# Lexical decision with pseudohomophones and reading in the semantic variant of primary progressive aphasia: A double dissociation

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## Abstract

The co-occurrence of semantic impairment and surface dyslexia in the semantic variant of primary progressive aphasia (svPPA) has often been taken as supporting evidence for the central role of semantics in visual word processing. According to connectionist models, semantic access is needed to accurately read irregular words. They also postulate that reliance on semantics is necessary to perform the lexical decision task under certain circumstances (for example, when the stimulus list comprises pseudohomophones). In the present study, we report two svPPA cases: M.F. who presented with surface dyslexia but performed accurately on the lexical decision task with pseudohomophones, and R.L. who showed no surface dyslexia but performed below the normal range on the lexical decision task with pseudohomophones. This double dissociation between reading and lexical decision with pseudohomophones is in line with the dual-route cascaded (DRC) model of reading. According to this model, impairments in visual word processing in svPPA are not necessarily associated with the semantic deficits characterizing this disease. Our findings also call into question the central role given to semantics in visual word processing within the connectionist account.

**Keywords:** svPPA; reading; lexical decision; visual word processing; semantics; surface dyslexia.

## 1. Introduction

The semantic variant of primary progressive aphasia (svPPA) is a neurodegenerative disease characterized by atrophy, usually more extensive in the left hemisphere (Gorno-Tempini et al., 2004; Noppeney et al., 2007; Wilson et al., 2012; Wilson et al., 2009), of the anterior temporal lobes (ATLs). This atrophy is manifested at the behavioral level in the progressive loss of semantic knowledge. In line with this semantic impairment, the ATLs are considered as a semantic "hub" that serves to create trans-modal semantic representations (Lambon Ralph, 2014).

Patients with svPPA also often exhibit a reading impairment known as surface dyslexia (Funnell, 1996; Marshall & Newcombe, 1973). This language impairment is characterized by difficulty in reading irregular words (i.e., words that have exceptional grapheme-to-phoneme correspondences, like *pint*), leading to regularization errors (e.g. reading *pint* to rhyme with *mint*). The extent of ATL atrophy has been found to correlate with the degree of impairment of irregular-word reading (Brambati, Ogar, Neuhaus, Miller, & Gorno-Tempini, 2009). This relationship between svPPA (and its neural correlate) and the impairment of irregular-word reading has been for decades at the heart of a debate over the role of semantics in visual word processing.

Connectionist models of visual word processing, the most influential of which is the Parallel Distributed Processing (PDP) framework, have taken the association between surface dyslexia and semantic impairment in svPPA as supporting evidence for the necessity of semantics to the correct reading of irregular words (Harm & Seidenberg, 2004; Plaut, McClelland, Seidenberg, & Patterson, 1996; Plaut, 1997). In the PDP framework, orthographic, phonological and semantic information is represented by patterns of activation distributed over groups or layers of units (Plaut et al., 1996). Visual word processing is carried out by the interaction of units in the network via weighted connections (Harm & Seidenberg, 2004; Plaut et al., 1996; Seidenberg & McClelland, 1989). There are two pathways for visual word processing in the PDP model: a direct pathway, from orthography to phonology (O→P), also known as the phonological pathway, and a semantic pathway (O→S→P). The model postulates that there is a division of labor between the two pathways whereby processing of consistent and/or high-frequency words can be achieved effectively by the phonological pathway, while processing of low-frequency inconsistent words depends on the contribution of the semantic pathway (Harm & Seidenberg, 2004; Plaut et al., 1996; Woollams, Ralph, Plaut, & Patterson, 2007). This is because the phonological pathway computes mostly consistent O→P correspondences and, in the course of learning, it comes to rely on the semantic pathway to read low-frequency words with inconsistent O→P correspondences (Plaut et al., 1996). It follows then that damage to the semantic system, such as the one witnessed in svPPA, would inevitably result in impaired reading of irregular words, namely surface dyslexia, since the phonological pathway alone cannot read them. According to Plaut et al. (1996), this division of labor is graded and varies from one individual to another (depending on a number of factors, such as the extent of the reader's experience). Thus, patients who premorbidly relied less on the semantic pathway will show reduced impaired irregular-word reading than those who relied on the semantic pathway for irregular-word reading to a great extent. This hypothesis draws support from a few computational simulations that showed that individual differences can account for the association of or dissociation between irregular-word reading and semantic impairment (Dilkina, McClelland, & Plaut, 2008; Plaut, 1997).

Another theoretical account of reading aloud, the dual route cascaded (DRC) model ( Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), supports a completely different view and claims that while surface dyslexia and semantic impairment may co-occur in svPPA, they are unrelated deficits. In other words, the co-occurrence or association of these two deficits does not entail a causal relationship. In this view, the degradation of semantics arises from ATL atrophy, while surface dyslexia results from additional lesions to other brain regions supporting the reading system (Coltheart, 2004; Coltheart, Tree, & Saunders, 2010a; Patterson et al., 2006).

The sharp contrast between the DRC's account of reading impairments in svPPA and that of the PDP stems from the fact that the two models' architectures and processing mechanisms are very different. One fundamental difference is that in the DRC, all word representations are local rather than distributed. Whole-word forms are thus represented as entries in orthographic and phonological lexicons (the existence of which is eschewed in the PDP framework). Another important point of difference between the two models is that in PDP the same processing mechanism supports both words and non-words, whereas in the DRC the two main routes for visual word processing (lexical for words and sublexical for non-words and regular words) operate according to two different mechanisms. The sublexical route, also known as the grapheme-to-phoneme conversion (GPC) route, operates according to a rule-based mechanism, as it converts graphemes into phonemes serially (i.e. letter by letter, from left to right) by applying spelling-to-sound correspondence rules. It processes non-words and regular words but cannot process irregular words, since their pronunciation does not follow spelling-to-sound correspondence rules. On the other hand, the lexical route operates with a lexical access mechanism and is subdivided in two routes. The first one is the lexical non-semantic route, which is basically a direct route from the orthographic input lexicon to the phonological output lexicon. When a word is presented, the visual features for the word's letters in each position spread activation to its corresponding letter units in each position. These then activate the word's lexical entry in the orthographic lexicon, which in turn activates its corresponding entry in the phonological lexicon. The second lexical route is the lexical semantic route which is supported by the same mechanism as the non-semantic route except that access to the phonological output lexicon is mediated by the semantic system. Both lexical routes (semantic and non-semantic) can process regular and irregular words. Consequently, in case of semantic impairment, and if the lexical non-semantic route is intact, reading of irregular words would remain unimpaired. Thus, in the DRC account, correct pronunciation of irregular words is possible without needing access to semantics. Case studies of svPPA patients who had a significant semantic impairment but had normal reading of irregular words (e.g., Blazely, Coltheart, & Casey, 2005; Cipolotti & Warrington, 1995; Lambon Ralph, Ellis, & Franklin, 1995; Schwartz, Saffran, & Marin, 1980; Wilson & Martínez-Cuitiño, 2012) have provided evidence for the DRC model and against the connectionist account.

The role played by semantics in lexical decision (LD), a visual word recognition task where participants are asked to decide whether a given letter string is a word or not, is also matter of debate. In the DRC model that, as mentioned before, posits local representations of words, LD is performed in quite a straightforward way. The visual stimulus' letter units activate a number of lexical entries in the orthographic lexicon. A real word is identified (i.e. a *yes* decision is made) when the activation level of one of those entries reaches some critical activation level that allows the *yes* decision to be made or when early in processing the activation of the orthographic lexicon as a whole reaches the critical activation level (Coltheart, Davelaar, Jonasson, & Besner, 1977; Coltheart et al., 2001; Coltheart & Rastle, 1994). Thus, in this model, recognition of words relies on the retrieval of their orthographic form and does not necessitate access to their meaning (i.e. their semantic representations) (Coltheart, 2004; Rastle & Coltheart, 2006). Non-words are identified (i.e. a *no* decision is made) when no entry in the orthographic lexicon reaches the set critical activation level after a given amount of time (i.e. number of processing cycles; Coltheart & Rastle, 1994). The criterion for this 'deadline' varies depending on the activation level in the lexicon in the first processing cycles: if it is high, the deadline will be longer, if it is low, the deadline will be shorter (Coltheart et al., 1977; Jacobs & Grainger, 1992). Making decisions on word-like stimuli like pseudohomophones (i.e., non-words that sound like a word but do not look like one, such as *brane*) takes longer because the assembled phonological form of the pseudohomophone through the GPC route activates an existing entry in the phonological output lexicon. This phonological activation (/breɪn/) feedforwards to the orthographic lexicon where it excites the orthographic entry corresponding to the real word (*brain*) from which the pseudohomophone was derived. It also receives excitation from the visual stimulus' letter units which overlap with the real word's letter positions (for instance, both *brane* and *brain* have *b* in the first position, *r* in the second, and *a* in the third, making the phonological overlap also orthographic). At the same time, those letter units which do not overlap with the real word will send inhibition to that same entry. This results in higher global activation of the orthographic lexicon and as a result, the deadline for pseudohomophones will be extended as compared to words and simple non-words. Thus, the DRC account of LD predicts that if the lexical non-semantic route is intact, svPPA patients will perform accurately on LD with pseudohomophones, in spite of their semantic impairment.

LD has posed quite a challenge for connectionist models, mainly because they posit distributed representations of words. In contrast with the DRC model, in the PDP framework, semantic activation is essential to perform LD under special circumstances, for example in the presence of particular items in the stimulus list like pseudohomophones or inconsistent words. For such stimuli, orthographic and phonological information alone may not be sufficient to make an accurate decision (Dilkina, McClelland, & Plaut, 2010; Evans, Lambon Ralph, & Woollams, 2012; Harm & Seidenberg, 2004; Plaut & Booth, 2000). Plaut (1997) has developed a connectionist model in which accurate LD could be successfully simulated by relying on a measure of semantic familiarity called *semantic stress*, which represents the strength of activation of semantic units. Words have much higher semantic stress than non-words. A decision criterion is adopted to distinguish between words and non-words, i.e. a *yes* decision is made if a stimulus generates a semantic stress value higher than the criterion. The decision criterion will vary depending on the stimulus list composition; it will be higher when the stimuli include pseudohomophones. When non-words are presented as input, the computed semantic activation patterns are of lower average stress than for real words. Pseudohomophones have higher semantic stress than simple non-words because of the mapping between the phonological pattern of activation (i.e. the phonological representation) and semantic representations which correspond to those of real words (i.e. /breɪn/ would activate the semantics of brain). However, the semantic stress of pseudohomophones is still lower than that of real words, since the mapping from orthography to semantics for those stimuli yields weak semantic activation, thereby resulting in a *no* decision. Thus, in the connectionist framework, recognition of words relies on semantic activation.

Support for this account comes, in part, from studies that found semantic effects in visual LD among healthy participants (e.g., Binder et al., 2003; Evans et al., 2012; Pexman, Hargreaves, Edwards, Henry, & Goodyear, 2007; Plaut & Booth, 2000; Samson & Pillon, 2004;

Yap, Lim, & Pexman, 2015). In an LD task, Evans et al. (2012) found that semantic effects increased the more word-like the non-words got, with semantic effects being greatest in the pseudohomophone condition. A recent fMRI LD study in healthy participants (Woollams, Silani, Okada, Patterson, & Price, 2011) has shown greater activation of the ATLs, the brain region atrophied in svPPA, in the pseudohomophone condition, where reliance on semantics is greatest. Other studies have found a correlation between the level of the semantic deficit in svPPA patients and the degree of impairment in LD (e.g., Dilkina et al., 2010; Lambon Ralph & Howard, 2000; Patterson et al., 2006; Rogers, Lambon Ralph, & Hodges, 2004). These findings have been taken as supporting evidence for connectionist models because they stress the idea that semantics is essential to accurate performance in LD. Thus, this connectionist account predicts that svPPA will always result not only in surface dyslexia but also in impaired LD, even more so in the presence of pseudohomophones.

However, as with reading, there exist cases of svPPA patients who performed accurately in LD. Coltheart (2004) reviewed a few such cases that had been presented in previous papers. Most notably, patients DC (Lambon Ralph et al., 1995) and SA (Ward, Stott, & Parkin, 2000) had an impaired semantic system but performed within the normal range in LD. It is of note, that the LD task performed by patient SA included pseudohomophones (of equal number to the pseudowords). Such cases challenge the connectionist account of LD according to which semantics is essential to distinguish between words and non-words.

Blazely et al. (2005) presented the cases of EM and PC who both showed a semantic impairment characteristic of svPPA. However, while PC suffered from surface dyslexia and performed below normal range in LD, EM showed unimpaired reading and LD. It is important here to point out that all nonwords in the LD presented in their study were pseudohomophones.

According to Plaut (1997), reliance on semantics is absolutely necessary to perform the task accurately with such stimuli. Thus, it is very difficult to see how the semantics-centric PDP connectionist framework of reading and LD can account for the performance of these two patients, especially when EM's performance was inferior to PC's on all semantic tests. By contrast, the pattern of performance of the two patients is easily explained within the framework of the DRC model where semantic activation may be present in LD but is not crucial to perform this task accurately. Therefore, Blazely et al. (2005) concluded that an impairment of the orthographic input lexicon of PC could explain both his surface dyslexia and impaired LD. By contrast, EM had an intact orthographic input lexicon that allowed her to perform well on both visual word processing tasks despite her severe semantic impairment. Thus, the different abovementioned cases represent a challenge for the semantics-centered connectionist account and support the DRC account's view that the lexical deficits that can affect reading or LD in svPPA are not a consequence of semantic deficits.

In the present study we present a double dissociation between irregular-word reading and LD with pseudohomophones in two cases of svPPA. Connectionist models predict that, in svPPA, both LD and irregular-word reading will be impaired, or spared (in case of less premorbid reliance on semantics). However, the DRC model predicts such a double dissociation is possible because impairments of different components of the visual processing system can lead to the impairment of some tasks but not others.

## 2. Method

### 2.1. Participants

The study was approved by the research ethics committee of the Institut universitaire en santé mentale de Québec (Project #300-2012) and written informed consent was obtained from all participants before they took part in the study.

### 2.1.1. Case 1: M.F.

M.F. is a 72-year-old right-handed French-speaking woman with 12 years of formal education. She was diagnosed with svPPA according to currently accepted criteria (Gorno-Tempini et al., 2011) by a neurologist with expertise in neurodegenerative diseases and took part in the present study two years post-diagnosis. Magnetic resonance (MR) images taken for the present study (see Fig. 1a) showed bilateral –though more left-lateralized- inferolateral temporal lobe atrophy, including the anterior temporal lobes. M.F. underwent a comprehensive neuropsychological assessment. The results of her performance are presented in Table 1. M.F. performed within normal limits for working memory and visuoconstruction (but not visual recall) tasks. Her performance in language and semantic tasks was below normal. For instance, in the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983), M.F. produced mostly no responses (71% of her errors), semantic paraphasias (15 %; e.g. *celery* instead of *asparagus*), the general category of the target item (8 %; e.g. *bird* instead of *pelican*), and visual errors (6%; e.g. *roof* instead of *pyramid*). She also presented with associative visual agnosia as standardly measured by the object decision task of the Birmingham Object Recognition Battery (BORB; Riddoch & Humphreys, 1993) and verbal fluency deficits.

Table 1. Demographic data and neuropsychological assessment of M.F. and R.L.

| | M.F. | Cutoff scores | R.L. | Cutoff scores |
|---|---|---|---|---|
| Demographics | | | | |
| Gender | F | N/A | M | N/A |
| Age (in years) | 72 | N/A | 53 | N/A |
| Education (in years) | 12 | N/A | 18 | N/A |
| Neuropsychological assessment | | | | |
| Working memory | | | | |
| Digit span - forward | 6 | N/A | 8 | N/A |
| Digit span - backward | 6 | N/A | 5 | N/A |

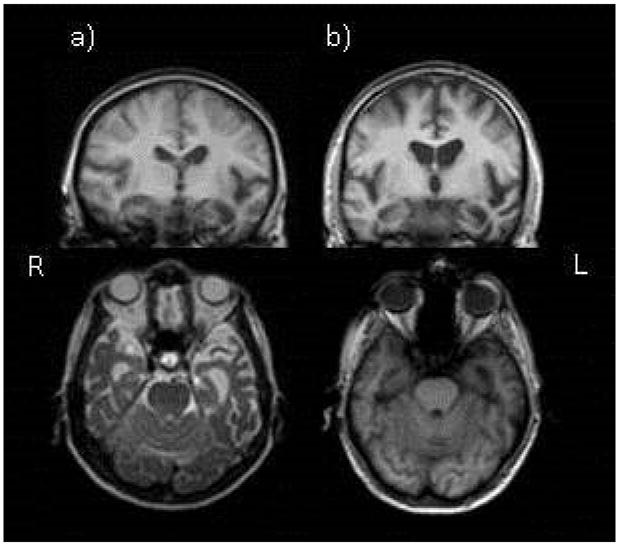
| | | | | |
|---|---|---|---|---|
| Visual perception and recognition | | | | |
| Length match task (BORB) | 25 | 24.50 | 26 | 24.50 |
| Object Decision - Hard (BORB) | 20* | 23.70 | 21* | 23.70 |
| Visuoconstruction and recall | | | | |
| Complex figure test (copy) | 32 | 30.9 | 35 | 32.4 |
| Complex figure test (immediate recall - 3 min) | 5.5* | 15.1 | 21.5 | 20 |
| Language and semantic memory | | | | |
| BNT | 12* | 32.5 | 28* | 37.5 |
| PPTT | 40* | 45 | 41.5* | 46 |
| Free Fluency (MEC) | 40* | 45.5† | 35* | 54† |
| Orthographic Fluency - P (MEC) | 9* | 19.5† | 19 | 17.5† |
| Semantic Fluency - clothing (MEC) | 16* | 19† | 21* | 24† |

* Indicates a score below the norms. † When not provided by norms, cutoff scores were calculated at 1.5 SD below the mean performance of controls. Gender: F=female, M=male; Digit span forward and backward calculated from Digit Span subtest of the Wechsler Adult Intelligence Scale—Fourth Edition (Wechsler, 2008); BORB: Birmingham Object Recognition Battery (Riddoch & Humphreys, 1993); Complex figure test (Osterrieth, 1944) and its norms (Tremblay et al., 2015); BNT: Boston Naming Test (Kaplan et al., 1983) and its norms (Roberts & Doucet, 2011); PPTT: Pyramids and Palm Trees Test – pictures version (Howard & Patterson, 1992) and its norms (Callahan et al., 2010); MEC: Protocole Montreal d'Evaluation de la Communication (Joanette, Ska, & Côté, 2004).

### 2.1.2. Case 2: R.L.

R.L. is a 53-year-old right-handed French-speaking man with 18 years of formal education. He was diagnosed with svPPA according to currently accepted criteria by a neuropsychiatrist with expertise in neurodegenerative diseases (S.P.) and participated in this study a month after his diagnosis. The MR images acquired at the time of assessment indicate bilateral temporal (including the anterior temporal) lobe atrophy, more right-lateralized (see Fig. 1b). The results of the neuropsychological assessment of R.L. are presented in Table 1. He performed within normal limits for working memory and visuoconstruction and visual recall tasks. His performance in language and semantic tasks was below normal. In the Boston Naming Test, R.L. produced mostly visual errors (31% of his errors; e.g. *lion* instead of *sphynx*), semantic paraphasias (25%; e.g. *duck* instead of *pelican*), produced the general category of a target (19%; e.g. *fruit* instead of *acorn*), no responses (13%), and circumlocutions (13%; e.g. *to measure the rhythm of the heart* for *stethoscope*). R.L. also presented with verbal fluency difficulties (except for orthographic fluency) and associative visual agnosia.

Fig. 1 a) and b). Coronal (top) and transverse (bottom) T1 weighted MR images for patients M.F. (a) and R.L. (b).



## 2.2. Reading aloud task

### 2.2.1. Materials.

The reading aloud task developed by Wilson et al., (2012) was used in this study. It consists of 60 irregular words (i.e. words with atypical grapheme-phoneme French correspondences, like *archange* in which the *ch* is exceptionally pronounced /k/ instead of the regular pronunciation /ʃ/), 60 regular words, and 60 pseudowords (i.e. letter strings with typical grapheme-phoneme correspondences that are not real French words; e.g. *javeur*). All words in this task are of low-frequency (mean frequency per million of occurrences = 5; range = 0–36). Both sets of irregular and regular words are matched for word frequency and imageability (both *p*-values were non-significant). The pseudowords were created by means of the WordGen programme (Duyck, Desmet, Verbeke, & Brysbaert, 2004). The irregular words, regular words, and pseudowords were matched by initial phoneme, length in letters and phonemes, and orthographic neighbourhood size (N-size) (all p-values at least >.08). The Lexique database (New, Pallier, Brysbaert, & Ferrand, 2004) was used to retrieve the values of these psycholinguistic variables. The stimuli used in each condition as well as their psycholinguistic characteristics are listed in the Appendix.

### 2.2.2. Procedure

The DMDX software (Forster & Forster, 2003) was used to present the stimuli and record the response onset by means of a headset with a microphone. Naming latencies were measured from word onset until the vocal response. Each participant was seated in front of a computer monitor. Participants were instructed to read the stimuli aloud as quickly and as accurately as possible. Each trial began with a blank screen presented for 400 ms. A fixation point then appeared at the center of the screen and remained for 400 ms. A pseudoword or word was then presented in lower case 15 pt Arial font for a maximum of 1500 ms. Each experimental session began with a practice set of ten pseudowords or ten words. The 60 pseudowords were divided in two blocks of 30 stimuli each. The irregular and regular words were mixed together in four blocks of 30 words each. The order of block presentation and that of the stimuli within the blocks was randomised.

Recorded responses were scored by one of the authors (M.B.) using the CheckVocal program (Protopapas, 2007). Incorrect responses to irregular words were classified as ‘regularization errors’ or ‘other errors’. Regularization errors are irregular words that are pronounced following the rules of orthography-to-phonology mappings for French (e.g., *archange* pronounced /æʁʃɑ̃ʒ/ with a /ʃ/ like in a regular word rather than with a /k/).

## 2.3. Lexical decision task

### 2.3.1. Materials

The task is made up of four sets of stimuli. Three of those sets were the same as the ones used in the reading task described above (Wilson et al., 2012). The fourth set was composed of 60 pseudohomophones (i.e. a legal letter string which has the same phonology as a real French word). Half the pseudohomophones were derived from regular words (e.g. *ydole* was derived from the French regular word *idole*), whereas the remaining 30 pseudohomophones were derived from irregular words (e.g. *vaksin* derived from the irregular French word *vaccin*).

The four stimuli sets were matched in length (in number of letters and phonemes), bigram frequency, and orthographic neighbourhood. Regular words, irregular words and the real words from which the pseudohomophones were derived were also matched on lexical frequency, imageability, number of homophones, number of homographs and phonological neighbourhood. Values for psycholinguistic variables were taken from Lexique (New et al., 2004). All stimuli and their psycholinguistic characteristics can be found in the Appendix.

### 2.3.2. Procedure

The task was run on a PC using the DMDX software (Forster & Forster, 2003). Participants were asked to decide as quickly and as accurately as possible whether a given stimulus was a real French word or not by pressing the button corresponding to their response on the keyboard. Stimuli were divided in 4 blocks of 60 stimuli each (30 words, 15 pseudohomophones and 15 pseudowords). The order of the presentation of blocks and that of the stimuli within the blocks was randomized across participants. A given trial ran as follows: a fixation point appeared at the center of the screen for 400 ms, then the stimulus was displayed in lower-case 15 pt Arial font for a maximal duration of 1500 ms or until the participant’s response. Each experimental session started with a practice set of 20 stimuli (10 words and 10 non-words).

## 2.4. Data analysis

M.F. and R.L. were each matched with five healthy controls on sex, age (means = 72.4 y.o. for M.F.'s controls and 55.6 y.o. for R.L.'s controls), and education (means = 13.6 years for M.F.'s controls and 17.8 years for R.L.'s controls) (all *p*s > .05). The performance of each of the two patients was compared to that of their control groups by means of Crawford's modified t-test (Crawford, Garthwaite, & Porter, 2010). The *p*-values reported are one-tailed.

## 3. Results

Table 2 presents the overall number of errors for M.F. and R.L. and their respective control groups in the reading and LD tasks as well as in each of their respective conditions.

Table 2. Number of errors for M.F. and R.L. and the mean number of errors and standard deviations of their respective healthy control groups.

| | | Matched healthy controls | | | Matched healthy controls | |
|---|---|---|---|---|---|---|
| | M.F. | Mean | SD | R.L. | Mean | SD |
| | | | Reading | | | |
| Irregular words | 20* | 11.2 | 3.70 | 5 | 7.4 | 3.05 |
| Regularizations | 15* | 7.2 | 2.52 | 5 | 6.6 | 2.88 |
| Regular words | 3 | 2.4 | 3.78 | 1 | 0.2 | 0.45 |
| Pseudowords | 11 | 10 | 8.63 | 10 | 9.6 | 3.91 |
| Overall | 34 | 23.6 | 15.34 | 16 | 17.2 | 6.30 |
| | | | Lexical decision | | | |
| Irregular words | 8 | 5.4 | 1.67 | 8 | 4.6 | 2.88 |
| Regular words | 4 | 2.8 | 0.84 | 8 | 5.2 | 2.39 |
| Pseudowords | 11 | 8.4 | 8.47 | 8 | 3.6 | 1.95 |
| Pseudohomophones | 14 | 15 | 11.20 | 22* | 8.4 | 4.16 |
| Overall | 37 | 31.6 | 20.50 | 46* | 21.8 | 6.80 |

*$p < .05$

### 3.1. Reading aloud task

When compared to her control group, M.F.'s overall performance in the reading aloud task was not significantly different from her normal controls, $t = 1.08$, $p = 0.17$. The analyses by condition showed that there were no significant differences between M.F. and her control group for the reading aloud of either regular words, $t = 0.15$, $p = 0.45$, or pseudowords, $t = 0.27$, $p = 0.40$. However, M.F.'s performance was significantly worse than her controls in reading aloud the irregular words, $t = 2.17$, $p < .05$. M.F. also made significantly more regularization errors for irregular words than did her controls, $t = 2.82$, $p < .05$. This is compatible with a profile of surface dyslexia.

For R.L. results revealed no significant differences, overall, between his performance and that of his controls in the reading aloud task, $t = -0.41$, $p = 0.35$. This was the case for all conditions, including irregular-word reading aloud (regular words: $t = 1.62$, $p = 0.09$; irregular words: $t = -0.72$, $p = 0.26$; pseudowords: $t = -0.093$, $p = 0.47$. This means that R.L. had no reading aloud difficulties.

### 3.2. Lexical decision task

M.F.'s overall performance in the task was comparable to that of her control group, $t = 0.24$, $p = 0.41$. No significant differences were found in the by condition analyses, including the pseudohomophone condition (regular words: $t = 1.30$, $p = 0.13$; irregular words: $t = 1.42$, $p = 0.11$; pseudowords: $t = 0.28$, $p = 0.40$; pseudohomophones: $t = -0.082$, $p = 0.47$).

Overall, R.L. made significantly more errors than his control group, $t = 3.25$, $p < 0.05$. The analyses by condition indicated that R.L.'s performance was significantly worse than his controls only in the pseudohomophone condition, $t = 2.98$, $p < 0.05$. No differences were found between lexical decisions of R.L. and his controls on regular words, $t = 1.07$, $p = 0.17$, irregular words, $t = 1.08$, $p = 0.17$, $p = 0.41$, or pseudowords, $t = 2.06$, $p = 0.06$.

As discussed in the introduction, the DRC model states that letter units inhibit the orthographic entry of the real word from which pseudohomophones are derived (which is activated through feedback from phonology), thus resolving the conflict between orthography and phonology and allowing an accurate decision to be made for pseudohomophones. According to Coltheart et al. (2001) this letter inhibition will be greater for pseudohomophones that differ in several letters from the real word than for those that differ in only one letter. We hypothesized that R.L.'s impaired LD was due to impairment, even partial, of the inhibitory connection from letter units to the orthographic input lexicon. To test this hypothesis, we divided the pseudohomophones used in our study in two conditions: one where the stimuli differed from the real word in one letter (e.g. the pseudohomophone *ydole* derived from the real French word *idole*) and one where they differed in two, or more, letters (e.g. the pseudohomophone *cayac* derived from the real French word *kayak*). Then, we ran post-hoc analyses to compare the two conditions. If R.L.'s impaired LD was due to a dysfunction of the inhibition from the letter units, then we should find a marked difficulty in the one-letter-difference condition in comparison with the several-letter-difference condition for this patient. Conversely, the difference between the two conditions should be less marked for M.F. and her performance should be comparable to that of her control group in both conditions.

Results of this analysis indicated, as expected, that both cases and their controls had greater difficulty making decisions on pseudohomophones that differed in only one letter from the real words versus those that differed in several letters. M.F. made 38% errors in the one-letter-difference condition and 33% errors in the several-letter-difference condition (a 5% difference), though this difference was non-significant, $t$ (4) = 1.70, $p = .08$. Critically, there were no significant differences between M.F.'s percentage of errors and her controls' in either condition (one-letter-condition: $t = -.35$, $p = 0.37$; several-letter-condition: $t = 0.24$, $p = 0.41$). On the other hand, R.L. made 44% errors in the one-letter-difference conditions compared to 32% errors in the several-letter-difference condition (a 12% difference) and this difference was not significant, $t$ (4) = .21, $p = .42$. Unlike M.F., R.L. made significantly more errors in comparison to his controls in both conditions (one-letter-condition: $t = 2.61$, $p < 0.05$; several-letter-condition: $t = 2.31$, $p < 0.05$).

## 4. Discussion

In the present study we presented two cases of svPPA: M.F. who was impaired at reading irregular words but performed within the normal range on LD with pseudohomophones, and R.L. who showed the opposite pattern, namely normal reading of irregular words but impaired LD with pseudohomohones.

M.F.'s results showed a reading impairment specific to irregular words, as her performance in regular- and pseudo- word reading remained within the normal range. Her irregular-word reading was also marked by an abnormally high number of regularization errors. M.F.'s reading profile is characteristic of surface dyslexia in svPPA (Graham, Simons, Pratt, Patterson, & Hodges, 2000; Price et al., 2003; Wilson et al., 2012; Woollams et al., 2007). By contrast, R.L.'s performance on all stimulus types of the reading task was unimpaired.

The opposite pattern of results was found in the LD task. M.F. performed within the normal range in this task, including in the pseudohomophone condition which, according to connectionist models, relies the most on semantics and should be impaired in svPPA cases. Conversely, R.L.'s performance was impaired on LD. Analyses by condition revealed that this impairment was specific to the pseudohomophone condition.

Thus, we have a svPPA case with surface dyslexia but intact LD with pseudohomophones and another svPPA case with no surface dyslexia and an impaired LD for pseudohomophones. How do models of visual word processing account for such a pattern of results?

In the PDP model of reading aloud (Plaut et al., 1996; Woollams et al., 2007), correct irregular-word reading relies on the semantic pathway. According to Plaut's (1997) connectionist account, accurate performance in LD also necessitates reliance on the semantic pathway, especially in the presence of inconsistent words and pseudohomophones in the stimulus list.

Previous studies have presented cases of single dissociations between semantic impairment in svPPA and irregular-word reading or LD with pseudohomophones (e.g., Blazely et al., 2005; Cipolotti & Warrington, 1995; Lambon Ralph et al., 1995; Schwartz et al., 1980; Wilson & Martínez-Cuitiño, 2012). Several hypotheses have been proposed by connectionists to account for these cases. For example, one explanation posits that the presence of visual word processing (reading and LD) impairments in svPPA will depend on the premorbid level of reliance on semantics for visual word processing, which varies among individuals. In other words, svPPA patients who relied less on the semantic pathway premorbidly and whose phonological pathway has mastered the inconsistent words would not present with surface dyslexia (Dilkina et al., 2010; Patterson & Hodges, 1992). Such a hypothesis does not hold for LD in the presence of pseudohomophones, since the only other way to distinguish between real words and pseudohomophones within the PDP framework is by relying on orthographic *typicality* (i.e. bigram and trigram frequency) instead of semantics (Rogers et al. 2004). However, this explanation does not apply to the present study where pseudohomophones and real words were matched on bigram frequency. Thus, M.F. could not have relied on orthographic typicality to perform the LD task. Within the connectionist account of LD, this leaves only semantic activation, impaired in svPPA patients, as the basis for distinguishing between real words and pseudohomophones.

Additionally, since the pronunciation of irregular words in reading and their recognition in LD both necessitate semantic activation in PDP models, M.F.'s ability to make accurate *yes* decisions on irregular words in the LD task but her inability to correctly pronounce those same stimuli in the reading task is particularly problematic for the connectionist view. To sum up, the major role given to semantics in visual word processing within the connectionist theoretical framework is incompatible with the double dissociation between irregular-word reading and LD with pseudohomophones found in this study.

By contrast, the presented double dissociation can be accounted for within the DRC model and supports the separation between lexical and semantic processing found in this model. There are three possible routes for lexical processing that can explain a wide variety of visual word processing impairment profiles. Regular words can be read via all three routes, irregular words can only be read through the lexical routes (semantic or non-semantic) and pseudowords can only be read through the sublexical route. Irregular (as well as regular) words are usually read via the lexical semantic route, but in cases of svPPA that are characterized by a semantic impairment, the lexical route (i.e. from orthography to phonology), which does not require semantic activation, can be used to correctly read irregular words. However, if one component of this route is impaired as well, then this would give rise to impaired reading of irregular words, but not of regular words which can be read via the sublexical route in case of damage to the lexical route (Coltheart, Saunders, & Tree, 2010b).

M.F.'s impairment on irregular-word reading could not be explained by impairment of the orthographic input lexicon, since her LD was intact. Without access to the orthographic store, a subject would not be able to look for a match for real words in the orthographic lexicon and would therefore fail to accurately make *yes* decisions for those stimuli. Rather, the most plausible explanation would be impairment in the excitatory link between orthography and phonology within the model. The orthographic and phonological lexicons are linked by excitatory connections that go in both directions. Thus, it seems that in addition to her semantic impairment, M.F. also suffered from an impairment of the excitatory link from the orthographic input to the phonological output lexicon. However, the excitatory link in the opposite direction, namely from the phonological output lexicon to the orthographic input lexicon was most likely preserved. This would explain why M.F.'s reading of irregular words was impaired but her performance on LD with pseudohomophones was preserved.

The fact that R.L. performed within the normal range in reading irregular words suggests that his orthographic and phonological lexicons were intact. Thus, an impairment of one of these two components of the lexical route is to be ruled out in explaining his abnormally high rate of errors in the pseudohomophone condition of the LD task. As described in the introduction, letter units and the orthographic input lexicon are connected via inhibitory links. When presented to the participant, the pseudohomophone is read through the grapheme-phoneme conversion system and activates the corresponding phonological representation in the phonological output lexicon which in turn feeds forward activation to a representation in the orthographic input lexicon (e.g. *roze* will activate the phonological and orthographic representations of *rose*). This is where the inhibitory link from letter units to the orthographic lexicon comes into play by inhibiting the activated orthographic representation of the real word from which the pseudohomophone is derived to allow a *no* decision to be made. However, if this inhibitory link was impaired, this would explain why R.L. was not able to accurately distinguish between real words and pseudohomophones. Thus, intact lexical and sublexical routes with impairment to the inhibitory link from letter units to the orthographic input lexicon would explain R.L.'s pattern of performance in reading and LD.

We sought to test this hypothesis by looking into the possible effect of the number of letters on which the pseudohomophone differed from its real word equivalent. According to Coltheart et al. (2001), the amount of inhibition sent from letter units to the orthographic input lexicon is sensitive to this difference. Pseudohomophones that differ in only one letter from a real word are more difficult to identify as non-words than pseudohomophones that differ on several letters from a real word. Consequently, the amount of inhibition applied by the letter units to the activated orthographic entry will be greater for those stimuli that differ on several letters than for those that differ in only one. Thus, we divided the pseudohomophones used in the LD task in the two abovementioned categories (i.e. one-letter-difference and several-letter-difference). R.L.'s errors were noticeably fewer in the several-letter-difference condition than in the one-letter-condition, while the difference between the two conditions was less marked for M.F. and control participants. This is in line with our proposed locus of impairment in the visual word recognition system for R.L.

In conclusion, in its present state, the interdependency of visual word processing and semantics in connectionist models cannot account for the double dissociation presented in this study. Our findings are rather in line with the hypothesis that the co-occurrence of lexical and semantic impairments in svPPA may reflect damage to different parts of the reading system caused by the spread of the atrophy from ATLs to other brain regions subserving visual word processing (Coltheart et al., 2010a). Other case studies should be conducted to further investigate the different patterns of performance of svPPA patients in reading and LD. It would be interesting for future research to include a pseudohomophone condition in the reading task, thus making it possible to study svPPA's performance for this stimulus type in both reading and LD as symmetrical tasks.

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# References

Binder, J. R., McKiernan, K. A., Parsons, M. E., Westbury, C. F., Possing, E. T., Kaufman, J. N., & Buchanan, L. (2003). Neural correlates of lexical access during visual word recognition. *Journal of Cognitive Neuroscience*, *15*(3), 372–393. http://doi.org/10.1162/089892903321593108

Blazely, A. M., Coltheart, M., & Casey, B. J. (2005). Semantic impairment with and without surface dyslexia: Implications for models of reading. *Cognitive Neuropsychology*, *22*(6), 695–717. http://doi.org/10.1080/02643290442000257

Brambati, S. M., Ogar, J., Neuhaus, J., Miller, B. L., & Gorno-Tempini, M. L. (2009). Reading disorders in primary progressive aphasia: A behavioral and neuroimaging study. *Neuropsychologia*, *47*(8-9), 1893–1900. http://doi.org/10.1016/j.neuropsychologia.2009.02.033

Callahan, B. L., Macoir, J., Hudon, C., Bier, N., Chouinard, N., Cossette-Harvey, M., … Potvin, O. (2010). Normative data for the pyramids and palm trees test in the Quebec-French population. *Archives of Clinical Neuropsychology*, *25*(3), 212–217. http://doi.org/10.1093/arclin/acq013

Cipolotti, L., & Warrington, E. K. (1995). Semantic memory and reading abilities: a case report. *Journal of the International Neuropsychological Society*, *1*(1), 104–110.

Coltheart, M. (2004). Are there lexicons? *Quarterly Journal of Experimental Psychology A: Human Experimental Psychology*, *57*(7), 1153–1171. http://doi.org/10.1080/02724980443000007

Coltheart, M., Davelaar, E., Jonasson, J. T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and Performance VI* (pp. 535–555). Mahwah, NJ: Lawrence Erlbaum Associates.

Coltheart, M., & Rastle, K. (1994). Serial processing in reading aloud: Evidence for dual-route models of reading. *Journal of Experimental Psychology: Human Perception and Performance*, *20*(6), 1197–1211. http://doi.org/10.1037/0096-1523.20.6.1197

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review*, *108*(1), 204–256. http://doi.org/10.1037/0033-295X.108.1.204

Coltheart, M., Tree, J. J., & Saunders, S. J. (2010a). Computational modeling of reading in semantic dementia: Comment on Woollams, Lambon Ralph, Plaut, and Patterson (2007). *Psychological Review*, *117*(1), 256–271. http://doi.org/10.1037/a0015948

Coltheart, M., Saunders, S. J., & Tree, J. J. (2010b). Computational modelling of the effects of semantic dementia on visual word recognition. *Cognitive Neuropsychology*, *27*(2), 101–114. http://doi.org/10.1080/02643294.2010.502887

Crawford, J. R., Garthwaite, P. H., & Porter, S. (2010). Point and interval estimates of effect sizes for the case-controls design in neuropsychology : Rationale, methods, implementations, and proposed reporting standards. *Cognitive Neuropsychology*, *27*(3), 245–260. http://doi.org/10.1080/02643294.2010.513967

Dilkina, K., McClelland, J. L., & Plaut, D. C. (2008). A single-system account of semantic and lexical deficits in five semantic dementia patients. *Cognitive Neuropsychology*, *25*(2), 136–164. http://doi.org/10.1080/02643290701723948

Dilkina, K., McClelland, J. L., & Plaut, D. C. (2010). Are there mental lexicons? The role of semantics in lexical decision. *Brain Research*, *1365*, 66–81. http://doi.org/10.1016/j.brainres.2010.09.057

Duyck, W., Desmet, T., Verbeke, L. P. C., & Brysbaert, M. (2004). WordGen: A tool for word selection and nonword generation in Dutch, English, German, and French. *Behavior Research Methods, Instruments, & Computers*, *36*(3), 488–499. http://doi.org/10.3758/BF03195595

Evans, G. A. L., Lambon Ralph, M. A., & Woollams, A. M. (2012). What's in a word? A parametric study of semantic influences on visual word recognition. *Psychonomic Bulletin & Review*, *19*(2), 325–31. http://doi.org/10.3758/s13423-011-0213-7

Forster, K. I., & Forster, J. C. (2003). DMDX: a windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, & Computers*, *35*(1), 116–24.

Funnell, E. (1996). Response biases in oral reading: An account of the co-occurrence of surface dyslexia and semantic dementia. *The Quarterly Journal of Experimental Psychology*, *49A*(2), 417–446. http://doi.org/10.1080/713755626

Gorno-Tempini, M. L., Dronkers, N. F., Rankin, K. P., Ogar, J. M., La Phengrasamy, B. A., Rosen, H. J., … Miller, B. L. (2004). Cognition and anatomy in three variants of primary progressive aphasia. *Annals of Neurology*, *55*(3), 335–346. http://doi.org/10.1002/ana.10825

Gorno-Tempini, M. L., Hillis, A. E., Weintraub, S., Kertesz, A., Mendez, M., Cappa, S. F., … Grossman, M. (2011). Classification of primary progressive aphasia and its variants. *Neurology*, *76*(11), 1006–14. http://doi.org/10.1212/WNL.0b013e31821103e6

Graham, K. S., Simons, J. S., Pratt, K. H., Patterson, K., & Hodges, J. R. (2000). Insights from semantic dementia on the relationship between episodic and semantic memory. *Neuropsychologia*, *38*, 313–324. http://doi.org/S0028-3932(07)00239-4 [pii]\r10.1016/j.neuropsychologia.2007.06.021

Harm, M. W., & Seidenberg, M. S. (2004). Computing the meanings of words in reading : Cooperative division of labor between visual and phonological processes. *Psychological*

*Review*, *111*(3), 662–720. http://doi.org/10.1037/0033-295X.111.3.662

Howard, D., & Patterson, K. (1992). *Pyramids and palm trees: A test of semantic access from pictures and words*. Bury St. Edmunds, England: Thames Valley Test Company.

Jacobs, A. M., & Grainger, J. (1992). Testing a semistochastic variant of the interactive activation model in different word recognition experiments. *Journal of Experimental Psychology: Human Perception and Performance*, *18*(4), 1174–1188.

Joanette, Y., Ska, B., & Côté, H. (2004). *Protocole Montreal d'Evaluation de la Communication MEC*. Isbergues, France: Ortho Editions.

Kaplan, E., Goodglass, H., & Weintraub, S. (1983). *Boston Naming Test*. Philadelphia: Lea & Febiger.

Lambon Ralph, M. A. (2014). Neurocognitive insights on conceptual knowledge and its breakdown. *Philosophical Transactions of the Royal Society of London. B*, *369*, 1–11. http://doi.org/10.1098/rstb.2012.0392

Lambon Ralph, M. A., Ellis, A. W., & Franklin, S. (1995). Semantic loss without surface dyslexia. *Neurocase*, *1*(4), 363–369. http://doi.org/10.1080/13554799508402380

Lambon Ralph, M. A., & Howard, D. (2000). Gogi aphasia or semantic dementia? Simulating and assessing poor verbal comprehension in a case of progressive fluent aphasia. *Cognitive Neuropsychology*, *17*(5), 437–465. http://doi.org/10.1080/026432900410784

Marshall, J. C., & Newcombe, F. (1973). Patterns of paralexia: a psycholinguistic approach. *Journal of Psycholinguistic Research*, *2*(3), 175–199.

New, B., Pallier, C., Brysbaert, M., & Ferrand, L. (2004). Lexique 2: A new French lexical database. *Behavior Research Methods, Instruments, & Computers*, *36*(3), 516–24.

Noppeney, U., Patterson, K., Tyler, L. K., Moss, H., Stamatakis, E. a, Bright, P., … Price, C. J.

(2007). Temporal lobe lesions and semantic impairment: a comparison of herpes simplex virus encephalitis and semantic dementia. *Brain*, *130*(Pt 4), 1138–47. http://doi.org/10.1093/brain/awl344

Osterrieth, P. A. (1944). Le test de copie d'une figure complexe; contribution à l'étude de la perception et de la mémoire. [Test of copying a complex figure; contribution to the study of perception and memory.]. *Archives de Psychologie*, *30*, 206–356.

Patterson, K., & Hodges, J. R. (1992). Deterioration of word meaning: implications for reading. *Neuropsychologia*, *30*(12), 1025–1040.

Patterson, K., Lambon Ralph, M. A., Jefferies, E., Woollams, A., Jones, R., Hodges, J. R., & Rogers, T. T. (2006). "Presemantic" cognition in semantic dementia: six deficits in search of an explanation. *Journal of Cognitive Neuroscience*, *18*(2), 169–183. http://doi.org/10.1162/jocn.2006.18.2.169

Pexman, P. M., Hargreaves, I. S., Edwards, J. D., Henry, L. C., & Goodyear, B. G. (2007). The neural consequences of semantic richness: When more comes to mind, less activation is observed. *Psychological Science*, *18*(5), 401–406. http://doi.org/10.1111/j.1467-9280.2007.01913.x

Plaut, D. C. (1997). Structure and function in the lexical system: Insights from distributed models of word reading and lexical decision. *Language and Cognitive Processes*, *12*(5-6), 765–806. http://doi.org/10.1080/016909697386682

Plaut, D. C., & Booth, J. R. (2000). Individual and developmental differences in semantic priming: Empirical and computational support for a single-mechanism account of lexical processing. *Psychological Review*, *107*(4), 786–823. http://doi.org/10.1037//0033-295X.107.4.786

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review*, *103*(1), 56–115.

Price, C. J., Gorno-Tempini, M. L., Graham, K. S., Biggio, N., Mechelli, A., Patterson, K., & Noppeney, U. (2003). Normal and pathological reading: Converging data from lesion and imaging studies. *NeuroImage*, *20*, 30–41. http://doi.org/10.1016/j.neuroimage.2003.09.012

Protopapas, A. (2007). CheckVocal: A program to facilitate checking the accuracy and response time of vocal responses from DMDX. *Behavior Research Methods*, *39*(4), 859–62.

Rastle, K., & Coltheart, M. (2006). Is there serial processing in the reading system; and are there local representations? In S. Andrews (Ed.), *From Inmarks to Ideas: Current issues in lexical processing* (pp. 3–24). New York, NY: Psychology Press.

Riddoch, M. J., & Humphreys, G. W. (1993). *BORB: Birmingham Object Recognition Battery*. Hove: Erlbaum.

Roberts, P. M., & Doucet, N. (2011). Résultats du Boston Naming Test chez des adultes francophones de Québec. *Canadian Journal of Speech-Language Pathology and Audiology*, *35*(3), 254–267.

Rogers, T. T., Lambon Ralph, M. A., & Hodges, J. R. (2004). Natural selection : the impact of semantic impairment on lexical and object decision. *Cognitive Neuropsychology*, *21*(2/3/4), 331–352. http://doi.org/10.1080/02643290342000366

Samson, D., & Pillon, A. (2004). Orthographic neighborhood and concreteness effects in the lexical decision task. *Brain and Language*, *91*, 252–264. http://doi.org/10.1016/j.bandl.2004.03.001

Schwartz, M. F., Saffran, E. M., & Marin, O. S. M. (1980). Fractionating the reading process in dementia: Evidence for word-specific print-to-sound associations. In M. Coltheart, K. Patterson, & C. Marshall (Eds.), *Deep Dyslexia* (pp. 259–269). London: Routledge.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, *96*(4), 523–568.

Tremblay, M.-P., Potvin, O., Callahan, B. L., Belleville, S., Gagnon, J.-F., Caza, N., … Macoir, J. (2015). Normative data for the Rey-Osterrieth and the Taylor complex figure tests in Quebec-French people. *Archives of Clinical Neuropsychology*, *30*(1), 78–87. http://doi.org/10.1093/arclin/acu069

Ward, J., Stott, R., & Parkin, A. J. (2000). The role of semantics in reading and spelling: evidence for the "summation hypothesis." *Neuropsychologia*, *38*(12), 1643–1653. http://doi.org/10.1016/S0028-3932(00)00064-6

Wechsler, D. (2008). *Wechsler Adult Intelligence Scale—Fourth Edition*. San Antonio, TX: Pearson Assessment.

Wilson, M. A., Joubert, S., Ferré, P., Belleville, S., Ansaldo, A. I., Joanette, Y., … Brambati, S. M. (2012). The role of the left anterior temporal lobe in exception word reading: Reconciling patient and neuroimaging findings. *NeuroImage*, *60*(4), 2000–7. http://doi.org/10.1016/j.neuroimage.2012.02.009

Wilson, M. A., & Martínez-Cuitiño, M. (2012). Semantic dementia without surface dyslexia in Spanish: unimpaired reading with impaired semantics. *Behavioural Neurology*, *25*(3), 273–84. http://doi.org/10.3233/BEN-2012-119009

Wilson, S. M., Brambati, S. M., Henry, R. G., Handwerker, D. A., Agosta, F., Miller, B. L., … Gorno-Tempini, M. L. (2009). The neural basis of surface dyslexia in semantic dementia. *Brain*, *132*(Pt 1), 71–86. http://doi.org/10.1093/brain/awn300

Woollams, A. M., Ralph, M. A., Plaut, D. C., & Patterson, K. (2007). SD-squared: On the association between semantic dementia and surface dyslexia. *Psychological Review*, *114*(2), 316–339. http://doi.org/2007-05396-004 [pii]\n10.1037/0033-295X.114.2.316 [doi]

Woollams, A. M., Silani, G., Okada, K., Patterson, K., & Price, C. J. (2011). Word or word-like? Dissociating orthographic typicality from lexicality in the left occipito-temporal cortex. *Journal of Cognitive Neuroscience*, *23*(4), 992–1002. http://doi.org/10.1162/jocn.2010.21502

Yap, M. J., Lim, G. Y., & Pexman, P. M. (2015). Semantic richness effects in lexical decision : The role of feedback. *Memory & Cognition*, *43*(July), 1148–1167. http://doi.org/10.3758/s13421-015-0536-0

APPENDIX. Items used in the reading task (irregular words, regular words, and pseudowords) and the lexical decision task (all four stimulus sets)

*Irregular words*

| French | English | letters | phonemes | bigram frequency | N-size | N-phon | Freq | IMAG | Homographs | Homophones |
|---|---|---|---|---|---|---|---|---|---|---|
| abbaye | abbey | 6 | 4 | 3514 | 0 | 2 | 3.31 | 5.7 | 1 | 2 |
| agenda | diary | 6 | 5 | 13623 | 1 | 1 | 5.41 | 5.75 | 1 | 2 |
| aiguille | needle | 8 | 5 | 16984 | 3 | 0 | 18.38 | 6.53 | 2 | 4 |
| almanach | almanac | 8 | 7 | 22396 | 0 | 0 | 1.22 | 4.35 | 1 | 2 |
| aquarelle | watercolours | 9 | 7 | 24742 | 0 | 0 | 6.55 | 4.43 | 1 | 2 |
| aquarium | aquarium | 8 | 8 | 14494 | 0 | 0 | 5.2 | 6.57 | 1 | 2 |
| archange | archangel | 8 | 5 | 20956 | 0 | 0 | 3.58 | 4.05 | 1 | 2 |
| aryen | Aryan | 5 | 4 | 11233 | 1 | 3 | 0.07 | 2.72 | 2 | 8 |
| asthme | asthma | 6 | 3 | 10863 | 1 | 6 | 3.11 | 3.4 | 1 | 2 |
| atlas | atlas | 5 | 5 | 9893 | 1 | 2 | 2.16 | 5.65 | 1 | 1 |
| aulne | alder | 5 | 3 | 6485 | 0 | 3 | 0.27 | 2.95 | 1 | 2 |
| aulx | garlic | 4 | 1 | 3230 | 1 | 18 | 0.27 | 1.95 | 1 | 16 |
| baptême | baptism | 7 | 5 | 8116 | 0 | 2 | 9.39 | 4.8 | 1 | 2 |
| bey | bey | 3 | 2 | 651 | 8 | 29 | 2.91 | 1.37 | 1 | 8 |
| bourg | village | 5 | 3 | 10263 | 0 | 27 | 13.85 | 3.7 | 1 | 8 |
| chaos | chaos | 5 | 3 | 6438 | 3 | 24 | 10.2 | 3 | 1 | 5 |
| chlore | chlorine | 6 | 4 | 15204 | 2 | 8 | 0.81 | 3.45 | 1 | 2 |
| choléra | cholera | 7 | 6 | 15454 | 1 | 3 | 2.36 | 2.75 | 1 | 3 |
| chorale | choir | 7 | 5 | 21599 | 2 | 5 | 1.76 | 5.98 | 2 | 9 |
| clef | key | 4 | 3 | 6012 | 1 | 12 | 35.61 | 6.57 | 1 | 4 |
| clerc | clerk | 5 | 4 | 16407 | 0 | 10 | 5.68 | 3.4 | 1 | 10 |
| clown | clown | 5 | 4 | 3244 | 1 | 7 | 6.49 | 6.87 | 1 | 2 |
| compteur | meter | 8 | 5 | 20731 | 1 | 7 | 4.19 | 5.35 | 1 | 4 |
| crawl | crawl | 5 | 4 | 6594 | 0 | 7 | 0.74 | 5.2 | 1 | 1 |
| croc | canine | 4 | 3 | 6084 | 8 | 17 | 1.15 | 4.12 | 1 | 2 |
| daim | deer | 4 | 2 | 4579 | 2 | 25 | 5.14 | 5.45 | 1 | 2 |
| dolmen | dolmen | 6 | 6 | 15156 | 1 | 0 | 1.15 | 4.21 | 1 | 2 |
| dom | don | 3 | 2 | 2830 | 11 | 26 | 0.34 | 1.63 | 1 | 5 |
| esche | bait | 5 | 2 | 7616 | 0 | 17 | 0.14 | 1.32 | 1 | 1 |
| escompte | discount | 8 | 5 | 15925 | 1 | 1 | 0.61 | 2.2 | 2 | 4 |
| escroc | crook | 6 | 5 | 8964 | 0 | 0 | 2.91 | 4.45 | 1 | 2 |
| faon | fawn | 4 | 2 | 8241 | 3 | 27 | 0.54 | 5.3 | 1 | 4 |
| fjord | fjord | 5 | 5 | 4137 | 1 | 0 | 0.27 | 4.95 | 1 | 3 |
| galop | gallop | 5 | 4 | 8526 | 2 | 16 | 12.77 | 4.8 | 1 | 6 |
| gentil | kind | 6 | 4 | 28643 | 0 | 6 | 1.15 | 2.9 | 2 | 4 |
| gnome | gnome | 5 | 4 | 8887 | 2 | 1 | 1.01 | 5.45 | 1 | 2 |
| gnou | gnu | 4 | 3 | 5889 | 1 | 0 | 0 | 5.11 | 1 | 2 |
| guano | guano | 5 | 5 | 11286 | 0 | 1 | 0.14 | 2.84 | 1 | 1 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| isthme | isthmus | 6 | 3 | 15075 | 1 | 1 | 0.54 | 2.26 | 1 | 2 |
| jaguar | jaguar | 6 | 6 | 7847 | 0 | 0 | 0.41 | 6.5 | 1 | 2 |
| lichen | lichen | 6 | 5 | 17538 | 1 | 2 | 1.28 | 5.15 | 1 | 2 |
| mazout | fuel oil | 6 | 5 | 8020 | 0 | 3 | 2.64 | 4.15 | 1 | 1 |
| million | million | 7 | 5 | 22695 | 1 | 6 | 7.84 | 4.95 | 1 | 2 |
| net | tennis let | 3 | 3 | 4882 | 14 | 24 | 1.69 | 2.75 | 3 | 7 |
| nombril | navel | 7 | 6 | 13248 | 0 | 0 | 5.2 | 6.55 | 1 | 2 |
| oeuf | egg | 4 | 2 | 3519 | 4 | 8 | 20.34 | 6.86 | 1 | 1 |
| oignon | onion | 6 | 3 | 11803 | 3 | 1 | 5.34 | 6.65 | 1 | 3 |
| oint | anointed | 4 | 2 | 16681 | 4 | 18 | 0.14 | 1.89 | 2 | 7 |
| once | ounce | 4 | 2 | 11091 | 2 | 13 | 1.76 | 2.9 | 1 | 2 |
| orchidée | orchid | 8 | 6 | 12519 | 0 | 0 | 1.42 | 6.2 | 1 | 2 |
| outil | tool | 5 | 3 | 14817 | 0 | 4 | 10.14 | 6.14 | 1 | 2 |
| paon | peacock | 4 | 2 | 9469 | 5 | 28 | 3.85 | 6.45 | 1 | 7 |
| paye | pay | 4 | 3 | 2343 | 12 | 17 | 7.5 | 4.05 | 2 | 2 |
| persil | parsley | 6 | 5 | 17315 | 0 | 11 | 2.36 | 6.25 | 1 | 1 |
| poêle | frying pan | 5 | 4 | 6891 | 2 | 6 | 17.84 | 6.73 | 2 | 6 |
| sculpture | sculpture | 9 | 7 | 16353 | 0 | 2 | 3.78 | 6.31 | 1 | 2 |
| second | second | 6 | 4 | 17320 | 0 | 2 | 30 | 2.65 | 2 | 4 |
| taon | horsefly | 4 | 2 | 10827 | 4 | 27 | 0.14 | 4.75 | 1 | 8 |
| thym | thyme | 4 | 2 | 1709 | 0 | 25 | 2.09 | 5.55 | 1 | 14 |
| yacht | yacht | 5 | 3 | 5568 | 0 | 14 | 3.78 | 5.95 | 1 | 2 |
| | *Mean* | 5.57 | 4 | 11223.65 | 1.87 | 8.75 | 5.02 | 4.55 | 1.18 | 3.73 |
| | *SD* | 1.51 | 1.56 | 6373.38 | 3.01 | 9.5 | 7.03 | 1.62 | 0.43 | 3.13 |

APPENDIX.
(Continued)

*Regular words*

| French | English | letters | phonemes | bigram frequency | N-size | N-phon | Freq | IMAG | Homographs | Homophones |
|---|---|---|---|---|---|---|---|---|---|---|
| aisance | wealth | 7 | 4 | 22948 | 0 | 1 | 15.2 | 1.75 | 1 | 2 |
| alchimie | alchemy | 8 | 6 | 15761 | 0 | 0 | 1.82 | 2.6 | 1 | 2 |
| alerte | alarm | 6 | 5 | 25443 | 2 | 0 | 10.47 | 3.63 | 5 | 9 |
| alun | alum | 4 | 3 | 5110 | 0 | 16 | 0.74 | 3.25 | 1 | 1 |
| amande | almond | 6 | 4 | 15734 | 2 | 2 | 3.99 | 6.28 | 1 | 7 |
| ampoule | light bulb | 7 | 4 | 15191 | 1 | 3 | 11.49 | 6.65 | 1 | 2 |
| arôme | flavour | 5 | 4 | 8802 | 0 | 8 | 2.43 | 2.2 | 1 | 2 |
| asile | asylum | 5 | 4 | 12233 | 1 | 5 | 11.55 | 4.67 | 1 | 2 |
| aval | approval | 4 | 4 | 5491 | 1 | 6 | 3.99 | 3.35 | 1 | 4 |
| avanie | snub | 6 | 5 | 16446 | 2 | 3 | 0.27 | 1.37 | 1 | 2 |
| balade | stroll | 6 | 5 | 11437 | 7 | 4 | 4.59 | 3.9 | 2 | 7 |
| bitume | asphalt | 6 | 5 | 11054 | 2 | 1 | 5.88 | 4.05 | 1 | 2 |
| buna | buna | 4 | 4 | 3249 | 2 | 5 | 0 | 1 | 1 | 1 |
| cagoule | hood | 7 | 5 | 16173 | 2 | 1 | 1.28 | 6.4 | 1 | 2 |
| cancre | cancer | 6 | 4 | 20525 | 2 | 5 | 2.5 | 3.58 | 1 | 2 |
| cargo | cargo | 5 | 5 | 7962 | 1 | 5 | 3.99 | 5.65 | 1 | 2 |
| cloque | blister | 6 | 4 | 11026 | 6 | 10 | 1.89 | 4.6 | 2 | 5 |
| clos | close | 4 | 3 | 4606 | 3 | 15 | 3.18 | 4.95 | 3 | 4 |
| cobra | cobra | 5 | 5 | 10723 | 2 | 4 | 0.74 | 6.45 | 1 | 2 |
| cocon | cocoon | 5 | 4 | 16308 | 5 | 15 | 2.91 | 5.35 | 1 | 2 |
| courge | squash | 6 | 4 | 14907 | 6 | 11 | 0.61 | 6.4 | 1 | 2 |
| courroie | strap | 8 | 5 | 21787 | 0 | 2 | 3.11 | 4.95 | 1 | 2 |
| cric | jack | 4 | 4 | 8011 | 12 | 14 | 1.08 | 4 | 1 | 6 |
| dard | sting | 4 | 3 | 5809 | 6 | 31 | 1.55 | 5.69 | 1 | 2 |
| datte | date | 5 | 3 | 12203 | 10 | 27 | 0.14 | 6.21 | 1 | 7 |
| décès | passing | 5 | 4 | 4435 | 0 | 12 | 4.66 | 3.55 | 1 | 1 |
| égalité | equiality | 7 | 7 | 14953 | 1 | 1 | 8.11 | 2.5 | 1 | 2 |
| érable | maple | 6 | 5 | 15463 | 3 | 3 | 1.15 | 5.85 | 1 | 2 |
| esquif | skiff | 6 | 5 | 8691 | 0 | 4 | 1.42 | 2.42 | 1 | 2 |
| filtre | filter | 6 | 5 | 14416 | 2 | 4 | 2.16 | 5.46 | 2 | 7 |
| frite | chip | 5 | 4 | 14243 | 9 | 11 | 0.54 | 6.45 | 2 | 5 |
| garage | garage | 6 | 5 | 14499 | 3 | 6 | 22.23 | 6 | 1 | 2 |
| gardien | watchman | 7 | 6 | 19171 | 3 | 4 | 18.45 | 5.35 | 2 | 4 |
| genou | knee | 5 | 4 | 14299 | 0 | 2 | 23.92 | 6.5 | 1 | 2 |
| gourde | flask | 6 | 4 | 12007 | 7 | 10 | 4.59 | 6.3 | 2 | 5 |
| gourmet | gourmet | 7 | 5 | 16413 | 0 | 3 | 0.81 | 3.1 | 1 | 2 |
| idéal | ideal | 5 | 5 | 7886 | 1 | 1 | 11.28 | 2.37 | 2 | 6 |
| junior | junior | 6 | 6 | 9293 | 0 | 0 | 0.14 | 2.95 | 2 | 4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| lascar | little rascal | 6 | 6 | 12821 | 0 | 0 | 1.89 | 2.63 | 1 | 2 |
| moka | mocha | 4 | 4 | 1759 | 1 | 12 | 1.55 | 6 | 1 | 4 |
| mythe | myth | 5 | 3 | 2602 | 1 | 27 | 5.61 | 1.75 | 1 | 6 |
| navet | turnip | 5 | 4 | 6109 | 1 | 9 | 0.88 | 5.75 | 1 | 2 |
| noirceur | darkness | 8 | 7 | 14937 | 0 | 1 | 2.97 | 3.75 | 1 | 2 |
| obstacle | obstacle | 8 | 7 | 14696 | 0 | 0 | 14.12 | 3.5 | 1 | 2 |
| oeillet | carnation | 7 | 3 | 13287 | 0 | 9 | 2.09 | 5.79 | 1 | 2 |
| omelette | omelette | 8 | 5 | 21820 | 1 | 1 | 5.14 | 6.76 | 1 | 2 |
| ongle | fingernail | 5 | 3 | 13885 | 2 | 6 | 10.14 | 6.68 | 1 | 2 |
| orgue | organ | 5 | 3 | 8085 | 3 | 8 | 5.41 | 6.43 | 1 | 2 |
| oscar | oscar | 5 | 5 | 8882 | 0 | 1 | 0.14 | 6 | 1 | 2 |
| ourlet | rim | 6 | 4 | 15169 | 1 | 3 | 2.36 | 3.85 | 1 | 4 |
| patate | potato | 6 | 5 | 19914 | 2 | 3 | 3.38 | 6.45 | 1 | 2 |
| poumon | lung | 6 | 4 | 15461 | 1 | 5 | 3.58 | 6.25 | 1 | 2 |
| prisme | prism | 6 | 5 | 18328 | 2 | 5 | 0.88 | 5.9 | 1 | 2 |
| pulpe | pulp | 5 | 4 | 3911 | 2 | 4 | 2.16 | 5.45 | 1 | 2 |
| sodium | sodium | 6 | 6 | 5155 | 1 | 1 | 0 | 2.55 | 1 | 1 |
| stage | internship | 5 | 4 | 10671 | 5 | 9 | 4.8 | 3.43 | 1 | 2 |
| tapir | tapir | 5 | 5 | 8544 | 6 | 5 | 0.34 | 4.42 | 2 | 3 |
| toxine | toxin | 6 | 6 | 11549 | 0 | 1 | 0 | 2.95 | 1 | 2 |
| whisky | whisky | 6 | 5 | 7370 | 0 | 0 | 25.14 | 5.85 | 1 | 4 |
| yoga | yoga | 4 | 4 | 2475 | 1 | 3 | 1.08 | 4.56 | 1 | 1 |
| | *Mean* | 5.72 | 4.55 | 12035.63 | 2.23 | 6.13 | 4.81 | 4.57 | 1.25 | 2.97 |
| | *SD* | 1.11 | 1.02 | 5550.74 | 2.7 | 6.68 | 6.01 | 1.63 | 0.65 | 1.85 |

APPENDIX A.
(Continued)

*Pseudohomophones*

| Stimuli | French | English | letters | phonemes | bigram frequency | N-size | N-phon | Freq | IMAG | Homographs | Homophones |
|---|---|---|---|---|---|---|---|---|---|---|---|
| afonie | aphonie | aphonia | 6 | 5 | 15079 | 2 | 4 | 0.14 | 2.15 | 1 | 1 |
| amydale | amygdale | tonsil | 7 | 6 | 11493 | 0 | 2 | 0.07 | 4.4 | 1 | 2 |
| bari | baril | barrel | 4 | 4 | 10062 | 8 | 7 | 2.03 | 6.4 | 1 | 2 |
| batiste | baptiste | Baptist | 7 | 6 | 27165 | 1 | 7 | 0 | 3.45 | 2 | 5 |
| carance | carence | shortcoming | 7 | 5 | 23806 | 2 | 6 | 1.49 | 3.75 | 1 | 2 |
| carité | karité | shea | 6 | 6 | 16926 | 3 | 8 | 0.14 | 1.95 | 1 | 1 |
| cayac | kayak | kayak | 5 | 5 | 4982 | 2 | 5 | 0.14 | 6.7 | 1 | 2 |
| célrie | céleri | celery | 6 | 5 | 10141 | 0 | 5 | 0.81 | 6.6 | 1 | 4 |
| cère | cerf | hart | 4 | 3 | 6900 | 7 | 35 | 20.27 | 6.5 | 1 | 13 |
| chiphon | chiffon | duster | 7 | 4 | 15372 | 0 | 9 | 10.41 | 6.05 | 1 | 2 |
| couti | coutil | drill | 5 | 4 | 15463 | 1 | 15 | 1.28 | 1.65 | 1 | 1 |
| crono | chrono | stopwatch | 5 | 5 | 13697 | 1 | 3 | 1.82 | 5.65 | 1 | 2 |
| crucifi | crucifix | crucifix | 7 | 7 | 6849 | 0 | 0 | 7.43 | 6.5 | 1 | 3 |
| dotte | dot | dowry | 5 | 3 | 9385 | 9 | 24 | 4.32 | 3.5 | 1 | 3 |
| édision | édition | edition | 7 | 6 | 21768 | 2 | 6 | 10.61 | 4.25 | 1 | 2 |
| estoma | estomac | stomach | 6 | 6 | 11806 | 0 | 2 | 30.14 | 5.8 | 1 | 2 |
| étan | étang | pond | 4 | 3 | 13012 | 5 | 11 | 10.47 | 6.9 | 1 | 6 |
| évié | évier | sink | 4 | 4 | 2054 | 1 | 5 | 11.35 | 6.55 | 1 | 2 |
| feseur | faiseur | maker | 5 | 5 | 13596 | 1 | 0 | 1.42 | 2.1 | 1 | 2 |
| fétus | foetus | fœtus | 5 | 5 | 4394 | 0 | 1 | 2.57 | 6.45 | 1 | 1 |
| filo | philo | philosophy | 4 | 4 | 6803 | 6 | 14 | 3.18 | 2.9 | 1 | 2 |
| fourni | fournil | bakery | 6 | 5 | 12187 | 2 | 5 | 3.92 | 2.4 | 1 | 11 |
| fygue | figue | fig | 5 | 3 | 4697 | 2 | 20 | 1.28 | 5.3 | 1 | 2 |
| ginsan | ginseng | ginseng | 6 | 4 | 18828 | 0 | 0 | 0.2 | 3.75 | 1 | 1 |
| guestapo | gestapo | Gestapo | 8 | 7 | 16309 | 0 | 0 | 1.69 | 4.5 | 1 | 1 |
| irrespet | irrespect | disrespect | 8 | 6 | 15361 | 0 | 0 | 0.68 | 3.75 | 1 | 1 |
| join | joint | seal | 4 | 3 | 7093 | 6 | 13 | 4.53 | 5.15 | 3 | 7 |
| kachette | cachette | hideout | 8 | 5 | 15062 | 4 | 14 | 14.59 | 4.45 | 2 | 4 |
| koquin | coquin | reprobate | 6 | 4 | 11239 | 1 | 8 | 2.43 | 5.25 | 2 | 4 |
| kouture | couture | seam | 7 | 5 | 17255 | 3 | 6 | 8.45 | 5.4 | 1 | 2 |
| kruche | cruche | jug | 6 | 4 | 6246 | 2 | 6 | 3.92 | 6.6 | 2 | 4 |
| lando | landau | pram | 5 | 4 | 14132 | 1 | 5 | 3.65 | 5.85 | 1 | 2 |
| mageur | majeur | adult | 6 | 5 | 14513 | 4 | 9 | 2.57 | 5.05 | 2 | 8 |
| mancheau | manchot | penguin | 8 | 4 | 19430 | 0 | 5 | 1.49 | 5.65 | 2 | 4 |
| ménir | menhir | menhir | 5 | 5 | 6643 | 3 | 4 | 0.2 | 4.9 | 1 | 2 |
| minerait | minerai | ore | 8 | 5 | 31623 | 0 | 8 | 0.95 | 6.3 | 2 | 3 |
| montaje | montage | assembly | 7 | 5 | 22452 | 1 | 4 | 2.77 | 4.75 | 1 | 2 |
| murrais | muret | low wall | 7 | 4 | 19647 | 0 | 21 | 2.64 | 5.85 | 1 | 4 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| noeu | noeud | knot | 4 | 2 | 4637 | 1 | 24 | 14.46 | 6.75 | 1 | 3 |
| oval | ovale | oval | 5 | 4 | 4985 | 3 | 4 | 3.24 | 6.35 | 2 | 4 |
| pèl | pelle | shovel | 3 | 3 | 71 | 1 | 26 | 11.35 | 6.55 | 1 | 5 |
| pikot | picot | wedge | 5 | 4 | 3221 | 3 | 14 | 1.22 | 4.85 | 1 | 3 |
| pimant | piment | chili | 6 | 4 | 23438 | 7 | 12 | 2.77 | 6.9 | 1 | 2 |
| pinso | pinceau | paintbrush | 5 | 4 | 9697 | 0 | 8 | 10.27 | 6.5 | 1 | 2 |
| portié | portier | doorman | 6 | 6 | 12749 | 0 | 6 | 6.89 | 5.7 | 1 | 3 |
| potery | poterie | pottery | 6 | 5 | 19299 | 0 | 4 | 1.89 | 6.65 | 1 | 2 |
| quatin | catin | doll | 6 | 4 | 21356 | 0 | 15 | 1.28 | 5.45 | 1 | 2 |
| rèdeur | raideur | rigidity | 6 | 5 | 9623 | 1 | 6 | 7.03 | 5.2 | 1 | 1 |
| rekin | requin | shark | 5 | 4 | 12227 | 0 | 12 | 1.62 | 6.85 | 1 | 2 |
| rinite | rhinite | rhinitis | 6 | 5 | 21758 | 0 | 0 | 0.07 | 2.15 | 1 | 2 |
| rotasion | rotation | rotation | 8 | 7 | 23465 | 1 | 5 | 3.38 | 3.8 | 1 | 2 |
| siro | sirop | syrup | 4 | 4 | 8203 | 4 | 21 | 7.64 | 6.3 | 1 | 3 |
| sirque | cirque | circus | 6 | 4 | 12245 | 1 | 12 | 18.38 | 6.8 | 1 | 2 |
| skout | scout | scout | 5 | 4 | 5204 | 2 | 5 | 0.95 | 5.55 | 2 | 6 |
| sonje | songe | dream | 5 | 3 | 9148 | 2 | 7 | 10.68 | 3.8 | 2 | 5 |
| suspet | suspect | suspect | 6 | 5 | 6465 | 0 | 2 | 1.55 | 3.95 | 2 | 4 |
| vagon | wagon | wagon | 5 | 4 | 11359 | 3 | 9 | 18.11 | 6.3 | 1 | 2 |
| vaksin | vaccin | vaccine | 6 | 5 | 8962 | 0 | 0 | 4.12 | 6.2 | 1 | 2 |
| varek | varech | varec | 5 | 5 | 11289 | 0 | 1 | 2.43 | 2.9 | 1 | 2 |
| ydole | idole | idol | 5 | 4 | 8362 | 1 | 4 | 6.35 | 5.05 | 1 | 2 |
| | | *Mean* | 5.73 | 4.57 | 12687.22 | 1.83 | 8.23 | 5.2 | 5.09 | 1.22 | 3.05 |
| | | *SD* | 1.22 | 1.06 | 6673.44 | 2.22 | 7.37 | 6.01 | 1.5 | 0.45 | 2.27 |

APPENDIX. (Continued)

*Pseudowords*

| Stimuli | letters | phonemes | bigram frequency | N-size |
|---|---|---|---|---|
| accive | 6 | 5 | 6152 | 2 |
| aflier | 6 | 5 | 18816 | 2 |
| aigaibur | 8 | 6 | 12503 | 0 |
| alvoloca | 8 | 8 | 13131 | 0 |
| andoilum | 8 | 7 | 16582 | 0 |
| apuvauna | 8 | 7 | 7564 | 0 |
| ardel | 5 | 5 | 8358 | 2 |
| arisou | 6 | 5 | 20103 | 2 |
| asire | 5 | 4 | 12819 | 4 |
| atandier | 8 | 6 | 33844 | 2 |
| audre | 5 | 3 | 9004 | 2 |
| auve | 4 | 2 | 3188 | 4 |
| bable | 5 | 4 | 9643 | 7 |
| bum | 3 | 3 | 1152 | 5 |
| burhuru | 7 | 6 | 10537 | 0 |
| cailli | 6 | 4 | 14639 | 2 |
| cais | 4 | 4 | 11088 | 5 |
| cartine | 7 | 6 | 23149 | 6 |
| cocle | 5 | 4 | 10792 | 5 |
| conlé | 5 | 4 | 12723 | 5 |
| conni | 5 | 4 | 15542 | 4 |
| corlier | 7 | 7 | 24734 | 4 |
| coye | 4 | 3 | 4293 | 4 |
| criajora | 8 | 9 | 15969 | 0 |
| culen | 5 | 4 | 14722 | 2 |
| dourbi | 6 | 5 | 10833 | 2 |
| dri | 3 | 3 | 5556 | 5 |
| drin | 4 | 3 | 11262 | 5 |
| efies | 5 | 3 | 7321 | 0 |
| escage | 6 | 5 | 9770 | 2 |
| esumuaru | 8 | 8 | 9603 | 0 |
| fuche | 5 | 3 | 5846 | 6 |
| fupe | 4 | 3 | 2388 | 5 |
| gadet | 5 | 4 | 5530 | 4 |
| gelilu | 6 | 6 | 11724 | 0 |
| glone | 5 | 4 | 13628 | 6 |
| gouf | 4 | 3 | 4886 | 6 |
| gusil | 5 | 4 | 7769 | 1 |
| heux | 4 | 1 | 5101 | 4 |

| | | | | |
|---|---|---|---|---|
| ievat | 3 | 4 | 9862 | 0 |
| issart | 6 | 4 | 16504 | 2 |
| javeur | 6 | 5 | 10032 | 6 |
| larrot | 6 | 4 | 13598 | 3 |
| mearlat | 7 | 5 | 17389 | 0 |
| miline | 6 | 5 | 17666 | 2 |
| nercure | 7 | 6 | 25809 | 2 |
| norou | 5 | 4 | 11683 | 0 |
| oica | 4 | 4 | 5700 | 2 |
| onanisue | 8 | 7 | 31547 | 2 |
| onca | 4 | 3 | 12082 | 2 |
| ouret | 5 | 3 | 16356 | 3 |
| ovudui | 6 | 6 | 2672 | 0 |
| pife | 4 | 3 | 3233 | 6 |
| pleu | 4 | 3 | 9158 | 4 |
| porti | 5 | 5 | 12312 | 5 |
| poubin | 6 | 4 | 13037 | 2 |
| semondant | 9 | 6 | 36327 | 2 |
| strien | 6 | 5 | 22296 | 2 |
| tont | 4 | 2 | 19472 | 7 |
| tuit | 4 | 3 | 5686 | 5 |
| *Mean* | 5.55 | 4.52 | 12578.08 | 2.87 |
| *SD* | 1.48 | 1.6 | 7501.99 | 2.13 |

Note. French = original stimuli in French (and the French words from which pseudohomophones were derived); English = English translation of the original French stimuli; letters = length in letters; phonemes = length in phonemes; bigram frequency = summed type bigram frequency (taken from the WordGen programme; Duyck, Desmet, Verbeke, & Brysbaert, 2004); N-size = neighbourhood size; N-phon = phonological neighbourhood; Freq = written frequency (in 1 million occurrences); IMAG = imageability; Homographs = number of homographs; Homophones = number of homophones. Values for all psycholinguistic variables (except for bigram frequency) were taken from Lexique (New et al., 2004).