015).

Anatomical findings are also coherent with the locus of atrophy associated with the degradation of semantic representations in svPPA. In the study of Whiting et al. (2013), semantic processing of morphologically complex pseudo-words involved the left anterior medial temporal gyrus. Anterior temporal lobe atrophy is consistently found in svPPA (Gorno-Tempini et al., 2011).

Following these studies, N.G.'s errors could be described in terms of difficulties in morpheme assembly validation. To further test this hypothesis, we constructed a lexical decision task that included N.G.'s incorrect morphological productions. This task was also designed to verify that unattested verbs are not widely and readily accepted as real words in normal speakers.

### *Lexical decision task*

About 2 months after she completed the verb production task, N.G. was given a lexical decision task of morphological paraphasias and unattested verbs she produced in verb production. The same control group of five education-and-age-matched women also performed this task. While lexical decision is not traditionally considered a task that involves semantic processing, studies of lexical decision of morphologically complex pseudo-words showed that semantic processing could play a role under certain circumstances, namely when semantic interpretability is at stake (Burani et al., 1999; Wurm, 2000).

The task included the 14 pseudo-verbs that N.G. produced in the verb production task, that is, five morphological paraphasias and nine unattested verbs. Another 14 pseudo-verbs that she could have produced but did not

produce were created by applying the same composition processes to the remaining nouns in lists 3 and 4. One was later excluded from the analysis because its pronunciation was too similar to an existing verb. Fourteen real verbs with an ending phonologically similar to N.G.'s pseudo-verbs (at least three phonemes) and 14 real verbs matched in frequency to the similar verbs were also included. The items were presented on a computer screen and were read by the experimenter at the same time.

N.G.'s performance for the pseudo-verbs she produced in the production task was at chance level. She rejected 6 of her own pseudo-verbs out of a total of 14. She also rejected 10 of the pseudo-verbs that were created by the experimenter out of a total of 13. On average, participants of the control group had a performance of 10/14 (*SD* = 1.41) for N.G.'s pseudo-verbs and 12.8/13 (*SD* = 0.45) for the pseudo-verbs created by the experimenter. N.G. incorrectly rejected one similar real verb but no frequency-matched real verb. All the participants of the control group had a perfect performance for both types of real verbs. Overall, the difference between N.G.'s performance (43/55) and the one of the control group (*M* = 50.8/55; *SD* = 1.48) was significant (*t* modified, two-tailed, α = 0.05: −4.801, *p* = .009) (Crawford & Howell, 1998). When each condition was compared individually, the only significant difference between N.G. and the control group was for the pseudo-verbs created by the experimenter (N.G. = 10/13; mean of the control group = 12.8/13, *SD* = 0.45) (*t* modified, two-tailed, α = 0.0125: −5.716, *p* = .005; all other differences > 0.05). The comparison between N.G. and the control group for the pseudo-words she produced in the verb production task did not reach significance. In other words, the controls did not show an advantage over N.G. for the pseudo-words that she failed to inhibit in verb production. For the control group, these errors were easier to avoid in production since they could count on intact semantic representations to generate correct answers related to the starting noun. They were less likely to get "stuck" in a morphological strategy that would result in the production of a pseudo-verb. However, when confronted with these items in lexical decision, they had slight difficulties to reject them, which is coherent with the literature on morphological decision of morphologically complex pseudo-words. The difference between N.G.'s pseudo-words and those that were invented by applying the same processes could also suggest that the pseudo-verbs N.G. produced were more "plausible." The compatibility of a root and a derivational morpheme follows several constraints (phonological, grammatical, semantic, pragmatic, etc.) (Bauer, 2001; Manouilidou & Stockall, 2014; Plag, 1999). Even though the influence of these constraints is not easy to tease apart (Lehmann & Martin-Berthet, 2003), consideration of these aspects at the stage of stimuli selection could contribute to the explanation of errors in future studies.

This study supports the conclusion that the validation of a root/affix combination involves semantic processing (Bölte et al., 2010; Burani et al., 1999; Fruchter & Marantz, 2015; Lavric et al., 2012; Levy et al., 2014; Whiting et al., 2013; Wurm, 2000). The impairment of an operation that involves semantic processing is an expected finding in svPPA. In this disease, semantic representations deteriorate gradually and become less specified, that is, less informative. Accordingly, they might not be able to play the roles they usually play in morphologically complex word processing.

## Conclusion

The aim of this study was to assess the use of basic derivational morphology abilities and self-appraisal of the production of morphologically complex words in a French-speaking woman with svPPA. We showed that N.G. was able to produce verbs that were semantically related to a noun by relying on derivational morphology. In this regard, our results are similar to those of Kavé et al. (2012), who studied the production of derived words in a Hebrew-speaking man with svPPA. Similar to these authors, we report the production of morphological paraphasias and neologisms in N.G. However, unlike Kavé et al. (2012), we consider these errors to be the manifestation of difficulties in the validation of morphologically complex word production. The results from the additional lexical decision task are also in line with this conclusion.

These difficulties can be related to a failure at the final processing stage of morphologically complex words and pseudo-words lexical decision (Bölte et al., 2010; Burani et al., 1999; Fruchter & Marantz, 2015; Lavric et al., 2012; Levy et al., 2014; Whiting et al., 2013; Wurm, 2000). They are also in line with recent MEG/EEG studies that report semantic involvement in morphologically complex word and pseudo-word processing (Bölte et al., 2010; Fruchter & Marantz, 2015; Lavric et al., 2012; Levy et al., 2014; Whiting et al., 2013). Anatomical correlates associated with this type of processing are also coherent with the locus of atrophy consistently found in svPPA (Gorno-Tempini et al., 2011; Whiting et al., 2013).

In sum, it seems that N.G. still has the "building blocks" of language at her disposal, but that their use is impaired due to the degradation of semantic memory, which normally plays a role in sanctioning morpheme assembly. Other studies with larger groups of participants could shed more light on the preserved and impaired aspects of morphological processing in svPPA.

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## Appendix.
## Stimuli used in the verb production task

| | Transparent list | Allomorph *–ateur* list | Root Allomorphy List | No Related Verb List |
|---|---|---|---|---|
| 1 | boxeur | admirateur | amateur | agriculteur |
| 2 | chanteur | animateur | bâtisseur | ambassadeur |
| 3 | charmeur | compositeur | buveur | auteur |
| 4 | chercheur | consommateur | conducteur | aviateur |
| 5 | chômeur | créateur | constructeur | bienfaiteur |
| 6 | coiffeur | décorateur | convertisseur | délateur |
| 7 | confesseur | dessinateur | correcteur | empereur |
| 8 | coureur | dictateur | corrupteur | farceur |
| 9 | cueilleur | explorateur | électeur | gladiateur |
| 10 | lanceur | fondateur | envahisseur | ingénieur |
| 11 | laveur | informateur | fournisseur | interlocuteur |
| 12 | livreur | libérateur | lecteur | malfaiteur |
| 13 | nettoyeur | manipulateur | percepteur | orateur |
| 14 | pêcheur | navigateur | producteur | pasteur |
| 15 | plongeur | observateur | promoteur | prédateur |
| 16 | soigneur | opérateur | protecteur | prédicateur |
| 17 | vendeur | réalisateur | rédacteur | sénateur |
| 18 | voyageur | réparateur | successeur | spectateur |