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Morphological Therapy Protocol

by

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To Caroline, Dominic, and Phillip

ABSTRACT

Investigations of morphological impairment in aphasia have revealed that patients may retain knowledge of a word's morphological status even when they cannot access that word (Delazer & Semenza, 1998). In addition, aphasiological investigations have shown that more errors are produced with multimorphemic words than with monomorphemic words (e.g., Nasti & Marangolo, 2005). This points to the fact that even though individuals with aphasia seem to have retained sensitivity to morphological status and morphological structure of words, they are unable to process morphologically complex words with ease. The goal of this thesis was to investigate whether a therapy that focuses on morphology, the Morphological Therapy Protocol (MTP), will improve the processing of multimorphemic words in these patients.

The MTP provides morphological training with four tasks administered sequentially in intense one-hour treatments over a period of only twelve days. Therapy effectiveness was measured by analyzing pre-therapy and post-therapy reading-aloud accuracy scores. The analyses of four patients' accuracy scores show significant reading-aloud improvement with therapy across trained and untrained words (trained words: $p < 0.0001$, control words: $p < 0.04$, new words: $p < 0.0001$). In addition, the therapy effect was maintained over a three-month post-therapy maintenance period.

The results of the MTP administration confirm that the notion of morphological constituents is important and that these constituents are involved in the processing of morphologically complex words.

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Chapter 1

Introduction

1.1. Morphological processing in the mental lexicon

The mental lexicon is generally perceived to be the cognitive system responsible for lexical activity that includes comprehending and producing linguistic information (e.g., Jarema & Libben, 2007). Speaking, reading, writing, as well as understanding words and sentences are lexical activities. Healthy individuals do not have any difficulties processing linguistic information. Accessing words and combining morphemes to form complex words which constitute part of our morphological ability is an automatic effortless process. However, in individuals with neurological disorders (e.g., aphasia, an acquired language impairment after stroke) the ability to produce and comprehend linguistic information may break down. Especially words that are made up with more than one morpheme (e.g., multimorphemic words such as *books*, *bookish*, *bookplate*) are challenging for these individuals (e.g., Jarema, 2008; Jarema & Kehayia, 1992; Jarema & Libben, 2006; Nasti & Marangolo, 2005). Morphological paraphasias (erroneous word productions), for instance, producing *booked* for *books*, and morpheme omission errors, for example, producing *comfort* instead of *discomfort,* are observed in all types of aphasia, but are prevalent in non-fluent aphasia. In addition, morphological deficits are observed in every type of complex words (i.e., compound words, derived words, and inflected words).

The predominant questions addressed by experimental work on morphology focus on understanding how morphological information is acquired, stored in long-term memory, and how this information is used during the process of language comprehension and production. Central to these questions is whether morphological decomposition takes place and whether morphological decomposition and composition are similar in all types of complex words. Frost, Grainger, and Rastle (2005) point out that the question of how morphological structure interacts with the lexical system is vital since it bears on the representational architecture of the mental lexicon. Previous research has shown that unimpaired and impaired speakers are sensitive to underlying linguistic structures (e.g., Andrews, Miller, & Rayner, 2004; Badecker & Caramazza, 1991; Delazer & Semenza, 1998; Hittmair-Delazer, Andree, Semenza, De Bleser, & Benke, 1994; Kehayia, Jarema, Tsapkini, Perlak, Ralli, & Kazielawa, 1999; Kuperman, Bertram, & Baayen, 2008; Kuperman, Schreuder, Bertram, & Baayen, 2009; Libben, 1994, 1998; Longtin, Sequi, & Hallé, 2003; Marslen-Wilson, Tyler, Waksler, & Older, 1994; Meunier & Longtin, 2007; Nasti & Marangolo, 2005; Nault, Bolger, & Libben, 2006; Rastle & Davis, 2008; Semenza, Luzzati, & Carabelli, 1997). In particular, speakers are aware of the architectural morphemic structure of multimorphemic words. For example, individuals with agrammatism know that words they are attempting to name are compound words, as the produced words, albeit incorrect, retain their compound structure (e.g., Hittmair-Delazer et al., 1994; Delazer & Semenza, 1998). Sensitivity to underlying structures is also discernible as individuals with aphasia omit a higher percentage of verbs in verb-noun compounds than nouns in noun-noun compounds (e.g., Semenza et al., 1997). This noun-verb dissociation in compounds is complemented by increased difficulty inflecting verbs and pseudo-verbs as compared to nouns and pseudo-nouns in a sentence completion task by individuals with aphasia (e.g., Shapiro & Caramazza, 2003). Inflectional morphology, both tense and agreement is particularly challenging for individuals with a morphological deficit. To account for this difficulty with inflectional morphology, various accounts including phonological and syntactic accounts have been proposed.

According to the dual-mechanism account (Pinker, 1999; Ullman, Corkin, Coppola, Hickok, Growdon, Koroshetz, & Pinker, 1997; Ullman, 2001), the basic distinction between regular and irregular verbs is the organization of the cognitive and underlying neural substrates: the past tenses of regular verbs (such as *stop – stopped*, *smile – smiled*, and *paint – painted*) are formed by a rule-governed procedural system that is also applied to novel verb forms whereas the past-tense forms of irregular verbs (such as *have – had*, *catch – caught*, and *cut – cut*) are stored in the lexicon. Both mechanisms are operated simultaneously, however, if a stored whole-word form of the verb is encountered in the lexicon (the case for irregular verbs), then the rule-governed procedure is inhibited and the correct irregular form is retrieved from the lexicon. As past-tense forms of regular and novel verbs are composed in the dual-mechanism account, no match is found in the lexicon and the past-tense rule has to be applied.

Recent research illustrated that the demonstrated advantage of irregular verbs over regular verbs by patients with Broca's aphasia was eliminated when the two sets of past-tense forms were matched for phonological complexity (Bird, Lambon Ralph, Seidenberg, McClelland, & Patterson, 2003; Braber, Patterson, Ellis, Matthew, & Lambon Ralph, 2005). Bird et al. (2003) included production tasks using regular and irregular verbs matched for CVC complexity (past-tense forms with the same phonological structures, such as *stepped – slept*), unmatched sets (such as *blink – blinked*), and irregular forms (such as *think –thought*). In the matched condition, the observed irregular verb advantage disappeared. Furthermore, in a same-different judgment task to spoken word pairs, contrasting regular verb stems with past-tense forms (e.g., *pray – prayed*, *press – pressed*) and non-verb words with matching phonological contrast (e.g., *tray – trade*, *chess – chest*), the accuracy for verb and non-verb word pairings was almost identical. This finding supports the view that greater impairment with regular past-tense forms reflects a phonological impairment sensitive to the complexity of spoken forms as the locus of the patient's language deficit, rather than a morphological deficit. However, note that in a similar task by Tyler, Randall, and Marslen-Wilson (2002) recording reaction time, no significant difference between the accuracy of verb-pair judgment versus non-verb pair judgment was observed, but significantly slower decision times were observed in the verb condition.

A syntactic account, the Tree Pruning Hypothesis (TPH, Friedmann & Grodzinsky, 1997), indicates that the degree of severity of agrammatic production can be deducted by the locus of impairment in a syntactic tree (a representational metaphor for the hierarchical organization of syntactic operations). The TPH stipulates that any node above an impaired node in the syntactic tree is defective, leading to impairment, while any node below an impaired node is spared. If, for example, the tree is pruned at the node for tense and agreement is ordered below, then tense would be impaired while agreement would be unimpaired. Even though the exact order of inflectional nodes has not been established, the TPH requires the nodes in a specific order to account for data. However, cross-linguistically, tense is more susceptible than agreement, irrespective to how tense and agreement are ordered in the syntactic tree. German-speaking agrammatics, for example, make more errors in tense agreement than subject-verb agreement, although, in German, agreement is claimed to be a higher node in the tree than tense (Wenzlaff & Clahsen, 2004). Accordingly, Wenzlaff and Clahsen (2005) proposed a Tense Underspecification Hypothesis (TUH), which posits that only semantically interpretable tense features are underspecified (leading to the tense impairment), while the uninterpretable agreement features are intact. The TUH has been further adapted to the Tense-Agreement Underspecification Hypothesis (TAUH) by Burchert, Swoboda-Moll, and De Bleser (2005) to accommodate a double dissociation between tense and agreement observed in nine German agrammatic patients on a sentence-completion task. Bastiaanse and van Zonneveld (2004) also propose a syntactic account for the inability to access inflectional morphology. They argue that, in Dutch, the verb inflection difficulty is due to the obligatory verb movement from canonical verb-final position in subordinate sentences to non-canonical verb-second position in matrix sentences. Bastiaanse and van Zonneveld indicate that this operation, located in Levelt's "grammatical encoder" where sentence patterns are being formulated (Levelt, 1989) is unavailable to agrammatic patients. As indicated above, all morphological types of complex words are affected by aphasia. If agrammatic aphasia reflects these kinds of syntactic deficits, inflectional morphology should be compromised, however, derivational morphology should not be compromised.

Importantly, empirical evidence points to the view that morpheme-level analysis underlies not only inflectional morphology and compounding, but also derivational morphology. Generally, derivational morphology is more stable than inflectional morphology (Jarema & Libben, 2006). However, a few neuropsychological studies have advanced evidence of a morphological deficit in derivational morphology (e.g., Kohn & Melvold, 2000; Marangolo, Incoccia, Pizzamiglio, Sabatini, Castriota-Scanderbeg, & Burani, 2003; Semenza, Girelli, Spacal, Kobal, & Mesec, 2002). With respect to derivational morphology in the healthy population, cross-model priming effects have been observed for semantically related (transparent) morphological pairs (e.g., *hunter* – *hunt*), but not for opaque morphological pairs (e.g., *gingerly* – *ginger*) (Marslen-Wilson et al., 1994). However, more recent studies (e.g., Longtin et al., 2003; Marslen-Wilson & Bozic, 2008; Meunier & Longtin, 2007; Rastle & Davis, 2008) indicate that masked-priming studies (using a visual prime word for a very brief period preceded by a pattern mask and followed by a visual target word for lexical decision) obtain robust priming effects not only for transparent morphological pairs, but also for morphological pairs such as *gingerly* – *ginger* and even for pairs without semantic relation such as *corner* – *corn*. This initial process of decomposition is supported for words that can be segmented into existing morphemes. Longtin et al. (2003), for example, found that the morphologically structured prime *baguette* ‘little stick’ primes *bague* ‘ring’, but *abricot* ‘apricot’ does not prime *abri* ‘shelter’ as -*cot* is not a suffix in French. Rastle and Davis (2008) found a similar result in English: *brother* primes *broth*, but *brothel* does not prime *broth*, as -*el* is not a suffix in English. Longtin and colleagues (2003) and Longtin and Meunier (2005) further report that non-word primes (such as **rapidifier*, ‘rapidify’) can prime their word pseudo-stem (*rapid*, ‘rapid’) as well as transparent real-word primes (*rapidement*, ‘rapidly’), but only if the pseudo-stem is affixed with an existing French suffix. Thus, non-morphological pseudowords such as **rapiduit* do not prime their pseudo-stem as –*uit* consonant to -*cot* in the real word prime *abricot* ‘apricot’ is not an existing suffix in French.

Recent literature, however, suggests that semantic similarity can influence morphological processing, even at early stages. Feldman, O’Connor, and Martín (2009) made use of a forward masked-priming variant of the lexical decision paradigm to investigate the importance of semantic transparency in the facilitation of pairs of words (e.g., semantically transparent word pairs: coolant – COOL and semantically opaque word pairs: rampant – RAMP). They report that semantically transparent word pairs morphologically prime significantly greater than opaque pairs. This in turn limits the scope of word-recognition models that argue for form followed by meaning. Yet, the finding that morphologically complex pseudo-stems can prime their stems implies that roots as well as affixes (inflectional and derivational) are represented in the mental lexicon. Processing models that allow access to the root of complex words only through whole-word representation cannot account for results that allow for morphologically structured non-word roots to prime their pseudo-stem. This includes models in which morphological information is represented only through links between whole-word representations of morphologically related words (cf. Bybee, 1985, 1995) and models in which morphemes are represented at a supralexical level and the individual constituent morphemes are accessed only after the complex word as a whole has been identified (e.g., Diependaele, Sandra, & Grainger, 2005; Giraudo & Grainger, 2001).

Sublexical models, in which complex words are initially decomposed into their constituents (e.g., *book* and *-let*) and then accessed as full-forms (e.g., *booklet*) via recombination of lemmas that are associated with morphemes are more likely to account for this data. The interactive activation model (a sublexical model) proposed by Taft (2003, based on Taft, 1994) seems to account for the parsing of the pseudo-affixed complex word primes. However, this model is not able to semantically incorporate pseudo- words such as **sportation* whose two constituents *sport* and *–ation* are conceptually incompatible into a meaningful legal concept and therefore it would reject the word and fail to activate the morphemes.

Dual route models put forward that full-form based processing is undertaken at the same time that decompositional processing takes place. The two routes are assumed to occur independently (e.g., Allen & Badecker, 2002; Baayen & Schreuder, 1999; Schreuder & Baayen, 1995); however, an interactive dual route model has also been proposed (Baayen & Schreuder, 2000). The spreading activation model by Schreuder and Baayen (1995), for example, can account for nonwords made up of a legal stem and a legal affix priming their pseudo-stem as the initial stage of the three-stage model, segmentation, would divide the nonword into its pseudo-stem and affix and thereby creating form-based access representations of free and bound affixes that are linked with one or more lexical representations. Only in the second stage of processing where a licensing mechanism checks the appropriateness of any given morpheme combination would the nonword fail to be licensed and thus fail to reach the third stage of the model, the morpheme combination stage. In the combination stage, if licensed, the semantic and syntactic information of the two morphemes are computed in order to realize the lexical representation of the complex word. Thus, even if there is no whole-word representation that can be accessed by this dual-route model (due to no lexical representation or inability to license a particular combination of morphemes as is the case with the nonword **sportation*), concept nodes are activated by the two access representations (*sport* and *–ation*) triggered by the initial segmentation stage.

Most of the authors of the preceding discussion had one thing in common: a certain conviction of presupposed morphological subunits, morphemes. There is abundant evidence that constituents matter, although, in some models, the morphemes come into play at earlier stages (e.g., Taft & Forster, 1975) than in others (e.g., Diependaele et al., 2005; Giraudo & Grainger, 2001), and in hybrid models decomposition and holistic representations are included (e.g., Allen & Badecker, 2002; Baayen & Schreuder, 1999; Schreuder & Baayen, 1995). In addition, whole-word knowledge matters. For instance, the number of times a certain morphological rule that represents a conventionalized way of expressing certain things in a specific language (e.g., the concept of ‘resembling something’ being expressed as STEM + *like*, such as *treelike*, *hornlike*, or *childlike*) influences word access.

However, not all contributions to the overall discussion of linguistic access, storage, and usage use morphemes and thus a morphemic level as a presupposed building block in the structural architecture of the mental lexicon. From a connectionist perspective, morphology represents simply the systematic relationship among orthography and phonology (the surface forms of words) and their meanings (e.g., Gonnerman, Seidenberg, & Andersen, 2007; Seidenberg, 2005; Seidenberg & Gonnerman, 2000; Seidenberg & McClelland, 1989; Plaut & Gonnerman, 2000). According to Plaut and Gonnerman (2000), connectionist models 'attempt to capture the essential properties of the neural mechanisms that give rise to behaviour by implementing cognitive processes in terms of cooperative and competitive interactions among large groups of simple, neuron-like units.' In essence, when a particular surface pattern that occurs in many words reliably maps to certain aspects of meaning (e.g., *like* in the words *treelike*, *hornlike*, and *childlike* has the meaning of 'resembling something'), the internal representation will begin to represent this structure as componential and represent and process it rather independently of the other components of the word. Surface patterns that behave less systematically, are, in turn, treated as less componential. The triangle model introduced as a theoretical framework by Seidenberg &McClelland (1989), shown in Figure 1, illustrates the three groups of processing units (in large ovals) that encode different types of information: orthography, phonology, and semantics. The smaller ovals represent the "hidden units" that provide the basis for abstraction (of repeated patterns) and increase the computational capacity of the network.

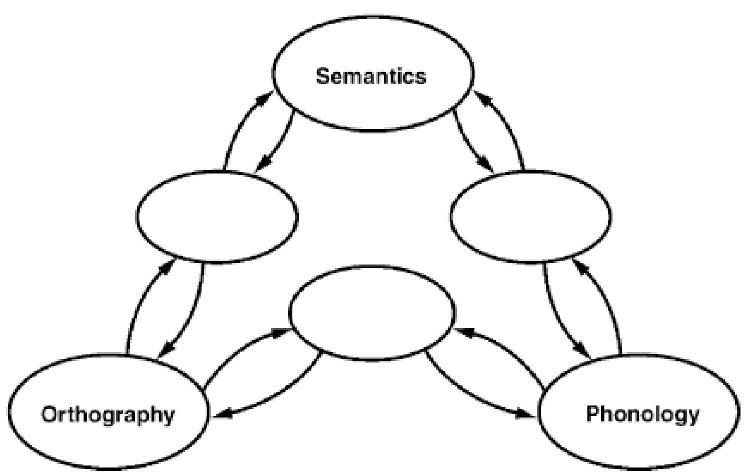

Figure 1. The initial triangle model (reproduced from Seidenberg & McClelland, 1989)

Within each of the processing units, similar words are represented by similar patterns of neural activity (e.g., *dog* and *cat* would be encoded by similar patterns within the semantic processing unit, but with dissimilar patterns within the phonological processing unit). Transformations between these patterns that are required for lexical tasks, such as generation of an appropriate semantic pattern for word comprehension of a specific written orthographic pattern (word) are carried out by interactions between the processing units and the "hidden units." Weights oversee these interactions between the units with excitatory or inhibitory connections. The network adapts as a function of presented input. Input to the network, for example via the orthographic unit, influences the specific values of the connection weights between units resulting in a network that improves performance by adjusting the weights based on exposure to written words, spoken words, and their meanings. Thus, the connectionist model differs from the full decompositional model in which decomposition is automatic and obligatory and from the hybrid models that allow both individual morpheme representations and whole-word representations. In addition, the connectionist model does not presuppose underlying linguistic knowledge (e.g., morphological rules that operate over symbolic representations), rather it allows representations and processes to develop through a learning process that takes the connections and their attached weights into consideration.

Frequency of occurrence of a given word has been used as a diagnostic tool for existence of memory traces as it affects speed and accuracy of response in timed recognition tasks such as lexical decision. Word frequency has been attested to allow for shorter visual and auditory processing latencies in comprehension (e.g., Baayen, Feldman, & Schreuder, 2006; New, Brysbaert, Segui, & Rastle, 2004) and for fewer errors in speech production (e.g., Stemberger & MacWhinney, 1986). Frequent complex words tend to be stored as wholes whereas infrequent words tend to be computed on-line. In addition, surface frequency effects of complex words are correlated with whole-word representations and stem frequency effects are correlated with decompositional representations. However in recent studies, the compound frequency effect on reading times of Dutch and Finnish polymorphemic compounds in eye-tracking studies preceded the inspection of the compound-final characters and the compound's right constituents (e.g., Kuperman et al., 2008; Kuperman et al., 2009). Strict bottom-up models do not predict such a finding. Furthermore, these two studies indicate that the complexity of morphological processing may also not be fully captured by single-route and most dual-route models proposed in the literature.

The study of acquired language deficit highlights properties of normal language processing. The morphological deficits demonstrated in aphasia offer a unique perspective into the role of morphology in lexical processing and representation. If morphology did not play a role in the access and representation of complex words, then an identical mental organization for all complex and simple words could be reasonably assumed. However, the abundance of phonological and semantic paraphasias in morphologically complex words in comparison to morphologically simple words points to the view that morphology is involved in the access and representation of complex words. If we presuppose that the demonstrated patterns of language deficits are derived by the normal language system, then through studying these deficits and their remediation, we can infer the functional organization of the normal system.

1.2. Purpose of the present dissertation

This thesis investigates the representation and processing of multimorphemic words. In particular, this study explores whether morphological training that overtly reveals the individual smaller parts in complex words will facilitate the access to the whole word and *vice versa*, and whether complex words can be broken into manageable parts and recombined with more proficiency. In addition, this thesis presents a new type of therapeutic intervention, the Morphological Therapy Protocol (MTP), which is designed to treat the underlying functional deficit of aphasia. Until now, aphasia therapies have treated the presenting symptoms in aphasia, phonological and semantic paraphasias, as well as short, often incomplete sentences by using tasks that address phonology, semantics, and syntax. The tasks in the MTP, however, address morphological deficits by administering a therapeutic programme that concentrates on the morphological system that seems to be impaired. Although the present study provides a treatment protocol for aphasia, the design of the treatment modules is planned similarly to that of psycholinguistic experiments. Therefore, the questions this study strives to answer are motivated by developments in psycholinguistic models of lexical processing and representation.

The goals of the present study are to

- Review the psycholinguistic and neurolinguistic perspectives, studies, and evidence most relevant to the design of morphological therapy.
- Design a therapy that has the following properties:
    - it improves the reading-aloud ability of individuals with aphasia
    - it gives a heuristic to individuals with aphasia
    - it is clear and easy to follow for individuals with aphasia
    - it addresses impairment in all morphologically complex word types
    - it examines the role that morphological and other properties of words affect in performance and therapy effectiveness
- Implement the protocol with a small group of participants in order to
    - understand the importance of morphological training in aphasia
    - examine how easy/difficult it is to administer a computer-assisted MTP
    - develop an improved version (if necessary)
- Evaluate the outcome of the MTP implementation
    - the extent to which participants improved
    - the extent to which they show individual differences in improvement
    - the extent to which the therapy effect is maintained after therapy
    - to study whether a morphological therapy might improve other aspects of language besides morphology

- Examine the role that morphological and other properties of words affect in performance and therapy effectiveness
    - the extent to which reading aloud of inflected, derived, and compound words improves in comparison to the reading aloud of monomorphemic words
    - to inspect whether training effects generalize to untrained words
    - the extend to which a training effect generalizes to words with which patients had not practiced, but which they had read throughout the training phase and to words that they had not encountered throughout the training phase
    - to examine whether frequency plays a role in the improvement of reading aloud complex words for individuals with aphasia
- Evaluate the overall success of the MTP based on evidence currently available
- Draw conclusions and implications for the nature of morphological knowledge and its impairment as a result of damage to the brain.

1.3. Dissertation overview

This study involves four native speakers of English with speech impairment after a stroke. Four tasks that engage mainly the decomposition and composition of complex words were employed in order to investigate whether morphological training that overtly reveals the individual smaller parts in complex words will facilitate the access to the whole word and *vice versa*, and whether complex words can be broken into manageable parts and recombined with more proficiency.

Chapter 2 provides a detailed account of morphological impairments in aphasia. The types of morphological impairments are introduced as well as impairments within each complex morphological domain. Furthermore, current aphasia therapies are introduced.

Chapter 3 introduces the participants and the design of the morphological treatment protocol with its goals, structure and implementation.

Chapter 4 reports on the effectiveness of the treatment protocol. The overall effect of the therapy and the effect on individuals are shown.

Chapter 5 presents a summary of the findings.

Chapter 2

Morphological impairment in aphasia

2.0. Introduction

Complex words with internal morphological structures are common in many languages. Consider, for example, the English word *book* and its related words *books, booked, bookish, booklet, cookbook,* and *bookplate*. Although the latter words have an internal morphological structure, they do not present any difficulty for unimpaired individuals. These words can be easily produced and understood individually or in sentences. Individuals with aphasia, however, have more difficulty naming, repeating, understanding, reading, and writing morphologically complex words (e.g., Jarema, 2008; Jarema & Kehayia, 1992; Jarema & Libben, 2006; Nasti & Marangolo, 2005). According to Paradis (2001), the underlying impairment in aphasia is manifested by the difficulty of performing implicit computations. Certainly, demonstrated difficulties with morphologically complex words as compared to simple words reveals a possible difficulty in computing linguistic structures or an inability to automatically and implicitly compute complex words.

Not all morphological domains pose the same level of difficulty to individuals with aphasia. Inflectional morphology, the type of morphology that encodes the tense of verbs (e.g., look → looked) or the number of nouns (e.g., car → cars), is most difficult for individuals with aphasia. Derivational morphology, the type of morphology that creates words with new semantic meanings and new grammatical categories (e.g., leaf → leafless), is also challenging for most individuals with aphasia. Compounding, the type of morphology in which new words are formed by combining at least two existing words (e.g., lock + nut → locknut), seems to be the one morphological domain of complex word formation that proves to be less difficult for these individuals

In what follows, I am providing the types of morphological impairment, their instantiations in diverse complex words, and brief descriptions of currently available aphasia therapies.

2.1. Types of morphological impairment

The symptoms of morphological impairment can be separated into two broad categories: Substitution of morphemes (e.g., semantic substitution: *grandfather* → *grandmother,* phonological substitution*: grandfather* → *trandfather*) and omission of morphemes (e.g., *unzip* → *zip*). Morpheme substitution and omission are found in diverse languages; however, the degree and type of morphological deficit and their instantiations or surface manifestations may vary from language to language as well as from one type of morphological category to an other (e.g., Badecker, 2001; Blanken, 2000; Delazer & Semenza, 1998; Friedman, 2001; Hittmair-Delazer et al., 1994; Jarema & Kehayia, 1992; Jarema & Libben; 2006; Kohn & Melvold, 2000; Libben, 1998; Månsson & Ahlsén, 2001; Menn & Obler, 1990; Nasti & Marangolo, 2005; Semenza et al., 2002).

In semantic substitutions, morphemes are exchanged for other morphemes that are semantically related to the target morpheme. For example, if the target word were *godfather* and the produced word were *godbaby*, then the head of the compound word has been replaced with the semantically related word *baby*. In this case, the substituted morpheme is related to the morpheme that it replaced. However, a substituted morpheme may relate to the meaning of only the target morpheme or to the meaning of the whole complex word (e.g., Badecker, 2001; Delazer & Semenza, 1998; Hittmair-Delazer et al., 1994; Libben, 1998; Nasti & Marangolo, 2005). In phonological substitutions, morphemes may be exchanged for morphemes that sound similar to the target morpheme. For example, if the complex word *books* is replaced with *nooks*, then the target morpheme *book* has been replaced with another morpheme, *nook*, that has the same phonological rhyme as the target word while the affix has been kept constant. Other substitutions that are not semantically or phonologically motivated may also be produced. For instance, the target word *train station* may be produced as *sky station* where the produced morpheme *sky* has no apparent semantic or phonological relation to *train*. This error may be due to a simple mis-selection. Moreover, Jarema and Libben (2006) indicated that morphological paraphasias, although incorrect for the specified context, typically adhere to the well-formedness principles of a language. Thus, morphological substitutions often share the same grammatical category or are members of the same paradigm as the replaced morpheme (e.g., a verbal inflection is replaced with another inflection of the verbal paradigm, *she wanted* → *she wants*, whereas a derivational affix is replaced with another derivational affix of a specific category, *humidity* → **humidness*). However, substitutions are not always limited to within-grammatical-category substitutions (e.g., a derivational suffix is replaced with an inflectional affix, *booklet* → *books*). In addition, morphemic paraphasias, even neologisms (non-existing words) are in general phonotactically acceptable in that the produced phonological sequences exist in the given language. It has been observed that in those languages in which morpheme omission in multimorphemic words would produce phonotactically unacceptable words (i.e., Greek, Polish, Arabic, and Hebrew), morpheme substitutions are more widespread than morpheme omissions. Grodzinsky (1984) suggested a new characterization of agrammatism from the omission of closed-class items to the view that a mis-selection of items + default occurs. Grodzinsky indicated that in word-based languages (e.g., English) omission is the default procedure, whereas in stem-based languages (e.g., French, Italian) substitution or “unconscious guessing” is more common. He stated that patients with agrammatism would not omit bound inflectional morphemes if omission results in a nonword. In stem-based languages, inflections are attached to a stem and not to a complete word (e.g., French: cherch- + -e, 1st pers. sing., present tense). Thus, any omitted inflections will result in a nonword. In word-based languages, inflections attach to an existing word (e.g., English: jump- + -s, 3rd pers. sing., present tense); hence, omission of the inflection does not result in a nonword. In a recent study, Friedman (2001) reported that tense markers perceptible by specific vowel patterns (binyan) in Arabic and Hebrew are frequently substituted. Omission of the whole vowel pattern in Semitic languages is not observed. One possible reason for this finding may be that after a vowel pattern has been omitted, only the consonantal pattern is left, and that by itself is an unacceptable phonotactic sequence, and therefore is not pronounceable. In Arabic, for example, the word *kaatib* 'writer' cannot be produced with the vowel pattern omitted as *ktb*; rather, the vowel pattern will be replaced with another vowel pattern, as for example, with *kitaab* 'book.' However, Månsson and Ahlsén (2001) reported that the omission of morphemes does not always result in acceptable words. In their study of aphasia in Swedish, some inflected forms were changed to root forms that were not acceptable words in Swedish (svimmade 'fainted' → *swim 'faint'). Nault and Libben (2004) investigated verb roots that are constituents in German verb-noun compounds. In that study, unimpaired German-speaking participants accepted even nonword verb roots that are compound constituents as possible words in a lexical decision task. The authors suggested that constituency in compounds imbued the nonword root with some type of 'wordhood.' Although Swedish root forms are not considered to be acceptable words, the fact that they are constituents in morphologically complex forms may also imbue them with some type of 'wordhood' similar to that of the nonword verbal roots of German.

In the next sections, morphological impairment is surveyed with respect to different morphological domains (i.e., compound words, inflected words, and derived words).

2.1.1. Impairments of inflectional morphology

2.1.1.1. Morpheme substitution in inflected words

Impaired processing of inflectional morphemes is possibly the most widely studied symptom of agrammatic performance. Inflectional morphemes that encode tense seem to be more susceptible to breakdown than inflectional morphemes that mark number agreement, mood, or case. In addition, cross-linguistically, substitution of verb forms is common (e.g., in English: Nadeau &

Rothi, 1992; in German: Wenzlaff & Clahsen, 2004; in Italian: De Bleser, Bayer, & Luzzatti, 1996). With a multiple-choice experiment involving morphological complexity versus diacritic encoding and retrieval (e.g., + PAST → Verb + D) with ten English-speaking individuals with Broca’s aphasia, Faroqi-Shah and Thompson (2007) found that in an error analysis, inflectional morpheme substitutions (e.g., Yesterday Mary *speaks to the President) made up the largest proportion of errors (46.5%). Stem substitution, in which the verb stem replaces an inflected verb, made up the second-largest proportion (27.9%), followed by inflection additions (8.9%), inflection for derivation (3.1%), and other errors (13.6%). These researchers also found that the accuracy of derived words was relatively high (93.1%) in comparison to the reduced accuracy of inflected words (e.g., non-finite verbs, 80%; regular past, 51.6%; irregular past, 58%; third-person present tense, 52.6%).

Diverse interpretations exist to account for morphological deficits and in particular for deficits in verb production (e.g., morpho-semantic, morpho-lexical, morpho-syntactic, and morpho-phonological). Jarema (2008) suggested, for example, that existing unmarked forms may be produced if tense or agreement is underspecified. This suggestion may explain the relatively high accuracy of non-finite verbs in the Faroqi-Shah and Thompson (2007) study, which found that overt tense markers were omitted (jumped → jump) or substituted for an unmarked tense marker (jumped → jumping). However, overt tense markers may not be omitted in languages in which unmarked stems are phonologically unacceptable (e.g., Greek, Italian, Hebrew, or Arabic). Nadeau and Rothi (1992) stated that the predominance of paragrammatic errors in languages such as Greek, Italian, and German could result because the greater number of inflectional morphemes in such languages allows for greater inflectional selection errors. An investigation of all production errors of bound grammatical markers (n = 434) in Italian highlighted the predominance of substitution errors in languages that do not permit omission of inflections in cases where a nonword would be produced (Miceli, Silveri, Romani, and Caramazza, 1989).

2.2.1.2. Morpheme omission in inflected words

Morpheme omission is often found in the speech of English-speaking individuals with agrammatism. Menn (1990) confirmed this observation in her study of two English-speaking patients. One patient, Mr. Franklin, omitted 33percent of the 3rd person singular present tense markers, 22 percent of the past tense markers, and 8 percent of the *–ing* progressive markers. He replaced only 8 percent of the 3rd person singular present tense markers and none of the past tense markers or *–ing* progressive markers. Mr. Eastman, the second patient, did not replace any morphological markers, but omitted 44 percent of the past-tense markers, 67 percent of the *-ing* progressive markers, and 8 percent of the 3rd person singular present tense markers. Nadeau and Rothi's study (1992) also highlighted morpheme omission in inflectional morphology. Their English-speaking patient omitted 33 percent of [–s] and [–z] endings and 50 percent of [-əz] endings of possessives in a test of inflectional morphology. This patient rarely missed plural endings, indicating that the omission was not phonologically based, but rooted in morphology.

2.1.2. Impairments of derivational morphology

2.1.2.1. Morpheme substitution in derived words

Although complex words with derivational affixes did not prove as difficult as inflectional affixes in a study of four individuals with aphasia (two fluent and two non-fluent speakers) by Kohn and Melvold (2000), derivational affixes were also substituted. In order to investigate the notion of morphological complexity, a subtest of the study looked at derived words and pseudo-derived words (e.g., dance + er versus spider) that were matched for frequency and length. Kohn and Melvold reported that the patients seemed to be sensitive to morphological structure: more pseudo-derived words were repeated correctly than derived words. One patient, JW, produced five substitution errors for derivative suffixes while he produced only one omission. In a recent study investigating Slovenian aphasic speech (Semenza et al., 2002), two patients frequently produced neologisms by substituting stems of words while usually preserving derivational prefixes. Patient

SA, for example, maintained the prefixed derivational affix and substituted the stem in 79.6 percent of the cases (e.g., povabilo, po+vabilo, 'invitation' → *po*zazito*, po+nonword). This patient, however, did not preserve the initial phoneme more often than any other phonemes in monomorphemic words; thus, a phonological account can be set aside. In addition, SA replaced the initial preposition with other prepositions in reading (18.3% of the errors), in repetition (15.6% of the errors) and in writing (7.7% of the errors). Similarly, in the reading task, OM, the other patient in this study, retained the preposition and replaced the stem (e.g., prizanesljiv 'indulgent' → prizadenvnost 'industriousness') in 54.7 percent of the errors and replaced the initial preposition (e.g., podhod 'underpass' → prihod 'arrival') in 28 percent of the errors.

2.1.2.2. Morpheme omission in derived words

While derivational affixes seem to be most often replaced, derivational morpheme omission also occurs. For example, Semenza et al. (2002) reported that the Slovenian patient SA produced more simple words instead of prefixed derived words in writing (31.1%) than in reading or repetition (2.6% and 1.2%, respectively). SA omitted prefixes in verbs (vlepiti 'to stick → *bediti) and in nouns (pri eska 'hair-dressing' → *pisek). OM, the other patient in this study, also usually preserved derivational prefixes (71.8%). She substituted in 20.5 percent and omitted in only 7.7 percent of the cases in reading. In addition to verbs (narasti 'to increase' → *mrazasti) and nouns (nadsvetnik 'saint' → *svetovnik), she also omitted derivational prefixes in adjectives (zahrbten 'insidious' → hladnokrvnost 'impassivity') and nonwords (predcoz → rdeloz).

Kohn and Melvold (2000) reported on four English-speaking patients, three of whom also omitted derivational affixes. Patient BD, for instance, omitted all but three prefixes (88%). These omissions resulted in non-derived simple words (e.g., discomfort → comfort; mislead → lead, redrew → drew, misplace → place). The other patient with Broca's aphasia, JW, also displayed difficulty with prefixed derived words although not to the same extent as fewer prefix omissions

(46% versus 88%) led to the production of formal paraphasia (e.g., redrew → jew; derailed → trail). No details were provided for the two derivational-affix omissions (one prefixed, one suffixed) of patient RD, who was a fluent aphasic speaker.

2.1.3. Impairments in compounding

2.1.3.1. Morpheme substitution in compounded words

Substituting one constituent for another morpheme in compound words often results in well-formed existing and non-existing compound words. Badecker (2001) reported on an English patient, CSS, whose picture-naming and naming-to-definition accuracy was poorer for compound words than for monomorphemic words (50% versus 79%, respectively). When naming pictures, CSS produced substitution errors as neologisms (seahorse → water horse, cheer leaders → gym leaders, wheelchair → wheel pill) and as other existing compounds (stop watch → time clock). Most often (43%), CSS replaced a compound constituent with a morpheme that was semantically related to the whole-word (e.g., southpaw → southball). CSS was aware that the target was a compound word. Sometimes, when he was unable to produce both compound constituents, he replaced the missing word with an empty compound component, a filler word (e.g., slowdown → something down, weather vane → air something, and seahorse → horse something). Although CSS retained knowledge of the morphological structure, he did not always keep the positions of the constituents constant (snowshoe → *shoe snow, trash can → *can trash, pin cushion → *stop pin, teddy bear → *bear baby). Importantly, he never produced sequence errors of non-constituents in monomorphemic words (e.g., the hypothetical error *pettrum for trumpet). Hittmair-Delazer and colleagues (1994) reported that their German-speaking patient often replaced only one compound component with a semantically closely related word in target responses. Generally, the compounding positions of both compound elements were respected. For example, instead of producing the target *Schneemann* 'snow man,' the non-existing compound word *Schneefrau* 'snow woman' was produced. Nasti and Marangolo (2005) reported on a patient who replaced target components with lexical items that were semantically related to the replaced target compound components (e.g., millipiedi, literally: one thousand feet, 'centipede' → *millscarpe, literally: one thousand shoes, a neologism). Although this Italian-speaking patient recovered almost completely from other aphasic disturbances, he continued to exhibit morphological disturbances with compound words. Correspondingly, Delazer and Semenza (1998) described an Italian-speaking patient whose prevalent difficulty was with multimorphemic compound words. This patient usually retrieved one compound constituent correctly while replacing the other constituent morpheme. For this patient, the replacements were semantically related to the overall meaning of the compound word (as they also were for the patients in Hittmair-Delazer et al.'s 1994 study). For instance, instead of producing *portarifiuti*, literally carry rubbish, 'dustbin' the patient produced the neologism **bidonerifiuti* 'bin rubbish.'

2.1.3.2. Morpheme omission in compound words

Morpheme omission in compounds may occur for either constituent in both semantically transparent and semantically opaque compound words. Blanken (2000) reported that in a naming study with twenty German-speaking patients, the omission of compound constituents was a very common error in transparent compound words. The right constituent, which is the head constituent in German compound words, was almost always produced with the first constituent being omitted (e.g., Teebeutel 'tea bag' → Beutel 'bag'). However, in 19 cases, the head of the compound word was omitted while the first constituent was named. Importantly, in this study, not only relatively transparent compound words, but also relatively opaque compound words and very opaque compound words were affected by morpheme omissions. Blanken specified that, normally, the more opaque constituent was omitted in opaque compound words.

2.2. Aphasia therapies

Individuals with non-fluent aphasia have difficulty producing words and sentences without omitting or substituting morphemes. Substituting morphemes results in semantic and phonological paraphasias. In addition, in Broca's aphasia with agrammatism, mainly short and simple sentences are produced: functional morphemes are frequently omitted.

Until now, an accepted hypothesis has been that each level of breakdown in word production should be remediated by a different kind of treatment (e.g., Nettleton & Lesser, 1991; Hillis & Caramazza, 1994). Accordingly, word-finding difficulties that are thought to have impaired semantics as their cause require a therapy that addresses semantics, whereas difficulties in retrieving sounds that are thought to have phonology as their cause require a phonological therapy, and sentence structural difficulties that are thought to have syntax as their cause require a syntactic therapy (e.g., Nettleton & Lesser, 1991; Miceli, Amitrano, Capasso, & Caramazza, 1996). Consequently, three types of aphasia therapies are widely used: semantic, phonological, and syntactic therapies. Semantic therapies (e.g., Boyle & Coelho, 1995; Visch-Brink, Bajema, & Van de Sandt-Koenderman, 1997) rely on semantic tasks; phonological therapies (e.g., Cubelli, Foresti, & Consolini, 1988; Franklin, Buerk, & Howard, 2002) depend on phonological tasks; and syntactic therapies (e.g., Thompson & Lee, 2009; Thompson & Shapiro, 2005; 2007) address the impairment by using syntactic tasks. Diverse tasks in these therapies have been effective for the remediation of production impairments (e.g., Hillis & Caramazza, 1994; Howard, Patterson, Franklin, Orchard-Lisle, & Morton, 1985), some of which can produce lasting effects (e.g., Pring, White-Thomson, Pound, Marshall, & Davis, 1990). In the next sections, the semantic, phonological, and syntactic tasks are discussed.

2.2.1. Semantic tasks as therapy

Almost all therapy tasks involve semantic processing, even those that are supposed to specifically address phonology (Nickels, 2002). A few tasks, however, focus to a greater extent on semantic processing. Selecting 'the odd one out' from a set of pictures or matching a word (spoken or written) to a set of other words or pictures with related meaning.

Semantic feature analysis (SFA) is one technique widely used for semantic therapy (e.g., Boyle & Coelho, 1995; Boyle, 2004; Wambaugh & Ferguson, 2007; Rider, Wright, Marshall, & Page, 2008). In this treatment, pictures or video clips are shown to patients, who have to name either the object or the action. Then they are encouraged to describe the picture by providing the semantic features pertaining to it. For example, they are encouraged to say *what it is*, *what it has*, *what it is used for*, *etc.* to generate semantic features that relate to other objects or actions associated with it. Therapy effects are generally seen for trained items and for untrained items (although not consistently). Wambaugh and Ferguson (2007), for example, established in their action-naming study that the accuracy of naming of treated items increased and was maintained at six weeks post-treatment. Repeated exposure to stimulus items without training resulted in only unstable and temporary naming accuracy increases. The results for items measured only in pre- and post-treatment intervals did not change in naming accuracy. A similar result was found in Rider et al.'s 2008 study: the naming accuracy scores improved only for treated words, and no generalization to untrained words was found.

Most semantic treatments incorporate the word form as part of the semantic therapy. Few semantic treatment studies have been carried out in which no word form was provided. In one study by Drew and Thompson (1999), the naming accuracy of two out of four patients receiving semantic treatment did not increase unless the word form was provided. Nickels (2002) indicated that in at least some cases, semantic treatment is more effective when the word form is also provided.

2.2.2. Phonological tasks as therapy

Repetition of the target, phonological cueing of picture naming, phoneme discrimination, rhyme judgments, syllable and phoneme counting, and phoneme segmentation tasks form the main body of phonological tasks in word finding remediation for individuals with aphasia. The monitoring and correction of phonological errors is one approach taken in a study by Franklin, Buerk, and Howard (2002). Their patient MB responded in long sequences of phonologically related answers in all speech-production tasks; however, these responses were most often incorrect. Response accuracy increased with phonological treatment across items and modalities. Franklin et al. suggested, however, that the treatment improved phoneme selection, not self-monitoring, which was efficient for MB before therapy.

It is proposed that phonological tasks focus at the activation level of individual entries in the phonological output lexicon (e.g., Miceli et al., 1996; Nettleton & Lesser, 1991). Miceli et al. (1996) argued that such improvements should be item specific, due to the priming of the phonological form. This argument has been supported in several studies (e.g., Nettleton & Lesser, 1991, patient DF; Hillis & Caramazza, 1994, patient HW; Miceli et al., 1996).

2.2.3. Syntactic tasks as therapy

Sentences in which noun phrases are moved out of their canonical position (e.g., the order in which subject (S), verb (V), and object (O) are most often found in a particular language: SVO in English, VSO in Arabic), such as passives and object relative clause constructions, present particular difficulties in both production and comprehension for individuals with aphasia (e.g., Bastiaanse, Hugen, Kos, & van Zonneveld, 2002; Caplan & Hildebrandt, 1988; Faroqi-Shah, & Thompson, 2003; Grodzinsky, 1986). Two main approaches to remediate syntactic impairment are 'mapping therapy' (e.g., Haendiges, Berndt, & Mitchum, 1996; Schwartz, Saffran, Fink, Myers, & Martin, 1994) and 'treatment of underlying forms' (Thompson, Ballard, & Shapiro, 1998; Thompson & Shapiro, 2005). Both methodologies deal with the syntactic properties of sentences as well as verbs and their thematic roles. Mapping therapy focuses on comprehension, while treatment of underlying forms focuses on comprehension and production.

Treatment of underlying forms involves training object relative clause structures (e.g., "The man saw the boy whom the girl chased."), object clefts (e.g., "It was the boy whom the girl chased."), and wh-questions (e.g., "Whom did the girl chase?"). Thompson, Ballard and Shapiro (1998) found that for patients who received treatment with the more complex object cleft structures, object cleft production increased significantly in addition to increased wh-question production for which no treatment was provided. Conversely, for patients who received treatment on wh-questions, no generalization occurred to object cleft production. Thus, treating the more complex structures favored generalizations to simpler structures, but treating simple structures did not favor generalizations to more complex structures.

The next chapter introduces the design of the Morphological Therapy Protocol.

Chapter 3

The design of the Morphological Therapy Protocol: Goals, structure, and implementation

3.0. Methods

3.1. Participants

Acceptance criteria – Individuals with non-fluent aphasic symptoms who were a minimum of 6 months post-onset of stroke. Prospective participants were asked to carry out the Alberta Language Function Assessment Battery (ALFAB). The ALFAB (Westbury, 2007) is a fully computerized aphasia battery that assesses language from the simplest to the most complex components. It includes tests of low level input and production, orthographic and phonological processing, word fluency, semantic access, sentence processing, and morphological processing. The subtests of the ALFAB have been normed on a large sample of a healthy elderly norming group (population is between 33 and 83 individuals, depending on the subtest). Because the subtests have been normed, every factor and pair-wise factor crossing in each subtest can be scored in standardized scores, giving a motivated measure of the severity of the deficit. Westbury (2007) indicated that individuals with z-scores of less than -2z should be considered significantly impaired.

Patients – Although five participants were included in the study, the fifth patient, CW, clearly differed from the other patients. He had a right hemisphere stroke and suffered from fluent aphasia. Due to ethical considerations, I completed the Morphological Therapy Protocol with CW. CW's progress differed qualitatively. As the focus of this dissertation is on non-fluent aphasia, his data will not be discussed here.

All patients undertaking the MTP had been continuously receiving some type of speech therapy (no details were available). Initially, all patients received individual therapy. Three patients (DR, PH, and JN) were participating in weekly group speech therapy at the time the MTP was administered. Unfortunately, patient DP discontinued one of his weekly group therapies approximately three years ago due to group size limitations. He was always happy to take part in any therapy session that was offered to him and participated in diverse short-term therapy sessions. Three of these patients (DR, DP, and PH) knew me from my volunteer work with the group speech sessions over a period of four-five years.

Unfortunately, the patients and their families did not know much about the medical diagnosis besides the fact that the patients had had a left hemisphere stroke (cerebral vascular accident). For the purpose of this study, the initial classification of the participants as individuals with non-fluent aphasia was accomplished on the basis of behavioral data (ALFAB). All the patients suffered from agrammatic speech, defined by reduced phrase length and reduced syntactic complexity.

A complete aphasia diagnostic did not seem to be available to these patients immediately after their strokes. Therefore, no absolute clinical aphasia classification was available. Accordingly, my reports on the patients' medical histories are very limited. However, as the ALFAB, administered before and after therapy, is an assessment battery, I am able to provide information about the patients' linguistic abilities immediately prior to therapy. Table 1 reports some background information of the patients who took part in this study.

Table 1

Summary of patient demographic data

Patient	Sex	Age	Time post onset	Years of education	Former occupation	Pre-morbid handedness
DR	F	39	4;1	12	Surveyor	Right
DP	M	59	6;11	12	Cook	Left
PH	M	59	11;9	11	Truck driver	Left
JN	M	70	10;7	10	Truck driver	Right

3.1.1. Patient DR

Patient DR is a 39-year-old female who suffered two successive strokes after a ruptured aneurism in August 2003. She remained in a coma for four weeks after the strokes. DR had completed 12 years of education and was working as a surveyor at the time of her cerebral accident. DR grew up as a monolingual English speaker. She is the mother of three children living at home with her extended family. DR received private speech therapy from 2003- 2005 and had been attending weekly group speech sessions since October 2004. She is active in her community.

Prior to therapy, three baseline measurements were administered in three weekly sessions in which 105 words were presented for reading out loud. The aggregate pre-therapy testing sessions of 315 words (45 monomorphemic words, 270 complex words) revealed that the error percentage for patient DR was 56.4 percent (refer to Section 3.2.2.1. for details).

Table 2, the ALFAB subtests summary for patient DR, reports the actual scores in the centre column and the z-scores in the right-most column. I highlight the most difficult sections for patient DR here: Section A indicates that DR's monomorphemic and multimorphemic repetition scores were below 50 percent correct. DR repeated words with higher frequency values notably better than words with lower frequency values. DR's reading was highly impaired (27% correct, Section B). Section C indicates that DR's fluency was very low. DR was able to produce one word with the suffix *–ing* and three words with the suffix *–s*. DR's picture naming scores were very low (Section D). The semantic category of tools received the highest subscore (62.5%), animals and music the lowest (12.5%). Section E illustrates that sentence production was very difficult for DR (8% correct). DR was able to correctly produce only 40 percent of the active sentence structures. Passives, datives, dative passives, and subject-object relatives received a score of 0 percent correct. Thus, the ALFAB subtests illustrate that DR's difficulties were mainly in morpheme and sentence production. For patient DR's complete ALFAB profile, please refer to Appendix A.

Table 2

ALFAB subtests pre-therapy summary table for patient DR

	Pre-therapy results	
	Percent	Z-scores
A) Low level input & production		
Phoneme Discrimination:	98.9	0.8
Monomorphemic Repetition:	46.9	-9.6
Multimorphemic Repetition:	48.7	-9.3
B) Orthographic & phonological processing		
Visual Lexical Decision:	90.1	-1
Auditory Lexical Decision:	90.1	-1
Rhyme Judgment:	N/A	
Reading:	27	-13.6
Spelling:	100	1
C) Fluency		
Oral:	0 words	-18.8
Written:	2 words	-18.6
Multimorphemic:	4 words	-18.2
D) Semantic access		
Word-picture matching		
Visual:	96.7	0.3
Auditory:	95.1	0
Multimorphemic:	93.9	-0.2
Synonym judgment		
Visual:	72.5	-4.5
Auditory:	72.5	-4.5
Semantic decision		
Visual:	75	-4
Auditory:	81.3	-2.7
Multimorphemic:	86.5	-1.7
Picture naming		
Oral:	34.1	-12.2
Written:	25	-14
E) Sentence processing		
Visual comprehension:	67.9	-5.4
Auditory comprehension:	60.7	-6.9
Idiom judgment:	N/A	
Production:	8	-17.4

3.1.2. Patient DP

Patient DP is a 58 year-old right-handed male who suffered a hemorrhagic stroke in September 2001. He had 12 years of education. He enjoyed working as an industrial cook prior to his stroke. DP grew up as an English-French bilingual in a predominantly English-speaking town. DP had been attending individual and group speech and language therapy for consecutive treatment blocks since January 2003. He was very eager to participate in therapy sessions.

The aggregate pre-therapy testing sessions of 315 words revealed that the percentage of errors for patient DP was 53 percent (please refer to Section 3.2.2.2. for details).

Table 3 provides the subtests results of the pre-therapy ALFAB. Here, the sections that proved most difficult for patient DP are highlighted (please see Appendix B for DP's complete ALFAB profile). Section A illustrates that DP's monomorphemic and multimorphemic repetition were both highly impaired (26.6% and 33.8% correct, respectively). Section B shows that reading was very difficult for DP (20.7% correct). Surprisingly, DP's production of multimorphemic words was better than his production of monomorphemic words (9 words versus 1 word respectively; Section C). Section D illustrates that in semantic access, with the exception of word-picture matching, the multimorphemic component was always more difficult. In addition, picture naming was difficult. Unfortunately, patient DP did not do the sentence production task in the pre-therapy ALFAB administration. Overall, the results of the ALFAB pre-therapy administration indicate that the multimorphemic components were the most difficult for DP.

Table 3

ALFAB subtests pre-therapy summary table for patient DP

	Pre-therapy results	
	Percent	Z-score
A.) Low level input & production		
Phoneme Discrimination:	95.5	0.1
Monomorphemic Repetition:	26.6	-13.7
Multimorphemic Repetition:	33.8	-12.2
B.) Orthographic & phonological processing		
Visual Lexical Decision:	73.2	-4.4
Auditory Lexical Decision:	81	-2.8
Rhyme Judgment:	N/A	
Reading:	20.7	-14.9
Spelling:	100	1
C) Fluency		
Oral:	1 word	-18.8
Written:	1 word	-18.8
Multimorphemic:	9 words	-17.2
D.) Semantic access		
Word-picture matching		
Visual:	44.3	-10.1
Auditory:	98.4	0.7
Multimorphemic:	84.8	-2
Synonym judgment		
Visual:	65	-6
Auditory:	22.5	-14.5
Semantic decision		
Visual:	62.5	-6.5
Auditory:	67.5	-5.5
Multimorphemic:	50	-9
Picture naming		
Oral:	20.5	-14.9
Written:	27.3	-13.5
E) Sentence processing		
Visual comprehension:	75	-4
Auditory comprehension:	62.5	-6.5
Idiom judgment:	N/A	
Production:	N/A	

3.1.3. Patient PH

Patient PH is a 58-year-old left-handed male who suffered a left subcortical intra-cerebral hemorrhage in November 1996. PH grew up in a monolingual English family. He completed 11 years of schooling after which he drove large trucks. At the time of his stroke, PH owned a trucking business. He spent six months in a brain recovery unit in hospital before moving into a group home. PH has attended group therapy throughout his recovery. PH enjoys using his computer.

The aggregate pre-therapy MTP testing sessions of 315 words revealed that patient PH's error percentage was 29.2 percent (for more details, please refer to Section 3.2.2.3.).

Table 4 lists the few available pre-therapy ALFAB results for patient PH. PH's full ALFAB profile is listed in Appendix C. Unfortunately, patient PH did not complete the ALFAB administration[1]. Section A indicates that PH was impaired in all components. However, he scored better on the multimorphemic repetition than on the monomorphemic repetition (59% versus 46.9%). High-frequency words were easier for him than low-frequency words. Section B (Orthographic & phonological processing) was not completed. Section C illustrates that PH was able to produce 6 multimorphemic words (one with suffix *–er*, one with suffix *–ing*, and four with *–s*). PH's semantic access was impaired in multimorphemic word-picture matching, synonym judgment, and semantic decision (Section D). Unfortunately, PH did not do the picture-naming component. The pre-therapy ALFAB administration of patient PH does not allow for comparisons between monomorphemic and multimorphemic components, as he did not complete the assessment battery.

[1] Patient PH was not feeling well at the time of the ALFAB testing.

Table 4

ALFAB subtests pre-therapy summary table for patient PH

	Pre-therapy results	
	Percent	Z-score
A.) Low level input & production		
Phoneme Discrimination:	55.7	-7.9
Monomorphemic Repetition:	46.9	-9.6
Multimorphemic Repetition:	59	-7.2
B.) Orthographic & phonological processing		
Visual Lexical Decision:	N/A	
Auditory Lexical Decision:	N/A	
Rhyme Judgment:	N/A	
Reading:	N/A	
Spelling:	N/A	
C) Fluency		
Oral:	N/A	
Written:	N/A	
Multimorphemic:	6 words	-17.8
D.) Semantic access		
Word-picture matching		
Visual:	N/A	
Auditory:	N/A	
Multimorphemic:	90.9	-0.8
Synonym judgment		
Visual:	60	-7
Auditory:	N/A	
Semantic decision		
Visual:	N/A	
Auditory:	N/A	
Multimorphemic:	76.9	-3.6
Picture naming		
Oral:	N/A	
Written:	N/A	
E) Sentence processing		
Visual comprehension:	N/A	
Auditory comprehension:	57.1	-7.6
Idiom judgment:	N/A	
Production:	N/A	

3.1.4. Patient JN

Patient JN is a 70-year-old male who suffered a stroke ten years prior to this study. He had completed 10 years of schooling. JN also worked as a truck driver. JN grew up hearing and speaking a little Ukrainian; however, he considered himself as a monolingual English speaker. JN is living independently in his own house and attending weekly group speech sessions.

The percentage of error was 33.6 percent in the aggregate pre-therapy testing sessions of 315 words (see Section for a detailed description).

Table 5 reports the pre-therapy ALFAB subtests of patient JN. The monomorphemic word repetition was more impaired than that of his multimorphemic word repetition (42.2% versus 70.5%, respectively). JN repeated words with high frequencies more easily than words with low frequencies (Section A). Section B shows that JN was highly impaired in reading (45.9% correct). In comparison to the other patients, patient JN did not do very well with spelling: His accuracy is a low 5.5% correct. JN's fluency was very low (Section C). He was able to produce one spoken monomorphemic word and one multimorphemic word with the plural marker -*s*. Section D reports that for word-picture matching and semantic decisions, the multimorphemic components were most difficult for JN. Section E, importantly, reports that JN's sentence production was impaired. Interestingly, patient JN was able to produce 100 percent of the dative sentences and 60 percent of active sentences. None of the passive, dative passive, and subject-object sentences was produced correctly. Thus, JN's morpheme production as well as his sentence production (with the exception of dative sentences) was considerably impaired prior to therapy. Please refer to Appendix D for patient JN's complete ALFAB profile.

Table 5

ALFAB subtests pre-therapy summary table for patient JN

	Pre-therapy results	
	Percent	Z-score
A.) Low level input & production		
Phoneme Discrimination:	88.6	-1.3
Monomorphemic Repetition:	42.2	-10.6
Multimorphemic Repetition:	70.5	-4.9
B.) Orthographic & phonological processing		
Visual Lexical Decision:	85.2	-2
Auditory Lexical Decision:	76.1	-3.8
Rhyme Judgment:	69.8	-5
Reading:	45.9	-9.8
Spelling:	5.5	-17.9
C) Fluency		
Oral:	1 words	-18.8
Written:	0 words	-19
Multimorphemic:	1 words	-18.8
D.) Semantic access		
Word-picture matching		
Visual:	88.5	-1.3
Auditory:	95.1	0
Multimorphemic:	84.8	-2
Synonym judgment		
Visual:	55	-8
Auditory:	57.5	-7.5
Multimorphemic:	N/A	
Semantic decision		
Visual:	63.8	-6.2
Auditory:	68.8	-5.2
Multimorphemic:	40.4	-10.9
Picture naming		
Oral:	52.3	-8.5
Written:	N/A	
E) Sentence processing		
Visual comprehension:	58.9	-7.2
Auditory comprehension:	39.3	-11.1
Idiom judgment:	58	-7.4
Production:	32	-12.6

3.2. Material

3.2.1. Stimuli selection

Overall 115 stimulus items were critical to the experiment. These stimuli were made up of 15 monomorphemic identity words and 90 complex words (see Appendix E for the complete critical stimuli list). The complex items, based on the 15 monomorphemic identity words, were divided into three morphological domains: inflected, derived, and compound words. The stimuli represented 15 word families with the monomorphemic identity word kept constant across the morphological category contexts. For example, the word family stimuli for LOCK included the identity word LOCK, the inflected words *locked* and *locks*, the derived words *lockable* and *locker*, and the compound words *door lock* and *locknut.* The complex words were composed of a maximum of two constituents.

The stimuli were selected such that the identity word that was shared across the morphological categories could be shown as a picture. Being able to show the identity word pictorially was key as the pictures functioned as primes for the written words. The selection criteria for the identity-word photo stipulated that it could not have a complex background and that the visual identity of the stimulus item had to be clear.

The filler stimuli were selected so that memorization of critical items was hindered. For each identity word, a semantically related monomorphemic word and a semantically unrelated word were included. These words were chosen such that their surface frequency value was close to that of the corresponding identity word. Additionally, each identity word had three complex fillers created by combining one of the monomorphemic filler words and a morpheme that corresponded to one of the complex word domains. For example, the monomorphemic filler words for LEAF were *tree* and *nose* (related and unrelated word, respectively). The complex filler words associated with LEAF were *treed, nosy,* and *nose-ring*. (See Appendix F for the complete filler stimuli list).

The colour photographs used as a prime were downloaded from a royalty-free stock photo site (Stock.XCHNG, 2008).

3.3. Study design and measurements

The study consisted of three distinct phases: a pre-therapy baseline testing phase, a training phase, and a maintenance baseline phase (see Figure 2). Overall, the test administration covered a time period of about four months. The next sections detail the individual phases.

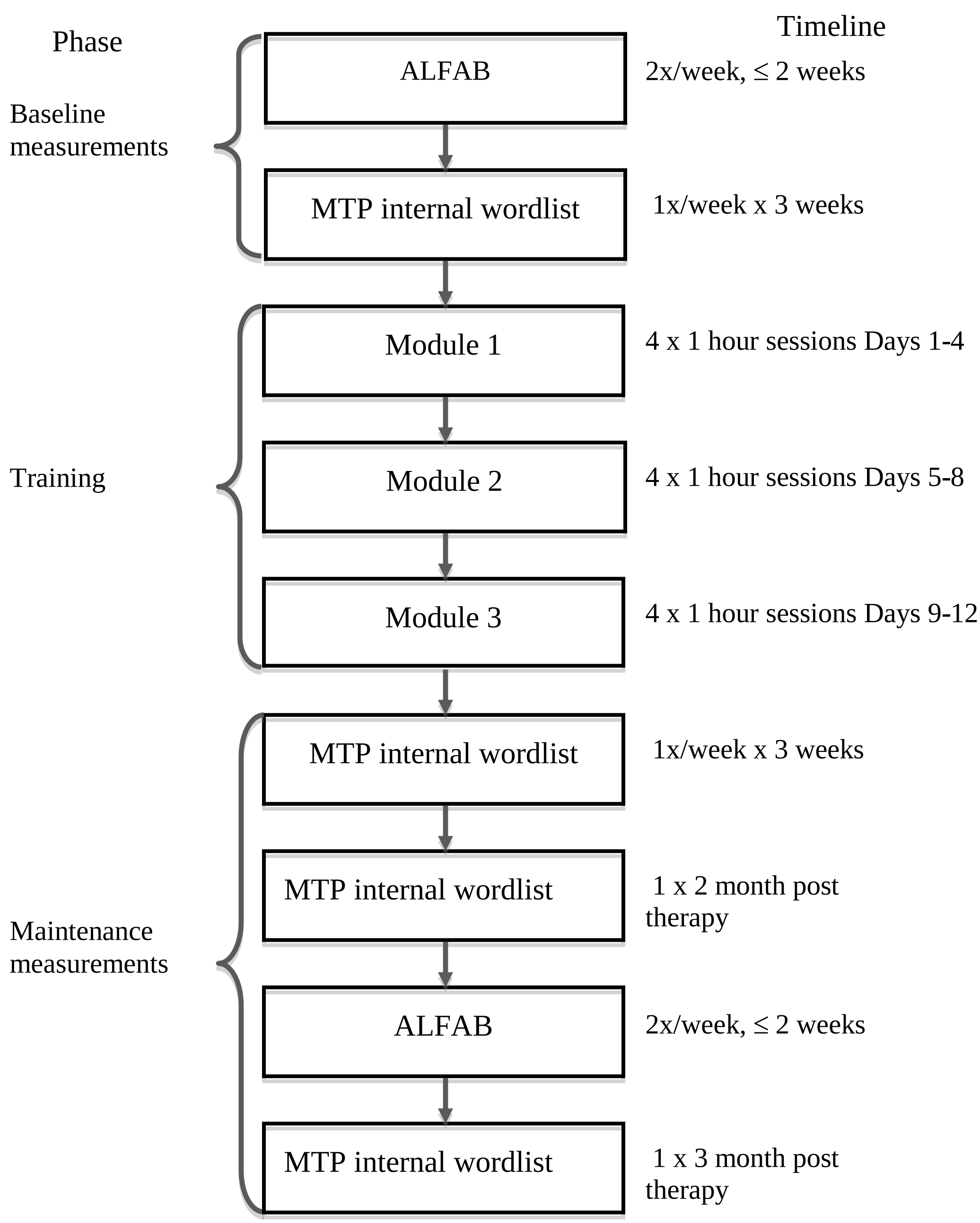

Figure 2. Design of the therapy.

3.3.1. Pre-therapy baseline

Two different baseline measures were taken: the ALFAB (Alberta Language Function Assessment Battery) and the MTP internal word list. Before starting the MTP word list baselines, patients completed as much of the ALFAB as possible (Patient PH decided not to complete all aspects of the ALFAB for personal reasons). Then, for the next three weeks, the MTP word list with 105 experimental items was presented on a MacBook Air using the PsyScope experimental software one word at a time once a week for reading out loud. The 105 experimental items consisted of the 15 word families. These baseline-testing sessions were administered in weekly sittings in order to control for learning versus spontaneous recovery, even though, spontaneous recovery is said to be possible in only about one-third of all patients during the first four weeks post-onset. Twelve months post onset of the stroke, at the very least, the impairment is judged to be chronic, at which point full recovery of speech is not expected. Even with continued speech therapy, language recovery is very limited (Huber, Poeck, & Weniger, 2006). The patients who participated in this study were at least four years post-onset of stroke, as illustrated in Table 1 (Section 3.1).

The results of the three MTP word list baselines also served to determine the training words. For each patient, error analyses of the three baseline naming tests revealed which word families had most errors across all words in that family (i.e., in monomorphemic, inflected, derived, and compound words). The five word families that resulted in most errors were selected as training items, resulting in different training words across the patients. Then the remaining ten word families for each patient were randomly assigned as either control or new items (for details, please refer to Section 4.3).

3.3.2. Pre-therapy reading error patterns

The results of the MTP pre-therapy baseline reading tests reveal these patients' diverse morphological errors in complex words: addition of morphemes, deletion of morphemes, substitution of morphemes, and reversal of morphemes. Overall, in multimorphemic words, more morphemes were substituted (259) than deleted (178), added (91) or reversed (3). This finding is in contrast to the statement by Grodzinsky (1984) who indicated that for English the default procedure is morpheme omission. The error analyses of the aggregate MTP baseline testing revealed a clear error pattern (see Table 6). Although, generally derivational morphology is more stable than inflectional morphology in aphasia (Jarema & Libben, 2006), for these four patients, derivational morphology was almost as difficult as inflectional morphology (218 errors in inflectional morphology, 193 errors in derivational morphology, 120 errors in compound morphology). For inflected words, more morphemes were omitted than substituted and very few morphemes were added. For derived words, the majority of errors were substitution errors, followed by omission and addition of morphemes. For compounds, the predominant error types were substitution and addition of a morpheme, while omission and reversal errors were very few.

Table 6

Overall pre-therapy reading error types

Morphological type (number of words)	Error type	Number of errors
Compounds (360)	Omission	9
	Substitution	50
	Addition	58
	Reversal	3
Derivations (360)	Omission	46
	Substitution	118
	Addition	29
Inflections (360)	Omission	123
	Substitution	91
	Addition	4
Monomorphemic words (180)	Omission	4
	Substitution	10
	Addition	20

3.3.2.1. Pre-therapy reading error patterns – patient DR

The error pattern displayed by patient DR is parallel to that of the group pattern. Derived and inflected words are most difficult followed by compounds. Monomorphemes were proportionally easier than compounds.

Table 7

Pre-therapy reading error types – patient DR

Morphological type (number of words)	Error type	Number of errors
Compounds (90)	Omission	7
	Substitution	13
	Addition	17
	Reversal	1
Derivations (90)	Omission	18
	Substitution	44
	Addition	9
Inflections (90)	Omission	30
	Substitution	36
	Addition	2
Monomorphemic words (45)	Omission	1
	Substitution	2
	Addition	1

3.3.2.2 Pre-therapy reading error patterns – patient DP

Patient DP's error pattern differs from the group's error pattern. DP added many unnecessary morphemes to all types of words. In addition, words with bound morphemes were challenging in terms of morpheme omission and morpheme substitution. Monomorphemes also posed a challenge for patient DP. He erroneously added plural morphemes to the monomorphemic words. Patient DP's different error pattern may have resulted from his bilingual French-English background.

Table 8

Pre-therapy reading error types – patient DP

Morphological type (number of words)	Error type	Number of errors
Compounds (90)	Omission	0
	Substitution	20
	Addition	13
Derivations (90)	Omission	2
	Substitution	43
	Addition	16
Inflections (90)	Omission	28
	Substitution	26
	Addition	1
Monomorphemic words (45)	Omission	0
	Substitution	7
	Addition	12

3.3.2.3. Pre-therapy reading error patterns – patient PH

Inflectional morphology was more difficult than derivational morphology for patient PH. Proportionally, the monomorphemic words were as difficult as the compound word.

Table 9

Pre-therapy reading error types – patient PH

Morphological type	Error type	Number of errors
Compounds (90)	Omission	1
	Substitution	6
	Addition	3
Derivations (90)	Omission	13
	Substitution	13
	Addition	2
Inflections (90)	Omission	32
	Substitution	14
	Addition	1
Monomorphemic words (45)	Omission	2
	Substitution	1
	Addition	4

3.3.2.4. Pre-therapy reading error patterns – patient JN

Inflectional morphology was most difficult for patient JN, closely followed by derivational morphology.

Table 10

Pre-therapy reading error types – patient JN

Morphological type	Error type	Number of errors
Compounds (90)	Omission	1
	Substitution	11
	Addition	5
	Reversal	3
Derivations (90)	Omission	13
	Substitution	18
	Addition	2
Inflections (90)	Omission	33
	Substitution	16
	Addition	0
Monomorphemic words (45)	Omission	1
	Substitution	0
	Addition	3

3.3.3. Treatment

Several days after the last baseline measurements were completed therapy was initiated. Treatment of complex words was divided into three morphological domain-specific modules presented consecutively for treatment over twelve days (Mondays to Fridays). Each therapy module consisted of four daily sessions of approximately 1 hour each, resulting in approximately 12 contact hours for therapy. Table 11 provides an overview of the treatment schedule for each patient. Compound words represent the morphological domain that elicited the least amount of errors during the baseline-testing sessions. As Thompson et al. (1998) established that treating with syntactically more complex structures generalized to syntactically simpler structures, I started out treatment with the more difficult morphological structures. Three patients received inflectional training first, while one patient received derivational training first.

Table 11.

Treatment module administration

Patient	Module 1 Day 1-4	Module 2 Day 5-8	Module 3 Day 9-12
DR	DERIVATION	INFLECTION	COMPOUND
DP	INFLECTION	DERIVATION	COMPOUND
Ph	INFLECTION	DERIVATION	COMPOUND
JN	INFLECTION	DERIVATION	COMPOUND

3.3.3.1 Measurements during the treatment phase

The measurements for the accuracy scores were collected in a reading test every day before treatment sessions started. The stimuli of the treatment-phase measurements consisted of 35 treatment items, 35 control items, and 50 filler items. The treatment stimuli were made up of the five identity words and their 30 complex related words (10 inflected, 10 derived, and 10 compound words; See

Appendix E) that elicited the most errors during the baseline-testing phase. These were the words that were trained. The control stimuli were made up of five identity words and their 30 complex related words randomly picked from the remaining five word families. These words were not trained. However, they were tested at every testing session. Therefore, the control words were produced as many times during the reading testing sessions as the trained words. In order to prevent memorization of treatment stimuli, filler items that were made up of 10 related and 10 unrelated monomorphemic words for each identity word (see Appendix F) were included. In addition, 15 complex words related to one of the two monomorphemic filler words were added. In summary, 50 filler items were included in every testing session throughout the training phase.

3.3.4. Post-therapy maintenance measurements

After completion of the three treatment modules, three post-therapy maintenance-testing sessions were carried out over three weeks to investigate whether any treatment effect was maintained. These post-therapy maintenance tests were made up of 180 stimuli: 35 training items, 35 control items, 35 new items (items with limited exposure at the pre- and post-training sessions only), and 75 fillers (two monomorphemic distracters and three complex distracters for every identity word). Following the maintenance tests, the ALFAB administration started about one week later. In addition, two longitudinal follow-up maintenance-testing sessions of the 180 stimuli were carried out two and three months after therapy.

3.4. Therapy

3.4.1. Introduction

The overall goal of the morphological therapy protocol is to make explicit the components that encompass our morphological ability. This morphological ability embraces implicit and explicit morphological knowledge. Implicit morphological knowledge can be characterized as the tacit understanding of the morphological rules system of the language. Explicit morphological knowledge includes the awareness of inflected and derived versions of words. The patients may have known (implicitly or explicitly) these morphological relations prior to the stroke, but were perhaps unable to process these relations as a result of the stroke. It was hypothesized that highlighting and making overt the covert morphological processes would give a heuristic to individuals with aphasia. Furthermore, it was theorized that providing this (de)composition strategy would affect not only the trained words, but also the control words, and generalize to items to which patients had had limited exposure, given that training affects and enhances our morphological ability through gained metalinguistic awareness.

Morphological combinatorial rules are made apparent in this therapy by tasks that allow patients to combine morphemes in a meaningful manner while respecting morphological restrictions. Awareness of morphological structure is realized by providing tasks that allow patients to decompose and compose complex words.

3.4.2. Therapy activity structures

The aim of the tasks was to reveal to the patients the components that make up our morphological ability. These components include composition and decomposition of complex words as well as morphological rules (i.e., selectional restrictions) that apply to morphemes. The Morphological Therapy Protocol (MTP) is made up of four tasks. Each task builds in complexity in comparison to the previous task. Below, each task is described as well as its goals, its presentation, its method, its design consideration, and compromises (if needed).

3.4.2.1. Task 1: Composition task

Goal: This task trained the patient to notice that complex words are made up of two meaningful units.

Introduction: In this activity, the patient pressed colour-coded keys on the keyboard to select two morphemes that made up meaningful complex words. The colours of the keys were colour-coded to the diverse morpheme choices made available on the computer screen. The morpheme choices on the left side of the screen always included the identity word, a semantically closely related morpheme, and a semantically unrelated morpheme. In this task, the morpheme choices on the right side of the screen always included three morphemes that could be used to possibly make up a complex word with the identity word. Across the three morphological domains, the three morpheme choices presented on the left-screen side (i.e., identity word, semantically related, and semantically unrelated word) were always kept constant, albeit in random order; the three morphemes on the right-screen side varied depending on the morphological category. For the inflection module, the choices were *-s, -ed*, and *–est*; for the derivation module, the choices included the prefix *re-* and the suffixes *-er, -less, -y, -ing, -ful, -like, -able, -ling*, and *–some*; for the compound module, the choices were unbound morphemes (nouns). The morphemes for the right screen side were selected so that two of them combined with the identity word to form a complex word, while the other morpheme did not combine with the identity word (e.g., the identity words never combined with the inflectional suffix *–est*).

Presentation: The presentation of the first screen in all tasks consisted of the same three items: a picture of a loud speaker, a picture of the identity word, and a picture of a dictionary in the top half of the screen (see Figure 3). This screen is similar for all tasks.

If the patient needed an auditory aid in order to know the pronunciation of the identity word, then the picture of the speaker could be clicked on by using the computer mouse. The pronunciation of the identity word could be heard up to three times per trial. If the patients were unsure of the meaning of the identity word, then the picture of the dictionary could be clicked on by using the mouse to give the patient two more choices: the auditory definition and written definition of the identity word. The patients never chose this option.

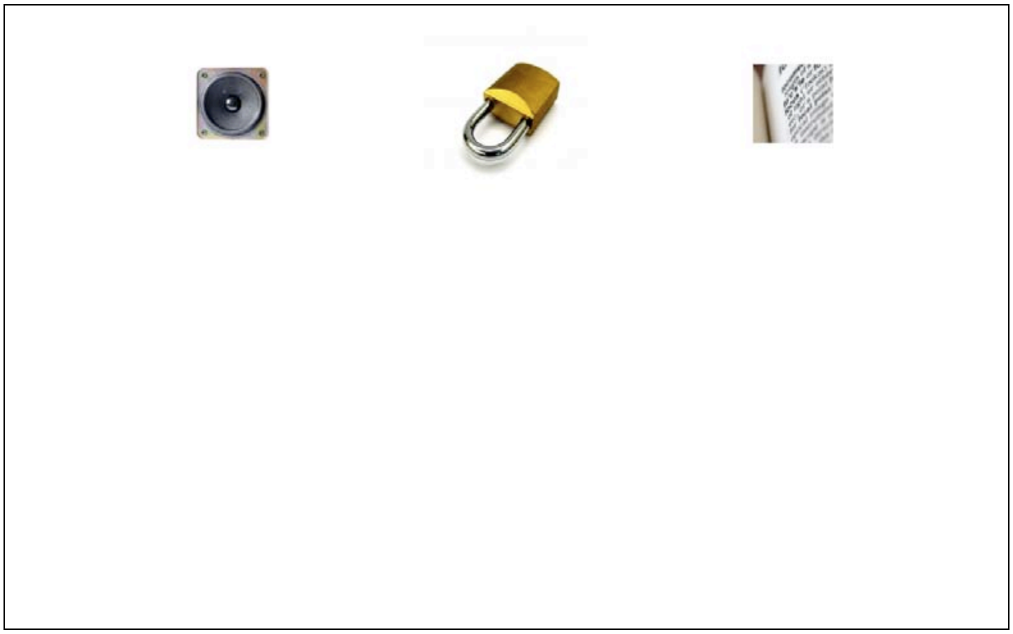

Figure 3. Representation of Screen 1.

The presentation of the second screen (Figure 4) had several key items that were the same in all tasks: the photo of the identity word on the top of the screen and six colour-coded morpheme choices arranged in a semi-circular fashion on the bottom half of the screen (with colour-coded keyboard keys arranged in the same semi-circular fashion).

Tasks 2-4 included a morpheme structure representation (e.g., Task 2:  + ___; Task 3: ____ + ____; Task 4: ____ + ____ = ____) on the top of the screen, below the photo of the identity word.

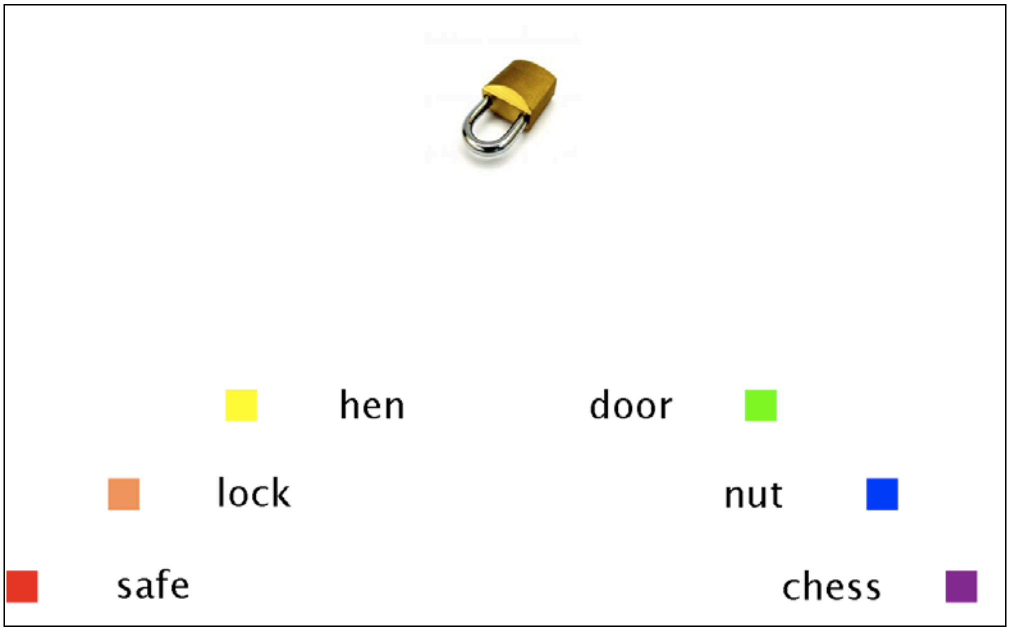

Figure 4. Representation of Screen 2 (showing the photo of the identity word LOCK and the six colour-coded morpheme choices for Task 1, here for compound words)

Screen 3 had two possible versions: (a) if the patient chose a correct morpheme, then this screen showed the photo of the identity word, the correctly chosen morpheme, and the remaining morpheme choices (see Figure 5) or (b) if the patient chose a morpheme that was inconsistent with the complex-word building, then the screen showed only the phrase “Try again” in the centre. The patient then moved on to the next trial.

Screen Four also had two possible versions: (a) if the patient chose one of the correct morphemes to complete the complex word, then the screen showed the photo of the identity word, the chosen morphemes represented within the morpheme structure representation if provided, and a “Congratulation” phrase or (b) if the patient chose a morpheme that did not combine with the identity word, only the “Try again” phrase was presented on the screen. Consequently, the patient moved on to the next trial.

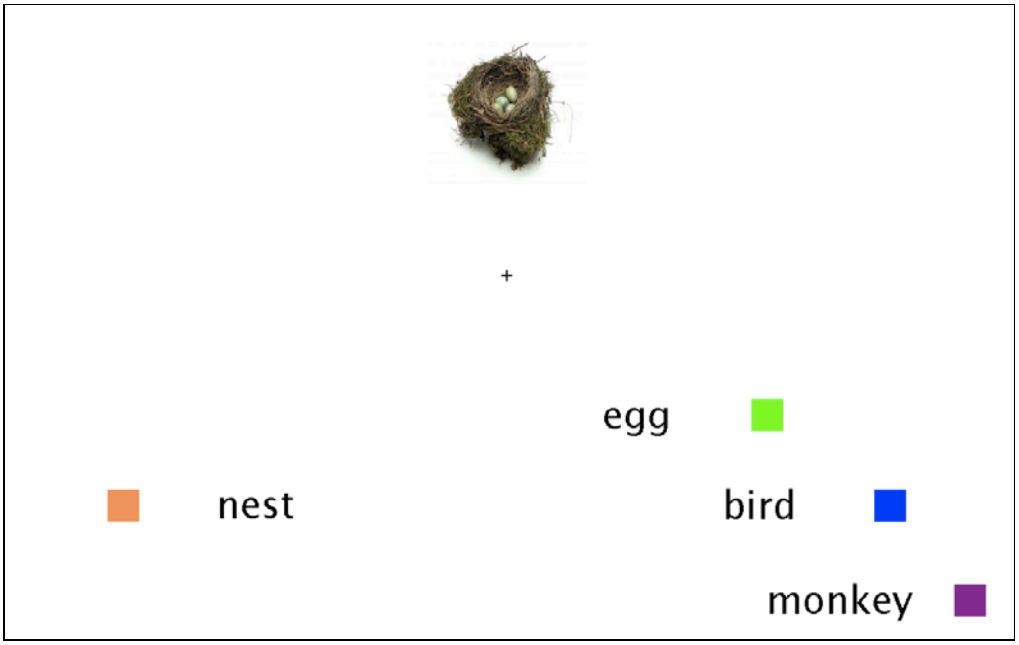

Figure 5. Screen 3 with the correct identity word chosen.

<u>Method</u>: The MTP is constructed as an input-oriented treatment. The patients are not required to speak during the therapy, although most patients did like to practice out loud. The training modules were based on the five identity words whose word families were most difficult to produce, with each patient having his or her specific identity words. Each identity word was able to combine with two morphemes in every morphological domain; thus, ten complex words were trained in each domain. The patients were encouraged to make up complex words with both possible morphemes, but were not required to do so. The task consisted of ten trials. Identity words were presented in random order; however, each identity word was shown in two consecutive trials. The task was repeated up to five times.

<u>Design considerations</u>: The two trials of each identity word were presented consecutively to encourage the patient to select a different complementing morpheme in each trial. In addition, I theorized that providing two morphemes that might combine with the identity word on each screen would illustrate the combinatorial nature of words.

<u>Compromises</u>: None.

3.4.2.2. Task 2: Composing complex words

Goal: This task trained the patient to select an appropriate morpheme to combine with the identity word to form an acceptable complex word. Ultimately, this task required knowledge of the selectional restriction properties of morphemes (i.e., a noun may take the morpheme -*s* as a plural marker, but not all nouns take the past tense affix –*ed*, only those that undergo a conversion).

Introduction: Similar to Task 1, Task 2 required the patient to select morphemes that made up existing words by pressing keys on the computer keyboard. The choices were the same as in Task 1.

Method: The presentation of the task was similar to that for Task 1. First, the screen with the identity word picture and the pronunciation and dictionary aid pictures, then the screen with the morpheme choices was shown; however, in this task, an abstract morpheme structure representation was presented on the screen at the same time as the six morpheme choices (i.e.,  + ____). Upon selection of the identity word, the other two choices on the left screen disappeared. Then the patient selected the other morpheme. Once both morphemes had been selected, the congratulatory screen appeared with the two morphemes replacing the picture and the underlined score in the morpheme structure equation.

Design considerations: As this task was the first morpheme structure equation representation in the series of tasks, it was kept simple with the pictorial representation of the identity word and only one blank space (represented by the line).

Compromises: Although prefixes are also used in this task, the space-keeping line was always represented after the identity word as the identity word had to be selected first.

3.4.2.3. Task 3: Composing complex

Goal: Like the previous tasks, this task trained the patient to choose the exact constituents that may make up possible complex words.

Introduction: Similar to Task 1 and 2, this task required the patient to press keys on the computer key board to select morphemes that made up existing words.

Method: The presentation of the task was similar to that of the previous tasks. First, the screen with the identity word picture and the pronunciation and dictionary aid pictures, then the screen with the morpheme choices was shown; however, in this task, a more abstract morpheme structure representation was presented on the screen at the same time as the six morpheme choices (i.e., ____ + ____). Upon selection of the identity word, the other two choices on the left screen cleared; then the patient selected the second morpheme that might combine with the identity word. Once both morphemes had been selected, the next screen appeared with the two morphemes replacing the underline scores in their correct position.

Design considerations: This morpheme structure representation was a little more complex than the one in the previous task in that both morpheme spaces were represented by a blank space (represented by underscore lines).

Compromises: None.

3.4.2.4. Task 4: Conscious composing and unaware decomposing of complex words

Goal: The goal of this task was to make the composition process consciously apparent to the patient while concurrently causing an unaware decomposition of the presented complex words.

Introduction: This task was the final task of the MTP. As the tasks continuously became a little more complex, this task represented the most challenging activity for the patients. They not only had to fill in the blanks for the whole morpheme structure representation (____ + ____ = ________), but also had to select the items in the right sequential order. In addition, the morpheme choices in this task were somewhat different. Besides the identity word, the semantically related word, and the semantically unrelated word, there were two complex words composed with the identity word and only one other morpheme. Thus, in order to fill in all of the blanks of the morpheme structure equation, the patient first had to identify the constituents in the two complex words that contained the identity word, and then look amongst the morpheme choices to identify which morphemes could be constituents for any one of these complex words. This identification of constituents caused the patients to perform a decomposition process for the complex words.

<u>Method</u>: The treatment administrator told the patient that this task was a little different and, importantly, that this time, the elements that made up the complex words needed to be selected in the correct sequential order. Thus, for example, if the six items *safe, hen, lock, locker, lockable,* and *-er* were shown on the screen with the picture of the identity word LOCK, then *lock* had to be selected first. As soon as it had been selected, it was shown in the first blank position in the equation (*lock* + ____ = __________). Then the morpheme *–er* needed to be selected, and it replaced the second blank spot of the equation (*lock* + *er* = __________). Once the complex word had been selected, the complete morpheme structure equation (*lock* + *er* = *locker*) was shown with the congratulatory message.

<u>Design considerations</u>: As this task was the most difficult, it was explained in particular detail to the patients.

<u>Compromises</u>: None.

3.4.3. Task sequencing

The tasks were administered sequentially as each one increased slightly with complexity. Each stage was administered for a minimum of three times and up to a maximum of five times before moving on. In general, the first task of each module was repeated on the second day of the appropriate module before moving on to the second task; the remaining activities were generally completed within one session (i.e., Task 1 on Day 1; Task 1 and 2 on Day 2; Task 3 on Day 3; and Task 4 on Day 4).

3.5. Treatment type

Similar to the training in Perkins and Hinshelwood's (2007) study in which training focused on thematic roles, the training of the MTP is considered a theoretically motivated treatment. In the MTP, treatment focuses on the kinds of words that are most difficult for individuals with non-fluent aphasia: morphologically complex words. The training is also considered an input-oriented treatment because the patients were encouraged to speak out loud the complex word they trained, but were not required to do so. As each identity word was presented twice in each run of a task, both times with the possibility of composing either of the complex words, the patients were encouraged to compose both versions of complex word forms, but, again, were not required to do so.

Chapter 4

Results

4.0. Introduction

Spontaneous reading aloud of simple and complex words presented on a computer screen resulted in a data set with 11520 observations. 6571 observations were experimental items, and the remaining observations were filler items.

General linear mixed-effects models (Bates, 2005; Bates & Sarkar 2005a; Baayen, Davidson, & Bates, 2008) were fitted to these data by using the lme4 package (Bates & Sarkar, 2005b) in the R statistical programming environment (R Development Core Team, 2005; 2007), with PATIENT and WORD as random effect factors. As fixed-effect factors MORPHOLOGY (monomorphemic, inflected, derived, **compound**; reference level in bold) and TRAINING (**before training**, after training) were considered. The considered covariates are the FREQUENCY of the complex word[2], the frequency of the identity word, and TIME. The frequency of the complex word was assessed through the lemma frequency of the word as listed in CELEX (Baayen, Piepenbrock, & van Rijn, 1993), which is then log-transformed. The frequency of the identity word was assessed in the same way. In our analysis, this predictor never reached significance and hence will not be discussed further. TIME denotes the time at which an experiment was administered expressed in number of days elapsed after the first experiment. Data were collected over a period of approximately four months for each patient. The data collection period divides into four sections as illustrated in Figure 6 for patient JN. Section A represents the three weeks during which pre-training baseline data were collected (Days 1, 7, 13). This baseline period allows us to establish both the severity of the impairment before therapy as well as whether any spontaneous

[2] Although age of acquisition, familiarity, word length, and imageability have been suggested to play a role in the ease of production for individuals with aphasia, the effects of word frequency appear to be the most stable (Nickels & Howard, 1995).

recovery or learning was underway before therapy started. Section B represents the 12 days of training (days 18, 19, 20, 21, 22, 25, 26, 27, 28, 29, 32, 33) during which daily measurements were obtained. Section C represents the three weeks of immediate post-training maintenance with weekly data collection (days 39, 46, 53). Section D represents the long-term maintenance phase with monthly data collection (days 88 and 117).

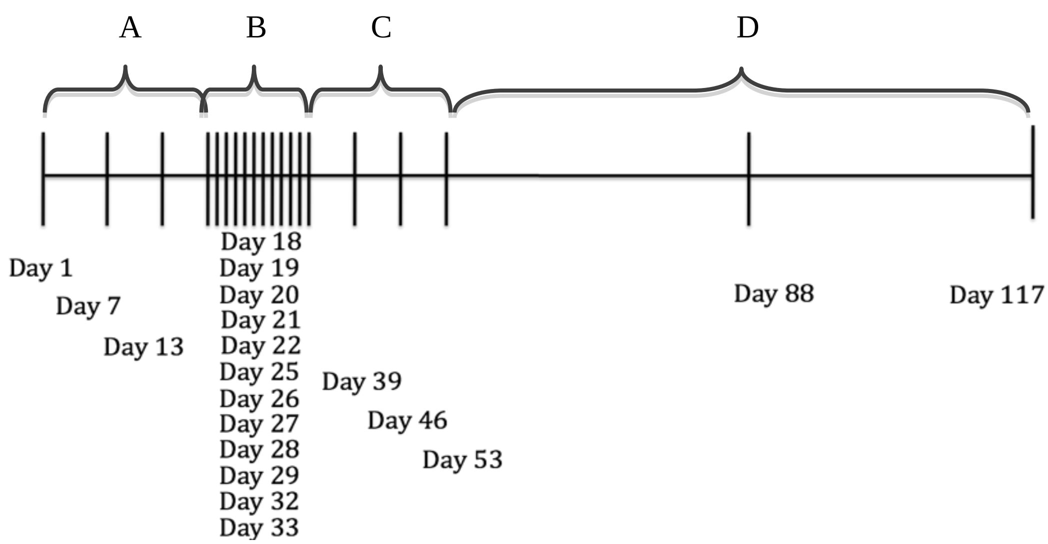

Figure 6. The four phases of data collection for patient JN.

In what follows, first various analyses contrasting the aggregated data collected for data collection phase A with the aggregated data collected during phase C are presented. Then data from all phases using TIME (day index as in Figure 6) as a numeric predictor are analyzed in a regression model with restricted cubic splines (see Section 4.4.1) in order to be able to model nonlinear developments over time.

Psycholinguistic investigations are normally based on group analyses whereas most neurolinguistic analyses investigate both group effects and individual effects of therapies. In this thesis, I present both analyses of individual data and analyses of the joint data of all four patients. For each subanalysis, I first present the analysis for all patients combined which I then follow up with separate analyses for each individual patient.

The subanalyses survey three sets of words: trained words, control words, and words with limited exposure. The analyses of the trained words investigate whether a training effect is realized with the training set, the words that the patients were actually trained on and with which they practiced repeatedly during phase B. The analyses of the control words aim to determine whether the practice received for the training words transferred to words with which they had not practiced, but that they had read aloud throughout phase B. Finally, the analyses of the words with limited exposure investigated whether transfer generalized to words that they had not encountered during training phase B. These three sets of words were investigated separately as previous studies reported therapy effects to be inconsistent across trained and untrained words (e.g., Wambaugh & Ferguson, 2007; Rider et al., 2008), and as the preservation of therapy effects may vary (e.g., Wambaugh & Ferguson, 2007).

In the final section of this chapter, I briefly discuss the results of the ALFAB tests administered to the patients. These tests show that patients improved not only in morphological processing, but also in other aspects of linguistic competence.

4.1. Trained words – Pre-post analysis

The data for this analysis were obtained from the three pre-therapy baseline testing sessions (phase A) and the three immediate post-therapy maintenance testing sessions (phase C), resulting in 840 observations.

4.1.1. Joint analysis

Logistic mixed-effects analyses (using a logit link and binominal variance) with random intercepts for PATIENT and ITEM were carried out with accuracy of response as the dependent variable and with MORPHOLOGY, TRAINING (contrasting phase A with phase C), and FREQUENCY as predictors. In this analysis, as in the analyses to follow, the most parsimonious model that adequately fits the data are presented. Predictors and interactions that are not listed in the tables of coefficients did not reach significance and were removed from the model specification.

Table 12

Fixed-effect coefficients (on the logistic scale) in a mixed-effects model fitted to reading aloud accuracy for trained words with an accuracy score timeline of three weeks post-therapy for four patients. Higher coefficients indicate higher likelihood of correct responses.

	Estimate	Std. Error	Z value	P value
(Intercept)	0.0852	0.3171	0.269	0.7880
TRAINING: Contrast before ↔ after	3.4681	0.6687	5.187	<0.0001
MORPHOLOGY: Contrast C ↔ D	-1.8010	0.4234	-4.254	<0.0001
MORPHOLOGY: Contrast C ↔ I	-1.9666	0.4778	-4.116	<0.0001
MORPHOLOGY: Contrast C ↔ M	-0.3975	0.7043	-0.564	0.5725
Contrast TRAINING before ↔ after by contrast MORPHOLOGY C ↔ D	-0.4226	0.7895	-0.535	0.5924
Contrast TRAINING before ↔ after by contrast MORPHOLOGY C ↔ I	-2.0906	0.8241	-2.537	0.0112
Contrast TRAINING before ↔ after by contrast MORPHOLOGY C ↔ M	12.7763	985.6655	0.013	0.9897
Slope log(FREQUENCY)	0.2419	0.0831	2.911	0.0036

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

Table 12 lists the coefficients of the resulting regression model. The INTERCEPT represents the group average for compounds before training with zero log frequency. The INTERCEPT is close to zero, indicating near chance performance for compounds with an absolute frequency equal to one. This baseline does not represent actual compounds presented to the patients, which were all of much higher frequency. The large positive and significant contrast coefficient for TRAINING indicates substantial improvement in performance for the compounds. The negative contrast coefficients for MORPHOLOGY indicate that the other morphological types did not reach the same high level of performance. Only the monomorphemic words revealed a level of proficiency that did not differ significantly from that of the compounds. The interaction of MORPHOLOGY by

TRAINING is characterized by only one significant contrast indicating that the training effect was reduced for the inflected words. Finally, the significant positive slope for FREQUENCY shows that, as expected, higher frequency words elicited more correct responses.

Figure 7 summarizes the model graphically. The left panel illustrates the increase in accuracy observed after therapy. After therapy, performance is near ceiling except for inflected words. The right panel presents the effect of FREQUENCY, which is linear on the logit scale, but emerges as nonlinear on the proportion scale. It is clear that therapy resulted in a considerable improvement in performance. However, compared to derived words the therapy was much less effective for inflected words.

The present results partially replicate previous findings that before therapy complex words are more difficult to produce for individuals with aphasia than monomorphemic words (e.g., Nasti & Marangolo, 2005). For the present group of patients, this initial processing difficulty is restricted to complex words with bound morphemes: performance for compounds starts out at an even slightly higher level of proficiency than that of monomorphemic words.

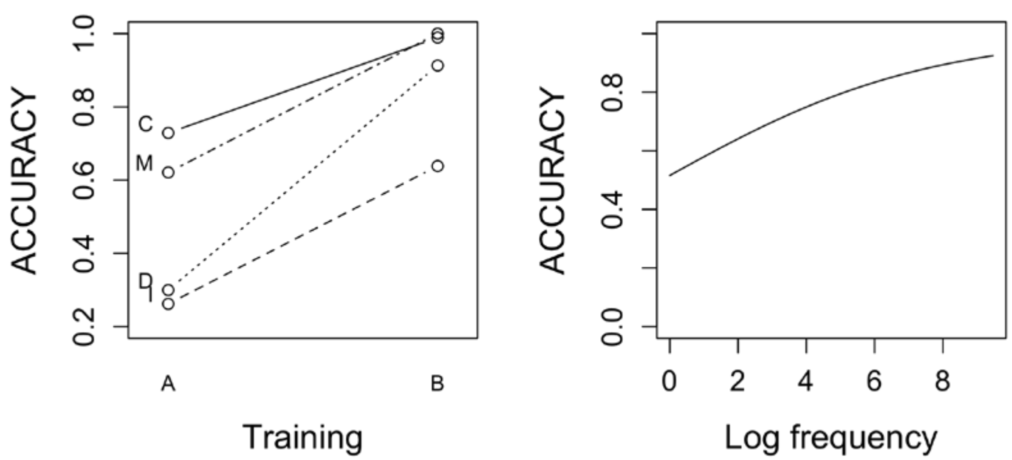

Figure 7. Reading-aloud accuracy scores for trained words as a function of MORPHOLOGY (left) and FREQUENCY (right), for all four patients. Left panel: A: before therapy, B: after therapy; C: compounds, M: monomorphemic words, I: inflected words, D: derived words. All curves are adjusted for median frequency. The right panel represents the frequency effect for compounds before therapy.

The effect of FREQUENCY mirrors results of naming studies that observed a positive correlation between word frequency and naming accuracy for people with aphasia (e.g., Newcombe, Oldfield, & Wingfield, 1965; Cuetos, Aguado, Izura, & Ellis, 2002; Bormann, Kulke, & Blanken, 2008).

Recall that PATIENT was included as a random-effect factor. Thus, the coefficients in the model listed in Table 7 allow the effect of the therapy to be predicted for an unseen patient from the same population of non-fluent individuals with aphasia. The estimated standard deviation for the random intercepts for PATIENT was 0.7693. The other random effect factor included in the model is ITEM. Including ITEM as a random effect allows the effects of the therapy to generalize to unseen words sampled from the same population of relatively common English words. The estimated standard deviation for the random intercepts for ITEM was 0.2638. More complex random effects structure was considered, but found to be superfluous.

4.1.2. Trained words tested for short-term effect in individual patients

This section investigates the MTP learning effects in individual patients. Although effects may be significant in a group analysis, Nickels and Howard (1995) indicated that frequency effects, for example, might not be found for all patients. In order to investigate the learning effect of TRAINING as well as the effects of MORPHOLOGY and FREQUENCY, each patient's reading-aloud accuracy scores were individually analyzed in regression analyses.

4.1.2.1. Trained words tested for short-term effect – patient DR

For technical reasons, that will become apparent below, I begin with presenting the results of a classification tree analysis using the `party` package (Hothorn, Hornik, & Zeileis, 2006). The resulting conditional inference tree, which provides a nonparametric model for the data, is shown in Figure 8. The first split in the tree is based on the factor TRAINING (Node 1). A Bonferroni-adjusted p-value associated with a test evaluating the significance of the split is provided for each node. The split on training receives good support (*p* <0.001).

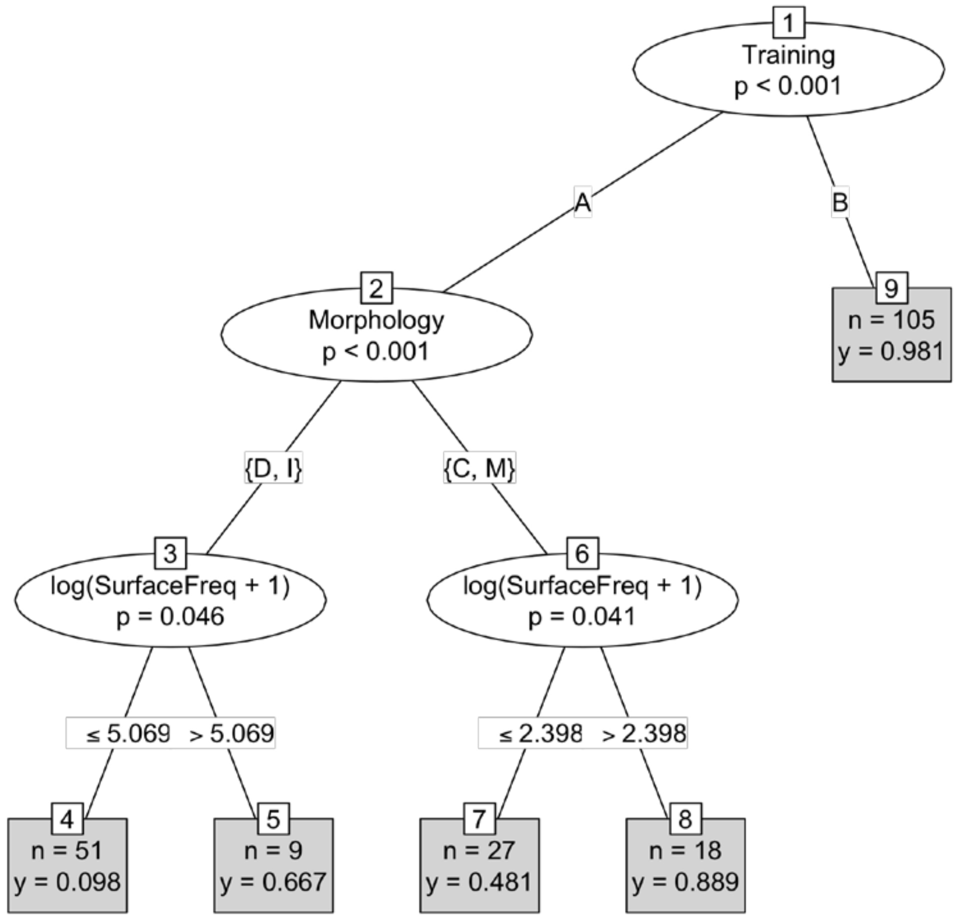

Figure 8. Conditional classification tree for the realization of reading aloud trained words accurately for patient DR. A: before therapy, B: after therapy; C: compounds, M: monomorphemes, I: inflected words, D: derived words. For each inner node, the Bonferroni-adjusted *P*-values are given.

Before MTP training (Branch A), a further split is based on MORPHOLOGY, distinguishing between derived and inflected word (D+I) on one hand and compounds and monomorphemic words (C+M) (*p* = 0.001). Within each of these subsets, further splits are based on FREQUENCY. After training (Branch B), performance is at ceiling (98.1% correct) for all morphological types, irrespective of FREQUENCY.

When using logistic modeling, the interpretation of the coefficients is rendered more difficult due to performance reaching ceiling after training, which is reflected in very large contrast coefficients. The model does not capture well the interaction of MORPHOLOGY by TRAINING and FREQUENCY by TRAINING that is clearly visible to the non-parametric method. Although the two models make very similar predictions, the classification tree provides the more insightful model. For instance, with performance at ceiling after training, it does not make much sense for a frequency effect to modulate performance: because we are at the boundary, the percentual increase in accuracy after training is negligible.

Table 13

Fixed-effect coefficients (in logistic scale) in a mixed-effects model fitted to reading-aloud accuracy for trained words as measured with the three-week baseline measurements and the three-week maintenance measurements for patient DR. The estimated standard deviation for the random intercepts for ITEM *was 1.1338.*

	Estimate	Std. Error	Z value	P value
(INTERCEPT)	-0.5155	0.6108	-0.844	0.3987
TRAINING: Contrast before ↔ after	6.2124	1.0144	6.124	<0.0001
MORPHOLOGY: Contrast C ↔ D	-3.3118	1.0294	-3.217	0.0013
MORPHOLOGY: Contrast C ↔ I	-3.7065	1.1907	-3.113	0.0018
MORPHOLOGY: Contrast C ↔ M	-0.4377	1.6357	-0.268	0.7890
Slope log(FREQUENCY)	0.4999	0.2283	2.190	0.0285

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

Figure 8 shows a dramatic improvement after training for patient DR especially for the lower frequency categories. Low frequency derived and inflected words that were at an accuracy rate of barely ten percent before therapy attained an accuracy rate of 98.1 percent after training, while the higher frequency derived and inflected words started off at 66.7 percent. Low frequency compounds and monomorphemes reached ceiling after an accuracy increase of 50 percent. It is only for the higher frequency compounds that an accuracy increase of a mere ten percent is observed. This patient is really exceptional and it may possibly have to do with the fact that intervention took place only four years after onset or the fact that her age at the time of stroke was much younger than that of the other patients (39 versus 59-70).

4.1.2.2. Trained words tested for short-term effect – patient DP

The coefficients of the logistic regression model fitted to DP's data set are listed in Table 14. The large positive contrast coefficient for TRAINING bares witness to a significant improvement in reading performance for compounds. Performance was worse for inflected, derived, and monomorphemic words, but significantly worse only for inflected words. Higher frequency words elicited higher accuracy scores as expected.

Table 14

Fixed-effect coefficients (in logistic scale) in a mixed-effects model fitted to reading-aloud accuracy for trained words as measured with the three-week baseline measurements and the three-week maintenance measurements for patient DP.

	Estimate	Std. Error	Z value	P value
(Intercept)	-1.0674	0.4780	-2.233	0.0255
TRAINING: Contrast before ↔ after	3.0329	0.4419	6.863	<0.0001
MORPHOLOGY: Contrast C ↔ D	-1.0178	0.6890	-1.477	0.1396
MORPHOLOGY: Contrast C ↔ I	-2.7152	0.8173	-3.322	0.0009
MORPHOLOGY: Contrast C ↔ M	-1.9727	1.1383	-1.733	0.0831
Slope log(FREQUENCY)	0.4134	0.1268	3.260	0.0011

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

Figure 9 presents the accuracy scores as a function of TRAINING, MORPHOLOGY, and FREQUENCY for patient DP. The left panel illustrates that for patient DP, the accuracy scores improved to ceiling level after therapy. Although for most individuals with aphasia monomorphemic words are easiest to produce, patient DP encountered difficulties with them prior to therapy comparable with his difficulties with inflected words (centre panel). Patient DP erroneously added a morpheme to the monomorphemic targets; he also substituted the target monomorphemic word more often that the other patients. Reading-aloud accuracy markedly increased for words with higher frequencies (right panel).

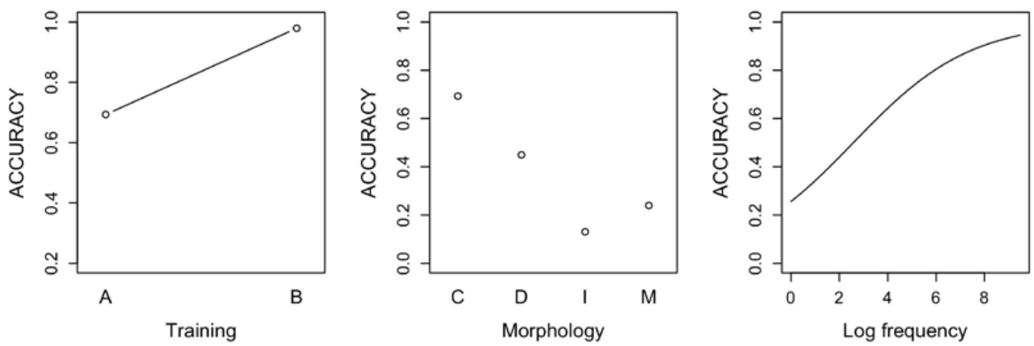

Figure 9. Reading-aloud accuracy scores as a function of TRAINING (left), MORPHOLOGY (centre), and FREQUENCY (right) for trained words - patient DP. Left panel: A: before therapy, B: after therapy; Centre panel: C: compounds, M: monomorphemic words, I: inflected words, D: derived words.

The training effect in logits is shown in the top left panel of Figure 10. This effect of training was identical across all four morphological types. However, due to their different initial baselines, in combination with the nonlinearity of the transformation from logits to proportions, the learning effect expressed in proportions is quite different for the four morphological types as can be seen in the remaining panels of Figure 10. Proportionally, the biggest increase in reading-aloud accuracy is seen for the simple words (top row, centre panel) and for the inflected words (bottom row, right column).

The estimated standard deviation for the random intercepts for ITEM was 0.7892.

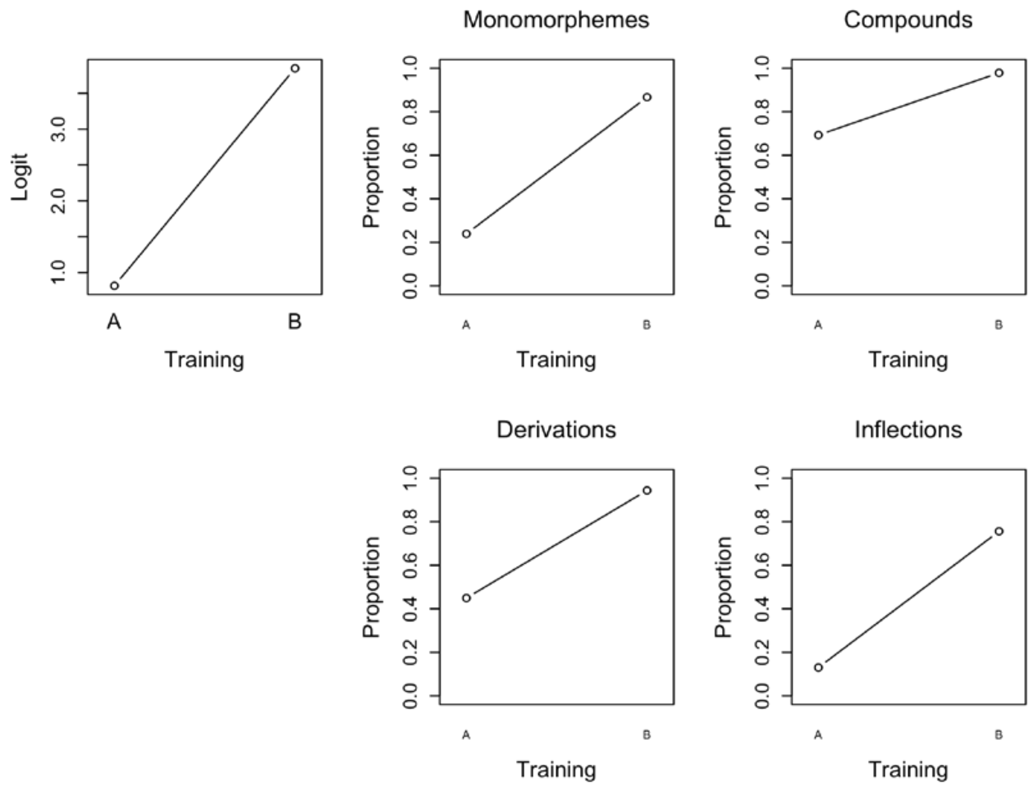

Figure 10. Reading-aloud accuracy scores for trained words as a function of TRAINING shown with the logit scale (on the y-axis) as predicted by the regression model (top left panel) and backtransformed from the logits predicted by the regression model to proportions (on the y-axis) for monomorphemes (top centre), compounds (top right), derivations (bottom left), and inflections (bottom right) - patient DP. A: before therapy, B: after therapy.

4.1.2.3. Trained words tested for short-term effect – patient PH

The general pattern for patient PH is very similar to that for patient DP. The main difference is that PH does not appear to be sensitive to differences in word frequency: the slope for frequency in Table 15 does not even approach significance. This corroborates with Nickels and Howard (1995) who indicated that frequency effects are not always observed for all patients.

Table 15

Fixed-effect coefficients (in logistic scale) in a mixed-effects model fitted to reading-aloud accuracy for trained words as measured with the three-week baseline measurements and the three-week maintenance measurements for patient PH.

	Estimate	Std. Error	Z value	P value
(INTERCEPT)	2.1064	0.6116	3.444	0.0006
TRAINING: Contrast before ↔ after	1.9678	0.4091	4.811	<0.0001
MORPHOLOGY: Contrast C ↔ D	-2.4229	0.7525	-3.220	0.0013
MORPHOLOGY: Contrast C ↔ I	-2.9893	0.7553	-3.958	<0.0001
MORPHOLOGY: Contrast C ↔ M	-0.8567	1.2744	-0.672	0.5014
Slope log(FREQUENCY)	0.1049	0.1438	0.729	0.4658

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

Figure 11 illustrates the reading-aloud accuracy improvement for compounds (left panel). Prior to therapy, words with bound morphemes were most difficult for patient PH (centre panel). The positive, albeit non-significant, slope for FREQUENCY is shown in the right panel.

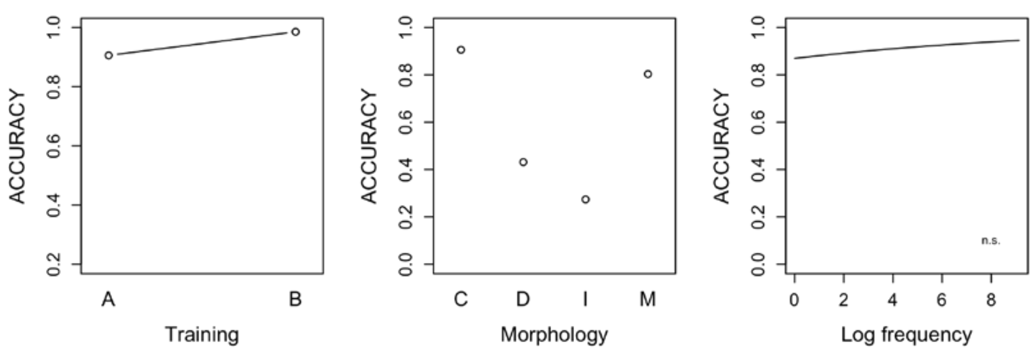

Figure 11. Reading-aloud accuracy scores as a function of TRAINING for all morphological domains (left), MORPHOLOGY (centre), and FREQUENCY for trained words - patient PH. Left panel: A: before therapy, B: after therapy; Centre panel: C: compounds, M: monomorphemic words, I: inflected words, D: derived words.

The substantial learning effect for derivations and inflections is shown in Figure 12 (bottom row, left column and bottom row, right panel, respectively).

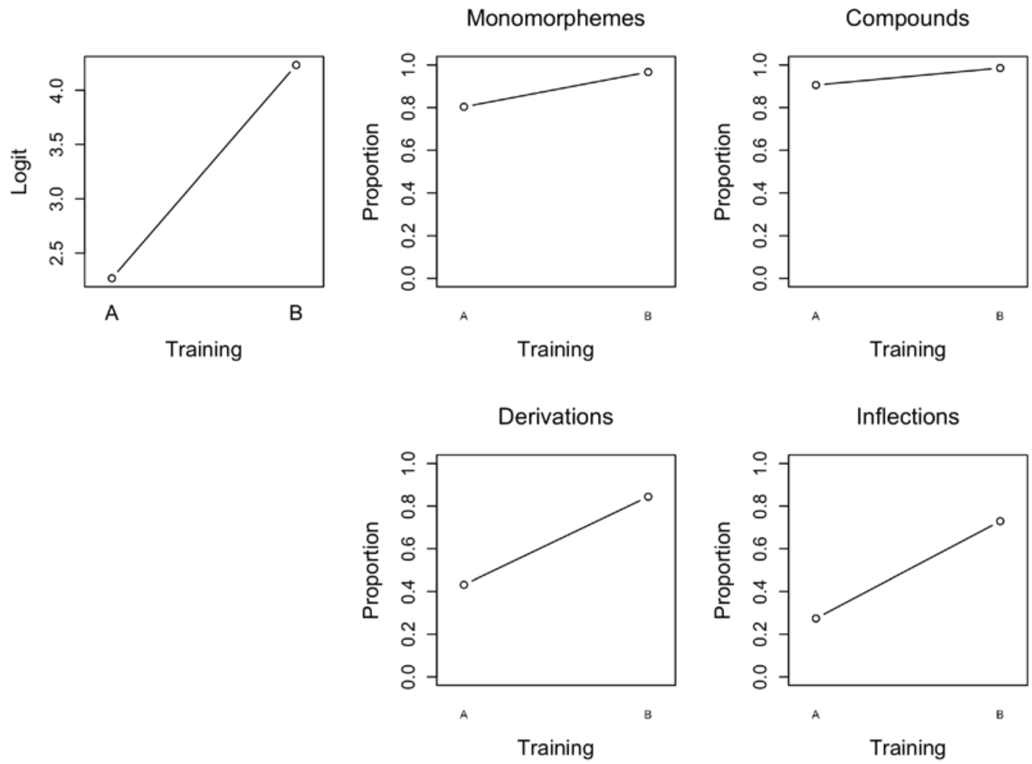

Figure 12. Reading-aloud accuracy scores for trained words as a function of TRAINING shown with the logit scale (on the y-axis) as predicted by the regression model (top left panel) and backtransformed from the logits predicted by the regression model to proportions (on the y-axis) for monomorphemes (top centre), compounds (top right), derivations (bottom left), and inflections (bottom right) - patient PH. A: before therapy, B: after therapy.

The estimated standard deviation for random intercepts for ITEM pertaining to patient PH was 0.9390.

4.1.2.4. Trained words tested for short-term effect – patient JN

The results for patient JN mirror those for patient PH. As for patient PH, the inflected and the derived words posed the largest challenge before training and benefitted most (proportionally) from therapy. The slope for FREQUENCY failed to reach significance under a stringent two-tailed test ($p < 0.08$). The partial effects for patient JN are shown in Figures 13 and 14.

Table 16

Fixed-effect coefficients (in logistic scale) in a mixed-effects model fitted to reading-aloud accuracy for trained words as measured with the three-week baseline measurements and the three-week maintenance measurements for patient JN.

	Estimate	Std. Error	Z value	P value
(INTERCEPT)	0.9592	0.5125	1.872	0.0613
TRAINING: Contrast before ↔ after	1.5071	0.3765	4.003	<0.0001
MORPHOLOGY: Contrast C ↔ D	-2.2887	0.7050	-3.246	0.0012
MORPHOLOGY: Contrast C ↔ I	-3.5349	0.8495	-4.161	<0.0001
MORPHOLOGY: Contrast C ↔ M	0.5510	1.6139	0.341	0.7328
Slope log(FREQUENCY)	0.2597	0.1497	1.734	0.0828

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

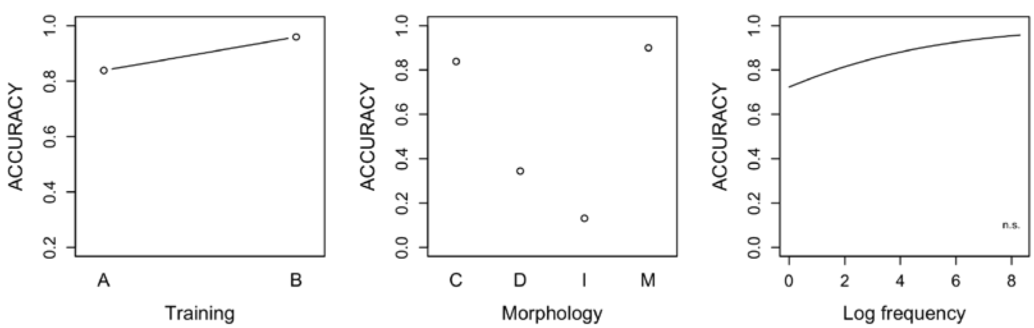

Figure 13. Reading-aloud accuracy scores as a function of TRAINING, MORPHOLOGY, and FREQUENCY for trained words - patient JN. Left panel: A: before therapy, B: after therapy; Centre panel: C: compounds, M: monomorphemic words, I: inflected words, D: derived words.

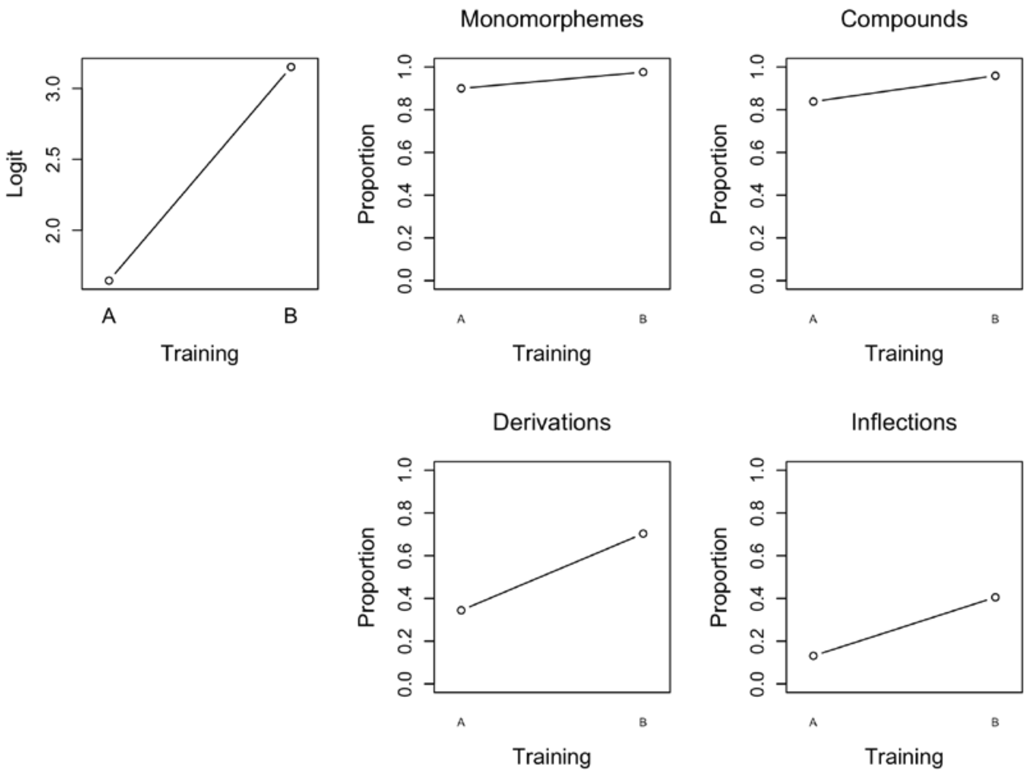

Figure 14. Reading-aloud accuracy scores for trained words as a function of TRAINING shown with the logit scale (on the y-axis) as predicted by the regression model (top left panel) and backtransformed from the logits predicted by the regression model to proportions (on the y-axis) for monomorphemes (top centre), compounds (top right), derivations (bottom left), and inflections (bottom right) - patient JN. A: before therapy, B: after therapy.

The standard deviation for the random intersect for item for JN's analysis of trained words was estimated to be 0.9854.

4.1.3. Discussion

The results of the pre-therapy versus short-term post-therapy analyses of trained items suggest that patients' reading-aloud difficulties in complex words can be remediated with a therapy that specifically addresses morphological deficits. The efficacy of the MTP emerged not only in the analysis of the joint data, but also found support in analyses scrutinizing the individual patients. FREQUENCY was estimated to be a significant predictor for improved accuracy in the joint analysis; however, although the frequency effect emerged with the expected positive coefficient for all patients, it reached significance only for DR and DP. This lack of significance has two possible sources. On the one hand, it might be due to a genuine absence of sensitivity to frequency for these two patients. On the other hand, it might be due to a lack of power for the smaller data sets of the individual patients. Interestingly, the joint analysis of all four patients' data shows that by-subject random slopes for frequency are not justified (χ^2 (2) = 1.018, p = 0.6, likelihood ratio test). In other words, there is no reason to suppose that the effect of frequency really differs across patients. Note, finally, that the frequency effect emerges in Figure 6 with an effect size similar to that of the effect of training.

The individual analyses suggested some minor differences between the patients with respect to their accuracies across the different morphological types. However, adding random contrasts did not result in a model with superior log-likelihood (χ^2 (9) = 11.034, p = 0.2734).

A striking feature of the present data is that the monomorphemic words and the compounds pattern together in opposition to the derived and inflected words. Patients performed with higher degrees of accuracy for the compounds and monomorphemic words as flipside of the same coin that the effect of therapy was much larger for the derived and inflected words. This finding contrasts with the general observation (see, e.g., Nasti & Marangolo, 2005) that complex words are more difficult than simple words. Although the inflected and derived words revealed impaired accuracy compared to the monomorphemic words, as expected, the compounds showed a very similar level of accuracy.

This discrepancy may be due to three factors. First, note that the articulatory gestures required for a monomorphemic word like *book* are very similar to the articulatory gestures for the first constituent of *bookcase.* By contrast, inflected forms such as *books* and *booked* require the planning of a complex coda and of resyllabification respectively. In other words, from an articulatory perspective, the monomorphemic words and compounds are much more similar to each other than the monomorphemic words and the inflections and derivations. Second, a given word occurs more than once in our experimental lists, not only as a bare stem, but also as a constituent in other forms. As a consequence, priming of words sharing the constituents may have occurred. This priming effect may have been larger for those pairs of words with more similar articulatory gestures, resulting in the attenuation of the processing advantage of monomorphemic words compared to compounds. Finally, noun-noun compounding in Italian is much less productive than in English, which leads one to expect greater processing difficulties for Italian speakers compared to English speakers.

Although these results are encouraging, some might argue that the patients' success was not due to relearning or strengthening underlying morphological processes, but, rather, to learning the therapy words by heart, particularly since analyzed words were extensively trained daily over twelve therapy days. Accordingly, two additional sets of investigations were carried out, one with control words, one with new words. The control words are words that were tested every testing session, but not trained. The new words are words that had limited exposure at pre- and post-training sessions only. They were tested only in the baseline and maintenance measurements, and, therefore, an average of 26 days intervened between the pre- and post-testing of new words. The response accuracy of reading out loud control words is discussed in the next section.

4.2. Control words – Pre-post analysis

The data for this analysis were obtained from the three pre-therapy baseline testing sessions (phase A) and the three immediate post-therapy maintenance testing sessions (phase C), resulting in 840 observations.

4.2.1. Joint analysis

Table 17 lists the coefficients of the logistic regression model for response accuracy.

Table 17

Fixed-effect coefficients (in logistic scale) in a mixed-effects model fitted to reading-aloud accuracy for control words as measured with the three-week baseline measurements and the three-week maintenance measurements for four patients.

	Estimate	Std. Error	Z value	P value
(Intercept)	1.00788	0.4736	2.128	0.0333
TRAINING: Contrast before ↔ after	1.56627	0.7649	2.048	<0.0406
MORPHOLOGY : Contrast C ↔ D	-1.33656	0.4337	-3.082	0.0020
MORPHOLOGY : Contrast C ↔ I	-2.76680	0.4763	-5.809	<0.0001
MORPHOLOGY : Contrast C ↔ M	-1.38618	0.7334	-1.890	0.0588
Slope log(FREQUENCY)	0.29335	0.0830	3.536	0.0004

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

It is clear that therapy resulted in an improvement in performance across all morphological types, as shown by the significant contrast coefficient for TRAINING (1.566). The effect of training was modulated by an interaction with patient as indicated by a likelihood-ratio test comparing models with and without random by-patient contrasts for training ($\chi^2(2) = 35.43$, $p < 0.0001$). The random contrasts were 0.137 for patient DR, 2.03 for patient DP, -1.68 for patient JN, and -0.74 for patient PH. To obtain precise estimates of the treatment effect for each individual patient, these random contrasts have to be added to the population contrast from the table of coefficients, 1.566. It is therefore anticipated that in the separate analyses of the individual patients, the effect of treatment will not be significant for patient JN.

The negative contrast coefficients for MORPHOLOGY indicate that compared to compounds, the other three morphological types started out before training with a greater impairment, although not significantly so for the monomorphemic words. As the effect of training is not as large for these control words as for the words on which the patients received training, performance does not reach ceiling after training, and notably so for the inflected words (see Figure 16). The significant positive slope for FREQUENCY demonstrates that higher frequency words elicited more correct responses, as expected. Its partial effects of the model are shown in the right panel of Figure 15.

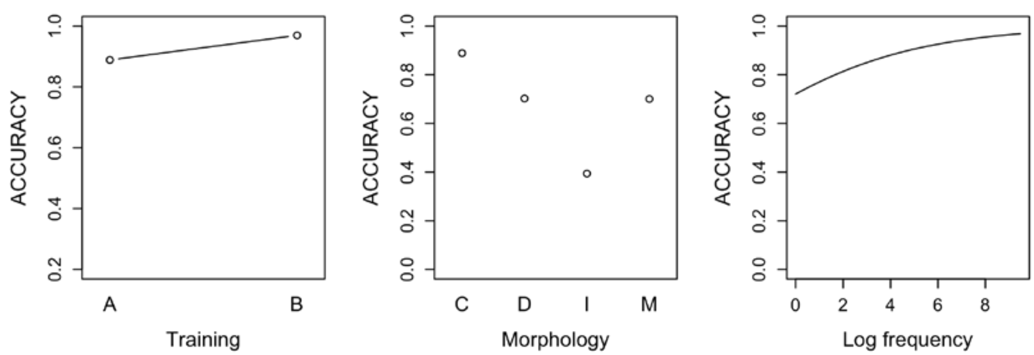

Figure 15. Reading-aloud accuracy scores for control words as a function of TRAINING (left), MORPHOLOGY (centre), and FREQUENCY (right) for all four patients. Left panel: A: before therapy, B: after therapy; C: compounds, M: monomorphemic words, I: inflected words, D: derived words. All curves are adjusted for median frequency. The right panel represents the frequency effect for compounds before therapy.

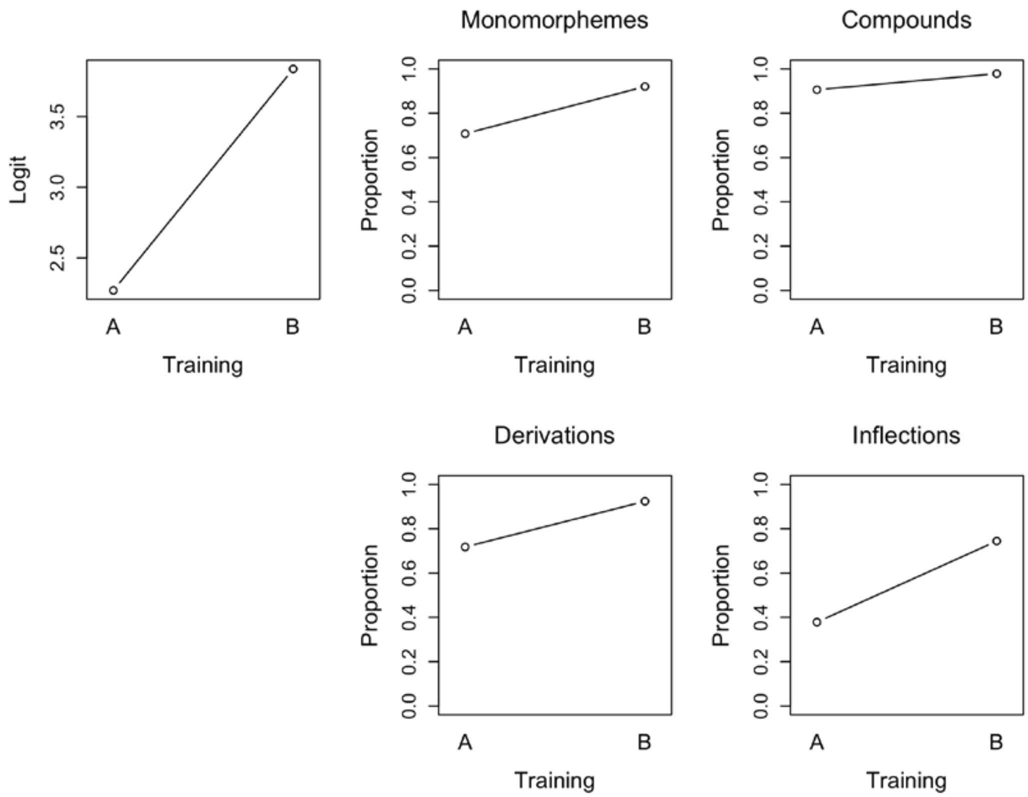

Figure 16. Reading-aloud accuracy scores as a function of TRAINING shown with the logit scale (on the y-axis) as predicted by the regression model (top left panel) and backtransformed from the logits predicted by the regression model to proportions (on the y-axis) for monomorphemes (top centre), compounds (top right), derivations (bottom left), and inflections (bottom right) for control words, for all four patients. A: before therapy, B: after therapy.

The estimated standard deviation for the random intercepts for PATIENT was 0.6657. The estimated standard deviation for the random intercepts for ITEM was 0.9075.

4.2.2. Control words – individual patients

4.2.2.1. Control words – patient DR

The logistic regression analysis for patient DR is summarized in Table 18. The large positive coefficient for TRAINING signifies that therapy effects are carried over to control words. FREQUENCY and MORPHOLOGY were not found to be significant for the data of this patient considered just by itself.

Table 18

Fixed-effect coefficients (in logistic scale) in a mixed-effects model fitted to reading-aloud accuracy for control words as measured with the three-week baseline measurements and the three-week maintenance measurements for patient DR.

	Estimate	Std. Error	Z value	P value
(Intercept)	0.7458	1.0935	0.682	0.495
TRAINING: Contrast before ↔ after	5.4695	0.9448	5.789	<0.0001
MORPHOLOGY: Contrast C ↔ D	-1.7473	1.4382	-1.215	0.224
MORPHOLOGY: Contrast C ↔ I	-1.8459	1.6019	-1.152	0.249
MORPHOLOGY: Contrast C ↔ M	3.1416	3.0068	1.045	0.296
Slope log(FREQUENCY)	0.0568	0.2649	0.214	0.830

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

The partial effects of the coefficients are presented in Figures 17 and 18.

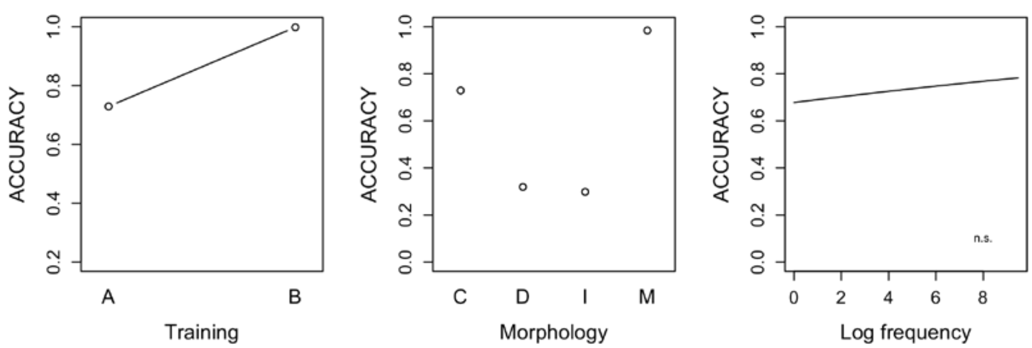

Figure 17. Reading-aloud accuracy scores for control words as a function of TRAINING, MORPHOLOGY, and log-transformed FREQUENCY - patient DR. Left panel: A: before therapy, B: after therapy; C: compounds, M: monomorphemic words, I: inflected words, D: derived words.

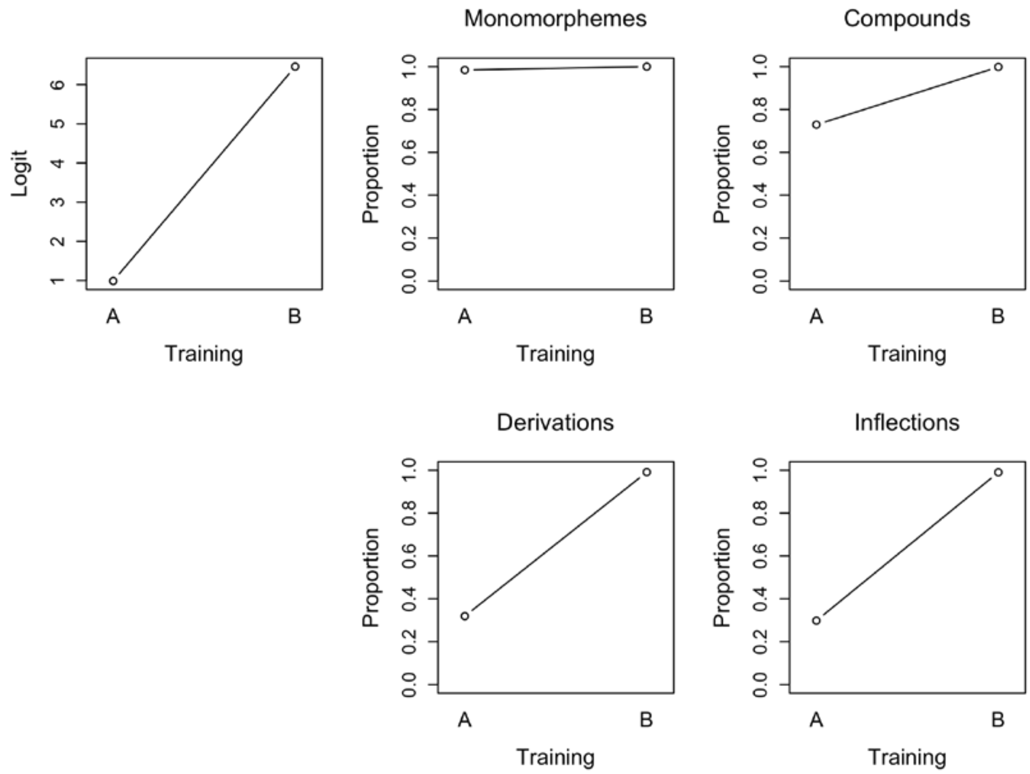

Figure 18. Reading-aloud accuracy scores for control words as a function of TRAINING shown with the logit scale (on the y-axis) as predicted by the regression model (top left panel) and backtransformed from the logits predicted by the regression model to proportions (on the y-axis) for monomorphemes (top centre), compounds (top right), derivations (bottom left), and inflections (bottom right) – patient DR. A: before therapy, B: after therapy.

The estimated standard deviation for the random effect of ITEM with 35 levels was 2.5334.

4.2.2.2. Control words – patient DP

The positive contrast coefficient for TRAINING of compounds in Table 19 shows that the training effects seen in trained words for patient DP again extend to control words. This patient had greater initial problems with inflected words as indicated by the significant negative contrast coefficients in Table 19. FREQUENCY did not affect reading-aloud accuracy before training when a conservative two-tailed test is used.

Table 19

Fixed-effect coefficients (in logistic scale) in a mixed-effects model fitted to reading-aloud accuracy for control words as measured with the three-week baseline measurements and the three-week maintenance measurements for patient DP.

	Estimate	Std. Error	Z value	P value
(INTERCEPT)	0.3815	0.7757	0.492	0.6228
TRAINING: Contrast before ↔ after	2.0665	0.4136	4.997	<0.0001
MORPHOLOGY: Contrast C ↔ D	-1.8004	0.9154	-1.967	0.0492
MORPHOLOGY: Contrast C ↔ I	-2.7856	1.0085	-2.762	0.0057
MORPHOLOGY: Contrast C ↔ M	-2.0765	1.5556	-1.335	0.1819
Slope log(FREQUENCY)	0.3709	0.2072	1.790	0.0735

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

The partial effects of the regression model for patient DP are visualized in Figures 19 and 20.

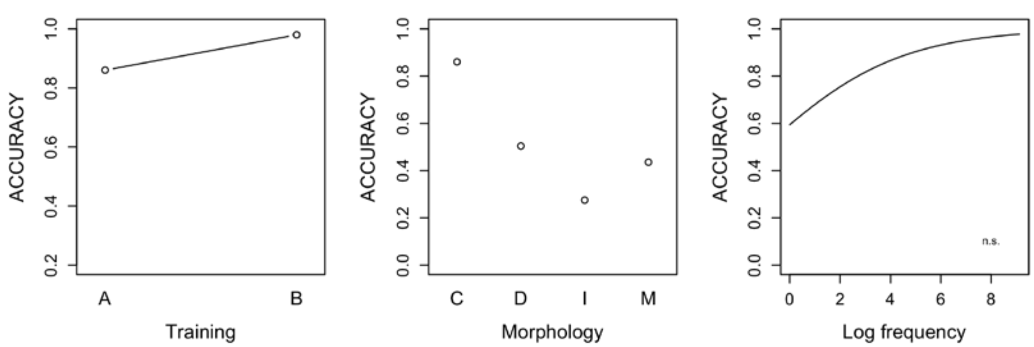

Figure 19. Reading-aloud accuracy scores for control words as a function of TRAINING, MORPHOLOGY, and log-transformed FREQUENCY - patient DP. Left panel: A: before therapy, B: after therapy; C: compounds, M: monomorphemic words, I: inflected words, D: derived words.

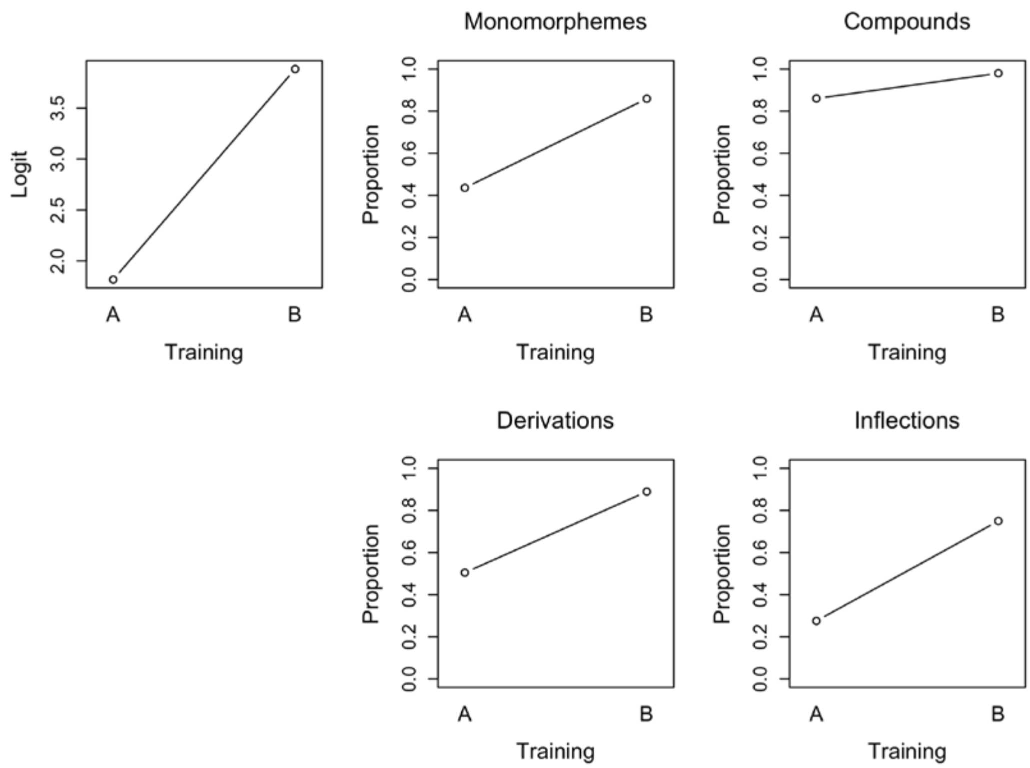

Figure 20. Reading-aloud accuracy scores for control words as a function of TRAINING shown with the logit scale (on the y-axis) as predicted by the regression model (top left panel) and backtransformed from the logits predicted by the regression model to proportions (on the y-axis) for monomorphemes (top centre), compounds (top right), derivations (bottom left), and inflections (bottom right) – patient DP. A: before therapy, B: after therapy.

The estimated standard deviation for random intercepts for ITEM was 1.5649.

4.2.2.3. Control words – patient PH

Table 20 shows that for patient PH, TRAINING hardly improved the reading-out loud ability of control words. The effect of training for control words for patient PH is significant only under a one-tailed test, the use of which is defendable as the effect of training is in the expected direction. As for patient DP, the inflected words were especially challenging before therapy, and although performance improved significantly further room for improvement remains (see Figure 22). The positive significant slope for FREQUENCY indicates that higher frequency words attained higher accuracy both before and after therapy.

Table 20

Fixed-effect coefficients (in logistic scale) in a mixed-effects model fitted to reading-aloud accuracy for control words as measured with the three-week baseline measurements and the three-week maintenance measurements for patient PH.

	Estimate	Std. Error	Z value	P value
(INTERCEPT)	1.1832	0.5101	2.320	0.0204
TRAINING: Contrast before ↔ after	0.9034	0.4634	1.950	0.0512
MORPHOLOGY: Contrast C ↔ D	-0.1979	0.8092	-0.245	0.8068
MORPHOLOGY: Contrast C ↔ I	-3.6971	0.8094	-4.568	<0.0001
MORPHOLOGY: Contrast C ↔ M	-1.9364	1.4539	-1.332	0.1829
Slope log(FREQUENCY)	0.4979	0.1444	3.448	0.0006

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

Figures 21 and 22 visually present the partial effects of the regression model in Table 20.

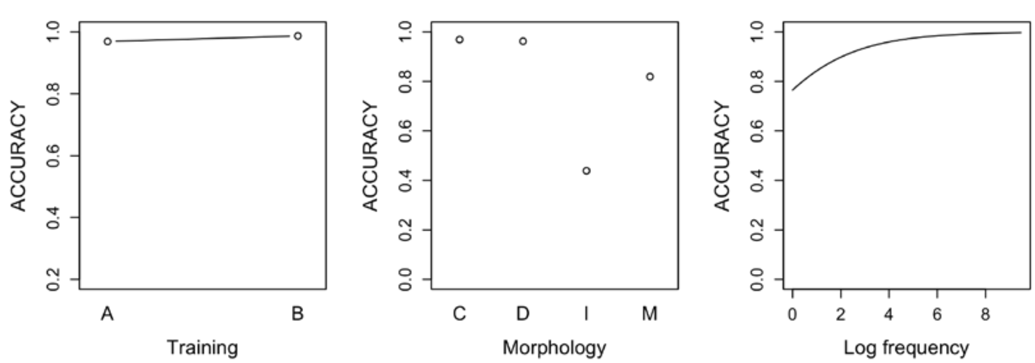

Figure 21. Reading-aloud accuracy scores for control words as a function of training, morphology, and log-transformed surface frequency - patient PH. Left panel: A: before therapy, B: after therapy; C: compounds, M: monomorphemic words, I: inflected words, D: derived words.

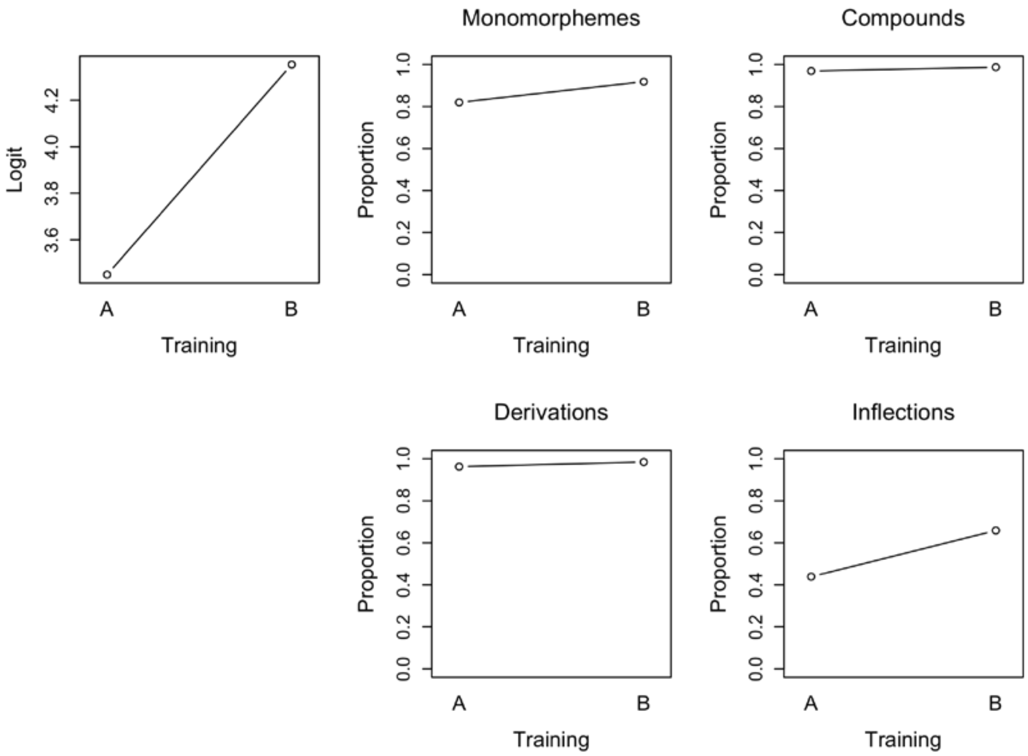

Figure 22. Reading-aloud accuracy scores for control words as a function of TRAINING shown with the logit scale (on the y-axis) as predicted by the regression model (top left panel) and backtransformed from the logits predicted by the regression model to proportions (on the y-axis) for monomorphemes (top centre), compounds (top right), derivations (bottom left), and inflections (bottom right) – patient PH. A: before therapy, B: after therapy.

The only random effect in this model was 0.2869 for ITEM.

4.2.2.4. Control words – patient JN

Table 21 presents the results of the regression analysis for patient JN. For control words, TRAINING was not effective. Inflected and monomorphemic words elicited more errors than derived and compound words (see Table 21). Patient JN shows some sensitivity to FREQUENCY.

Table 21

Fixed-effect coefficients (in logistic scale) in a mixed-effects model fitted to reading-aloud accuracy for control words as measured with the three-week baseline measurements and the three-week maintenance measurements for patient JN.

	Estimate	Std. Error	Z value	P value
(INTERCEPT)	2.0867	0.6582	3.170	0.0015
TRAINING: Contrast before ↔ after	-0.2289	0.3913	-0.585	0.5586
MORPHOLOGY: Contrast C ↔ D	-1.3290	0.8126	-1.636	0.1019
MORPHOLOGY: Contrast C ↔ I	-3.6630	0.8539	-4.290	<0.0001
MORPHOLOGY: Contrast C ↔ M	-2.8950	1.2474	-2.321	0.0203
Slope log(FREQUENCY)	0.3221	0.1431	2.251	0.0244

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

The estimated standard deviation for random intercepts for ITEM was 0.7750.

The partial effects of the regression model in Table 21 are shown in Figures 23 and 24.

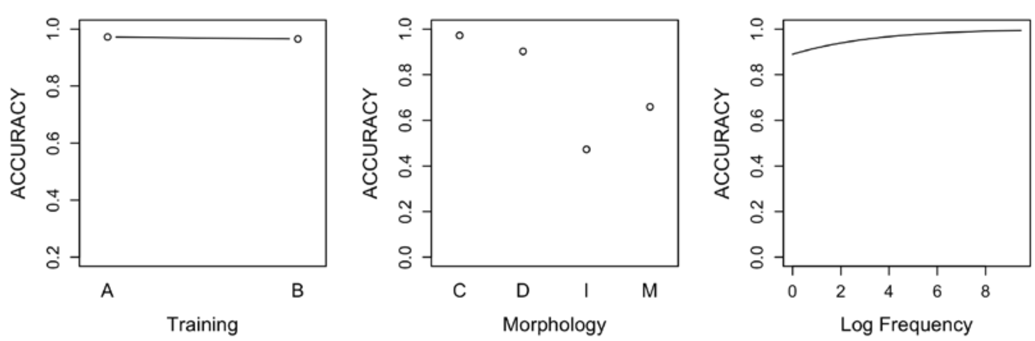

Figure 23. Reading-aloud accuracy scores for control words as a function of training, morphology, and log-transformed surface frequency - patient JN. Left panel: A: before therapy, B: after therapy; C: compounds, M: monomorphemic words, I: inflected words, D: derived words.

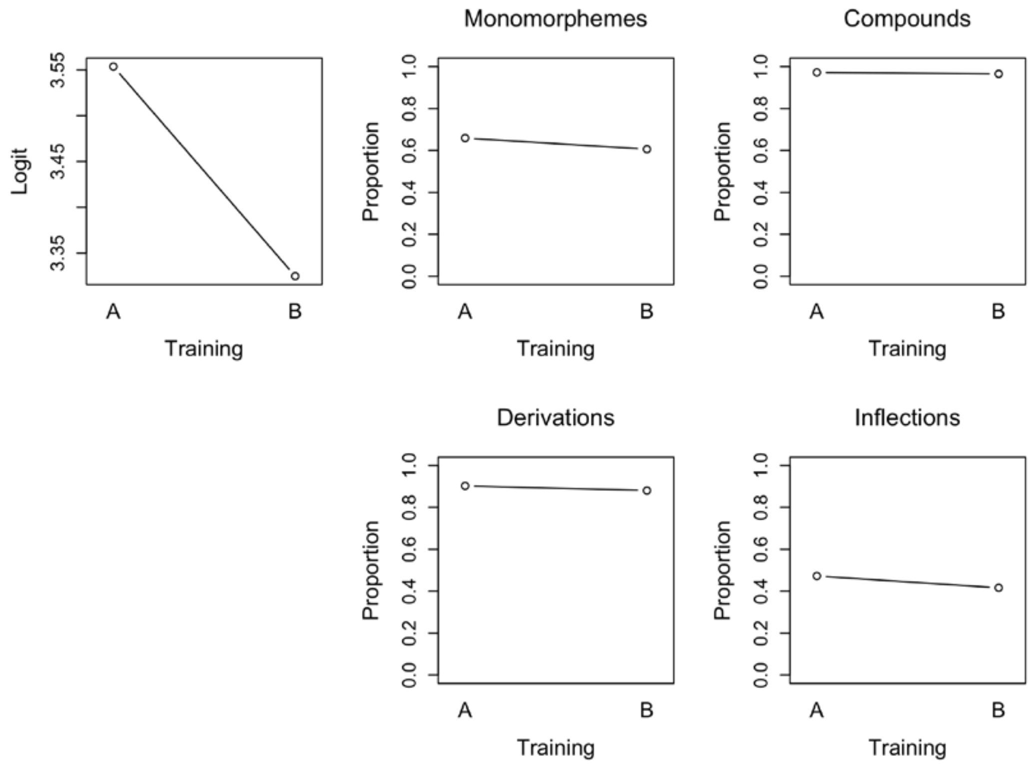

Figure 24. Reading-aloud accuracy scores for control words as a function of TRAINING shown with the logit scale (on the y-axis) as predicted by the regression model (top left panel) and backtransformed from the logits predicted by the regression model to proportions (on the y-axis) for monomorphemes (top centre), compounds (top right), derivations (bottom left), and inflections (bottom right) – patient JN. A: before therapy, B: after therapy.

4.2.3. Discussion

The analysis of control words across all four patients showed that for three out of the four patients the accuracy scores of control words increased as a result of TRAINING. Patient JN's accuracy score of control words did not improve as a result of training. However, it turns out that at a larger time scale JN also improved his reading ability for the inflected control words, albeit not significantly[3].

FREQUENCY was judged as a significant predictor to the reading-aloud accuracy in the group analysis, but as in the analysis of trained words, it was not

[3] Please refer to the models in Appendices AM-AO and the graph in Appendix AP.

significant for all four patients. However, similar to the trained words, the joint analysis of all four patients' data shows again that by-subject random slopes for frequency are not justified (χ^2 (1) < 0.01, likelihood ratio test); therefore, the effect of frequency does not differ significantly across patients.

Similar to the group analysis of trained words, the compound words and the monomorphemic words patterned together and the derived and inflected words patterned together with respect to the difficulty they pose to the speakers before training.

In conclusion, therapy resulted in an improvement in performance not only for the words on which patients were intensively trained but also for the control words. This suggests the MTP affords some generalization. The next section considers whether this generalization extends to words to which the patients have had a much more limited exposure: the words labeled above as new.

4.3. New words – Pre-post analysis

The data for this analysis were obtained from the three pre-therapy baseline testing sessions (phase A) and the three immediate post-therapy maintenance testing sessions (phase C), resulting in 839 observations.

4.3.1. Joint analysis

The contrast coefficients of the logistic regression model fitted to this data set are shown in Table 22. The positive contrast coefficient for TRAINING indicates an improvement in performance across all morphological types. As in previous analyses, inflected and derived words started out as much more problematic than the compounds and monomorphemic words. Although therapy improved performance for these words further improvements would be desirable. There was no significant effect of FREQUENCY.

Table 22

Fixed-effect coefficients (in logistic scale) in a mixed-effects model fitted to reading-aloud accuracy for new words as measured with the three-week baseline measurements and the three-week maintenance measurements for four patients.

	Estimate	Std. Error	Z value	P value
(Intercept)	1.3763	0.4427	3.109	0.0019
TRAINING: Contrast before ↔ after	1.1082	0.1842	6.016	<0.0001
MORPHOLOGY : Contrast C ↔ D	-1.2511	0.4463	-2.803	0.0051
MORPHOLOGY : Contrast C ↔ I	-2.1468	0.5028	-4.269	<0.0001
MORPHOLOGY : Contrast C ↔ M	0.3750	0.8262	0.454	0.6499
Slope log(FREQUENCY	0.0869	0.1033	0.841	0.4001

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

The model is summarized graphically in Figures 25 and 26.

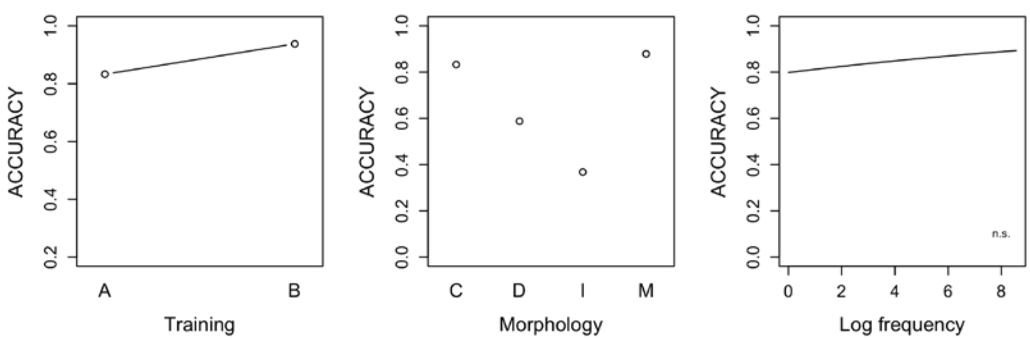

Figure 25. Reading-aloud accuracy scores for new words as a function of TRAINING, MORPHOLOGY, and FREQUENCY for all four patients. A: before therapy, B: after therapy; C: compounds, M: monomorphemic words, I: inflected words, D: derived words.

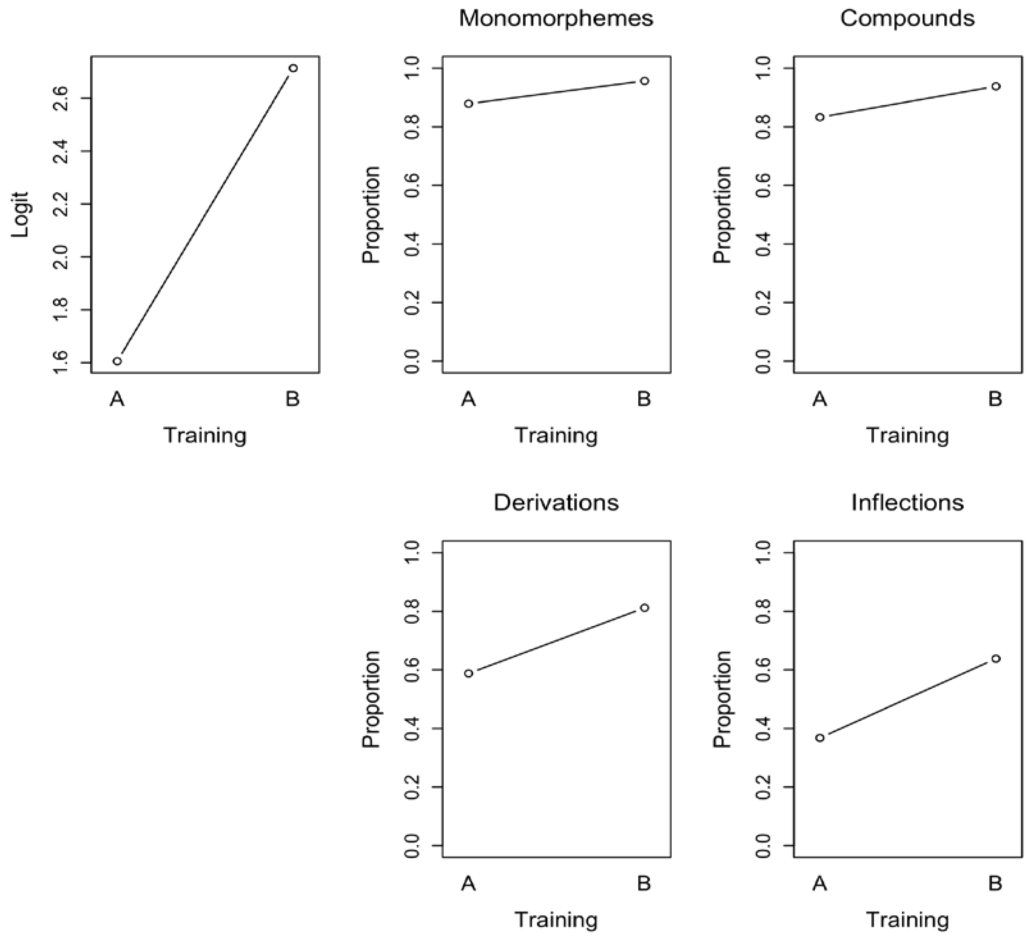

Figure 26. Reading-aloud accuracy scores for new words as a function of TRAINING shown with the logit scale (on the y-axis) as predicted by the regression model (top left panel) and backtransformed from the logits predicted by the regression model to proportions (on the y-axis) for monomorphemes (top centre), compounds (top right), derivations (bottom left), and inflections (bottom right) for all four patients. A: before therapy, B: after therapy.

The estimated standard deviation for the random intercepts for PATIENT was 0.4684. The estimated standard deviation for the random intercepts for ITEM was 0.8586.

In the next section, the results for individual patients' use of new words will be analyzed.

4.3.2. New words – individual patients

4.3.2.1. New words – patient DR

Table 23 shows the logistic regression model fitted to patient DR's data. The coefficient for TRAINING received a large positive value indicating a solid effect of therapy. FREQUENCY failed to reach significance. Derived and inflected words started out with a disadvantage compared to the monomorphemic and compound words and although therapy led to considerable improvement, performance is still far from perfect (see Figure 28).

Table 23

Fixed-effect coefficients (in logistic scale) in a fixed-effects model fitted to reading-aloud accuracy for new words as measured with the three-week baseline measurements and the three-week maintenance measurements for patient DR

	Estimate	Std. Error	Z value	P value
(INTERCEPT)	1.3442	0.7605	1.768	0.0771
TRAINING: Contrast before ↔ after	3.0226	0.5433	5.564	<0.0001
MORPHOLOGY: Contrast C ↔ D	-2.6521	0.9043	-2.933	0.0034
MORPHOLOGY: Contrast C ↔ I	-3.9670	1.0500	-3.778	0.0002
MORPHOLOGY: Contrast C ↔ M	14.7708	2804.9228	0.005	0.9958
Slope log(FREQUENCY	0.3658	0.2033	1.799	0.0720

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

The estimated standard deviation for the random intercepts for item was 1.4034.

Figures 27 and 28 show the partial effects of the regression model of Table 23.

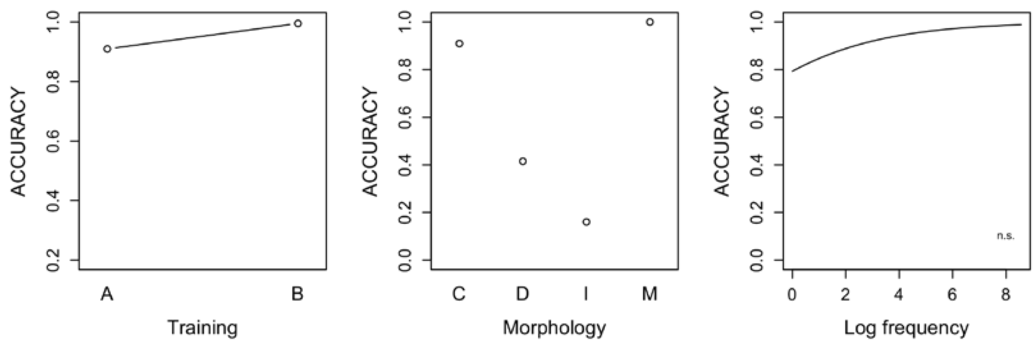

Figure 27. Reading-aloud accuracy scores for new words as a function of TRAINING, MORPHOLOGY, and log-transformed FREQUENCY – patient DR. A: before therapy, B: after therapy; C: compounds, M: monomorphemic words, I: inflected words, D: derived words.

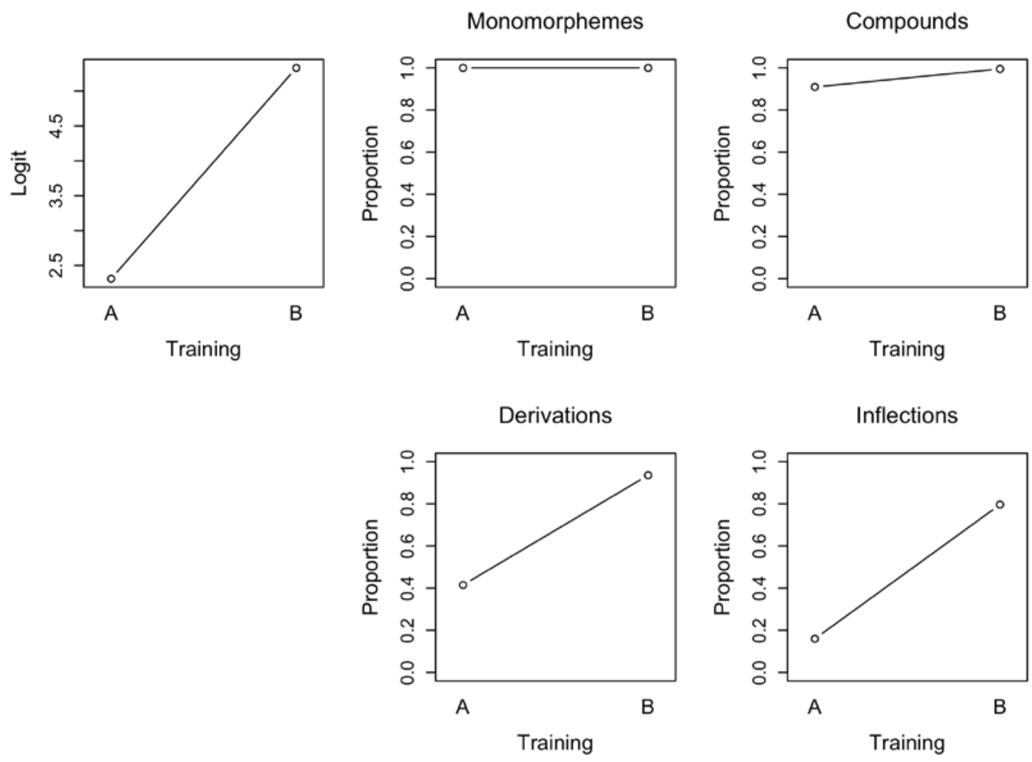

Figure 28. Reading-aloud accuracy scores for new words as a function of TRAINING shown with the logit scale (on the y-axis) as predicted by the regression model (top left panel) and backtransformed from the logits predicted by the regression model to proportions (on the y-axis) for monomorphemes (top centre), compounds (top right), derivations (bottom left), and inflections (bottom right) – patient DR. A: before therapy, B: after therapy.

4.3.2.2. New words – patient DP

The contrast coefficients for MORPHOLOGY and FREQUENCY failed to reach significance (see Table 24). TRAINING significantly improved the accuracy score of new words also for patient DP, from 49 percent correct to 80 percent correct. The estimated standard deviation for the random intercepts for ITEM was 0.781.

Table 24

Fixed-effect coefficients (in logistic scale) in a mixed-effects model fitted to reading-aloud accuracy for new words as measured with the three-week baseline measurements and the three-week maintenance measurements for patient DP.

	Estimate	Std. Error	Z value	P value
(INTERCEPT)	-0.0582	0.4603	-0.126	0.8995
TRAINING: Contrast before ↔ after	1.4795	0.3293	4.492	<0.0001
MORPHOLOGY: Contrast C ↔ D	-0.5223	0.5506	-0.949	0.3428
MORPHOLOGY: Contrast C ↔ I	-1.1434	0.6268	-1.824	0.0681
MORPHOLOGY: Contrast C ↔ M	0.7229	1.0463	0.691	0.4897
Slope log(FREQUENCY	0.1136	0.1304	0.871	0.3836

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

4.3.2.3. New words – patient PH

The positive contrast coefficient for TRAINING in Table 25 reveals that the training effect generalizes to new words for patient PH. As for patient PH's control words, the inflected words were especially challenging before therapy, and although performance improved significantly, performance after training was still error prone (see Figure 30). FREQUENCY failed to reach significance. The estimated standard deviation for the random intercepts for ITEM was 1.0750.

Table 25

Fixed-effect coefficients (in logistic scale) in a mixed-effects model fitted to reading-aloud accuracy for new words as measured with the three-week baseline measurements and the three-week maintenance measurements for patient PH.

	Estimate	Std. Error	Z value	P value
(INTERCEPT)	2.3157	0.7465	3.102	0.0019
TRAINING: Contrast before ↔ after	0.9531	0.4321	2.206	0.0274
MORPHOLOGY: Contrast C ↔ D	-1.3845	0.8638	-1.603	0.1089
MORPHOLOGY: Contrast C ↔ I	-2.6730	0.9203	-2.904	0.0037
MORPHOLOGY: Contrast C ↔ M	-1.6758	1.4566	-1.151	0.2499
Slope log(FREQUENCY	0.2207	0.1742	1.267	0.2052

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

Figures 29 and 30 present partial effects of the model shown in Table 25.

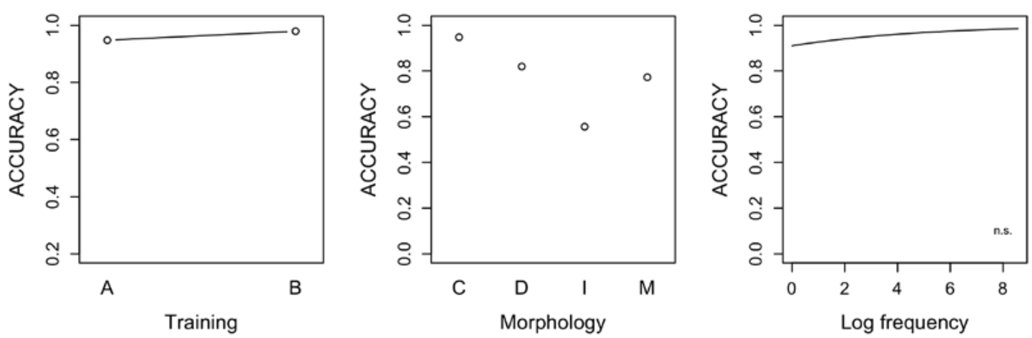

Figure 29. Reading-aloud accuracy scores for new words as a function of TRAINING, MORPHOLOGY, log-transformed FREQUENCY – patient PH. A: before therapy, B: after therapy; C: compounds, M: monomorphemic words, I: inflected words, D: derived words.

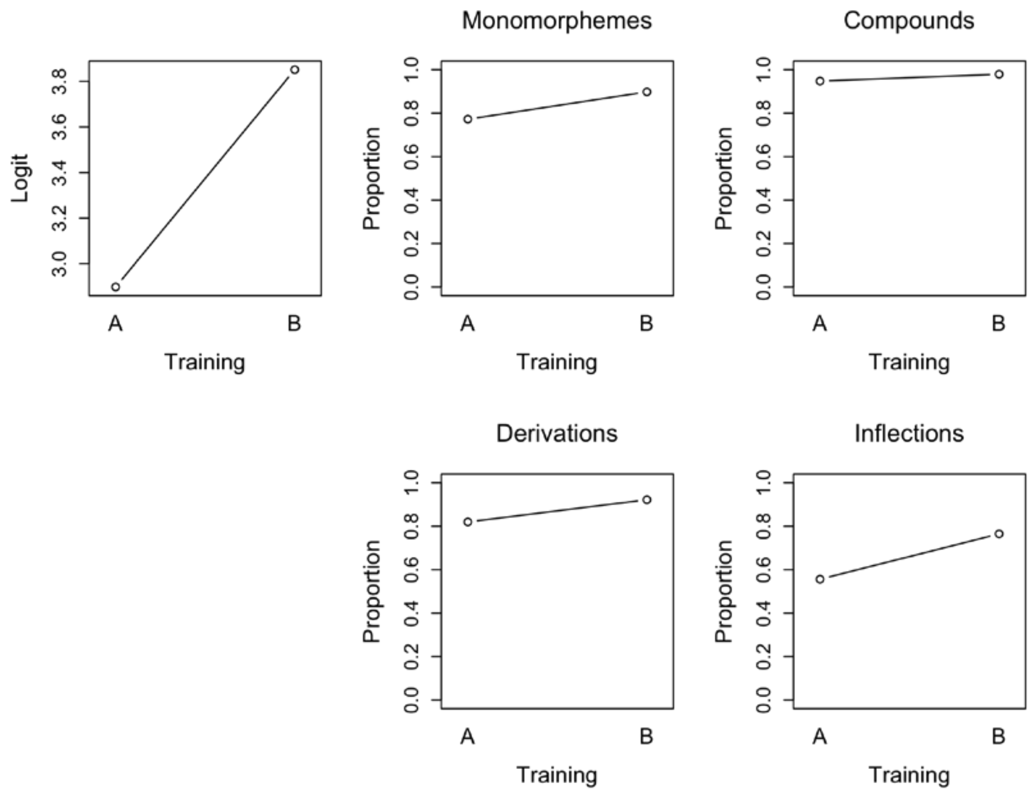

Figure 30. Reading-aloud accuracy scores for new words as a function of TRAINING shown with the logit scale (on the y-axis) as predicted by the regression model (top left panel) and backtransformed from the logits predicted by the regression model to proportions (on the y-axis) for monomorphemes (top centre), compounds (top right), derivations (bottom left), and inflections (bottom right) – patient PH. weeks post-therapy. A: before therapy, B: after therapy.

4.3.2.4. New words – patient JN

The summary of the regression model in Table 26 shows that TRAINING was not effective, similarly to JN's control words. Inflected and derived words were more challenging for patient JN before therapy. FREQUENCY was also not a significant predictor. The estimated standard deviation for the random intercepts for ITEM was 1.4873.

Table 26

Fixed-effect coefficients (in logistic scale) in a mixed-effects model fitted to reading-aloud accuracy for new words as measured with the three-week baseline measurements and the three-week maintenance measurements for patient JN.

	Estimate	Std. Error	Z value	P value
(Intercept)	3.6724	0.8847	4.151	<0.0001
Training: Contrast before ↔ after	-0.2279	0.3808	-0.598	0.5496
Morphology: Contrast C ↔ D	-2.1251	0.9267	-2.293	0.0218
Morphology: Contrast C ↔ I	-2.2158	1.0393	-2.132	0.0330
Morphology: Contrast C ↔ M	2.1278	1.7370	1.225	0.2206
Slope log(FREQUENCY	-0.3240	0.2138	-1.515	0.1297

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words)

4.3.3 Discussion

The joint analysis revealed that TRAINING improved accuracy for words that were neither trained nor tested during the training phase. As for the individual patients, accuracy scores improved for three patients (DR, DP, and PH). Patient JN's accuracy scores for complex words dropped slightly after therapy, similar to his accuracy scores for control words. However, JN did improve for the new words in a long-term analysis, albeit it did not reach significance[4].

FREQUENCY failed to reach significance for accuracy in the group analysis and in all of the individuals' analyses.

With respect to MORPHOLOGY, the monomorphemic and compound words patterned together contrasting with the most challenging words, the inflected and the derived words.

The results of the analyses of the trained, control, and new words over a short-term post-therapy period showed excellent improvement for the trained words, reasonable improvement for the control words, and even some improvement for the new words, suggesting that the MTP has the potential of generalizing beyond the words for which patients received intensive training.

[4] Please refer to the models in Appendices BE-BG and the graph in Appendix BH.

Training effects are observed in all group analyses and in most individuals' analyses.

The overall design of the study included a longitudinal component to investigate the maintenance of therapy effects over a longer time period. The next analyses investigate the therapy effects and the predictors of reading-aloud accuracy up to three months post therapy.

4.4. Longitudinal study

The accuracy scores of all 20 individual sessions covering a time period of approximately four months were investigated. All test scores from phase A, the pre-therapy baseline measurements, phase B, the measurements taken during training, phase C, the immediate post-therapy measurements, and phase D, the long-term maintenance measurements were taken into account.

4.4.1. Trained words – joint analysis

A general linear mixed-effects model was fitted to this longitudinal data. In this analysis, the fixed-effect predictor MORPHOLOGY and the covariate FREQUENCY was complemented by TIME as longitudinal measure. The random-effect factors were PATIENT and ITEM.

Table 27 lists the coefficients and their associated statistics that reached significance in a stepwise model selection[5]. The fixed-effect factor MORPHOLOGY emerged with coefficients supporting the previous observations that words with bound morphology patterned together in opposition to the compounds and simple words. The positive slope for FREQUENCY shows that words with higher frequencies attained more correct responses.

[5] Models and partial effects for trained words for the individual patients are shown in Appendices I – X.

Table 27

Fixed-effect coefficients in a mixed-effects model fitted to reading-aloud accuracy for trained words with a timeline of three months for four patients.

	Estimate	Std. Error	Z value	P value
(INTERCEPT)	-3.0552	1.5215	-2.008	0.0446
MORPHOLOGY: Contrast C↔ D	-1.5861	0.3999	-3.966	<0.0001
MORPHOLOGY: Contrast C↔ I	-2.7825	0.4452	-6.250	<0.0001
MORPHOLOGY: Contrast C↔ M	-0.3823	0.6829	-0.560	0.5756
Slope log(FREQUENCY)	0.2941	0.0767	3.834	0.0001
TIME (rcs(cDay, 5)cDay)	-0.0478	0.0246	-1.944	0.0519
TIME (rcs(cDay, 5)cDay')	3.3886	0.4032	8.405	<0.0001
TIME (rcs(cDay, 5)cDay'')	-34.2400	3.7756	-9.069	<0.0001
TIME (rcs(cDay, 5)cDay''')	51.2194	5.6999	8.986	<0.0001

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words; TIME: rcs = restricted cubic spline, cDay = centred day)

To model TIME, a restricted cubic spline with five knots is used, as restricted cubic splines provide superior flexibility compared to polynomials for modeling nonlinear trends. The splines for TIME are presented in the left-most column of Figure 31[6] for the compounds words (top), the derived words (centre), and the inflected words (bottom). No interaction of MORPHOLOGY by TIME could be discerned. The differences in the shape of the curves are due to the backtransformation from logits to proportions. The reading-aloud accuracy increased during the training phase, to ceiling for monomorphemic and compound words, and remained at the post-training level throughout phase D. The model includes random by-subject slopes for TIME, to do justice to the differences in the effect of training that are observed for the individual patients in the preceding sections. Inclusion of these random slopes was supported by a likelihood ratio test ($\chi^2(2) = 27.35$, $p < 0.0001$, likelihood ratio test).

Interestingly, the accuracy for the derived and inflected words continued to increase after training, in phase D. This suggests that the patients internalized (probably at the metalinguistic level), the relevant morphological rules. The rugs

[6] Figure 31 represents three analyses. Please refer to Appendix G for the model of the derived words and Appendix H for the model of the inflected words.

in the left two columns (the short vertical lines on the x-axes) show the distribution of the predictor variable.

The panels for MORPHOLOGY (in the right-most column) present the level of accuracy for the different morphological types for median FREQUENCY and median TIME. As a consequence, the accuracy levels shown are not the highest ultimately achieved, as accuracy further improved over post-training days.

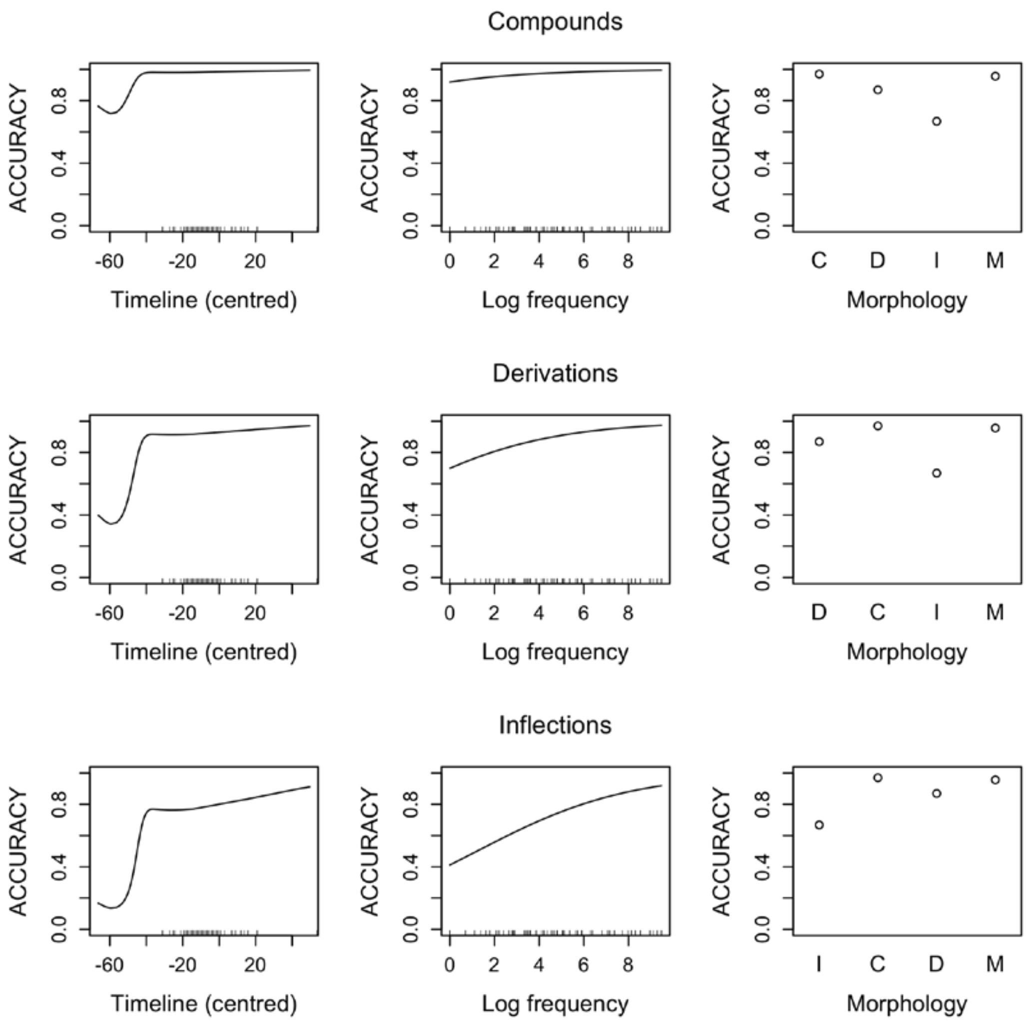

Figure 31. Partial effects of TIME (left column), log-transformed FREQUENCY (centre column), and MORPHOLOGY (right column) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for trained items - four patients. Panels for the monomorphemic words are very similar to those for the compounds and are not shown. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

The estimated standard deviation for the random intercepts for PATIENT was 1.6248. The estimated standard deviation for the random intersect for ITEM was 1.0372. The estimated standard deviation for the by-subject slopes for TIME was 0.0256.

4.4.2. Control words – joint analysis

Table 28 indicates that as in the group analysis of the trained words, in the group analysis of the control words, MORPHOLOGY, FREQUENCY, and TIME were estimated to be significant predictors of accuracy[7].

Table 28

Fixed-effect coefficients in a mixed-effects model fitted to reading-aloud accuracy for control words with compounds on the intercept in a longitudinal analysis.

	Estimate	Std. Error	Z value	P value
(INTERCEPT)	-2.21038	1.32623	-1.667	0.0956
MORPHOLOGY: Contrast C↔ D	-1.44069	0.39449	-3.652	0.0003
MORPHOLOGY: Contrast C↔ I	-2.69486	0.43142	-6.246	<0.0001
MORPHOLOGY: Contrast C↔ M	-1.48846	0.65738	-2.264	0.0236
Slope log(FREQUENCY)	0.33119	0.07623	4.344	<0.0001
TIME (rcs(cDay, 5)cDay)	-0.04652	0.02185	-2.129	0.0333
TIME (rcs(cDay, 5)cDay')	2.13503	0.39713	5.376	<0.0001
TIME (rcs(cDay, 5)cDay'')	-20.44701	3.66980	-5.572	<0.0001
TIME (rcs(cDay, 5)cDay''')	29.92577	5.51754	5.424	<0.0001

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words; TIME: rcs = restricted cubic spline, cDay = centred day)

For the control words, a significant difference not only between the words with bound morphemes and the compounds is observed, but also between the monomorphemic words and the compounds at Day 1 as indicated by the contrast coefficients in Table 28. Figure 32[8] shows that compound words reached ceiling with therapy and remained at that level throughout the maintenance phase. The

[7] Models and partial effects for control words for the individual patients are shown in Appendices AA-AP.

[8] Figure 32 represents three analyses. Please refer to Appendix AQ for the model of the derived words and Appendix AR for the model of the inflected words.

reading-aloud accuracy of the derived words (with median frequency) failed to reach the ceiling with therapy (see Figure 32, centre left panel), however accuracy scores continued to increase in the post-therapy phases. The inflected words had the greatest improvement proportionally and continued to improve during the post-testing phase.

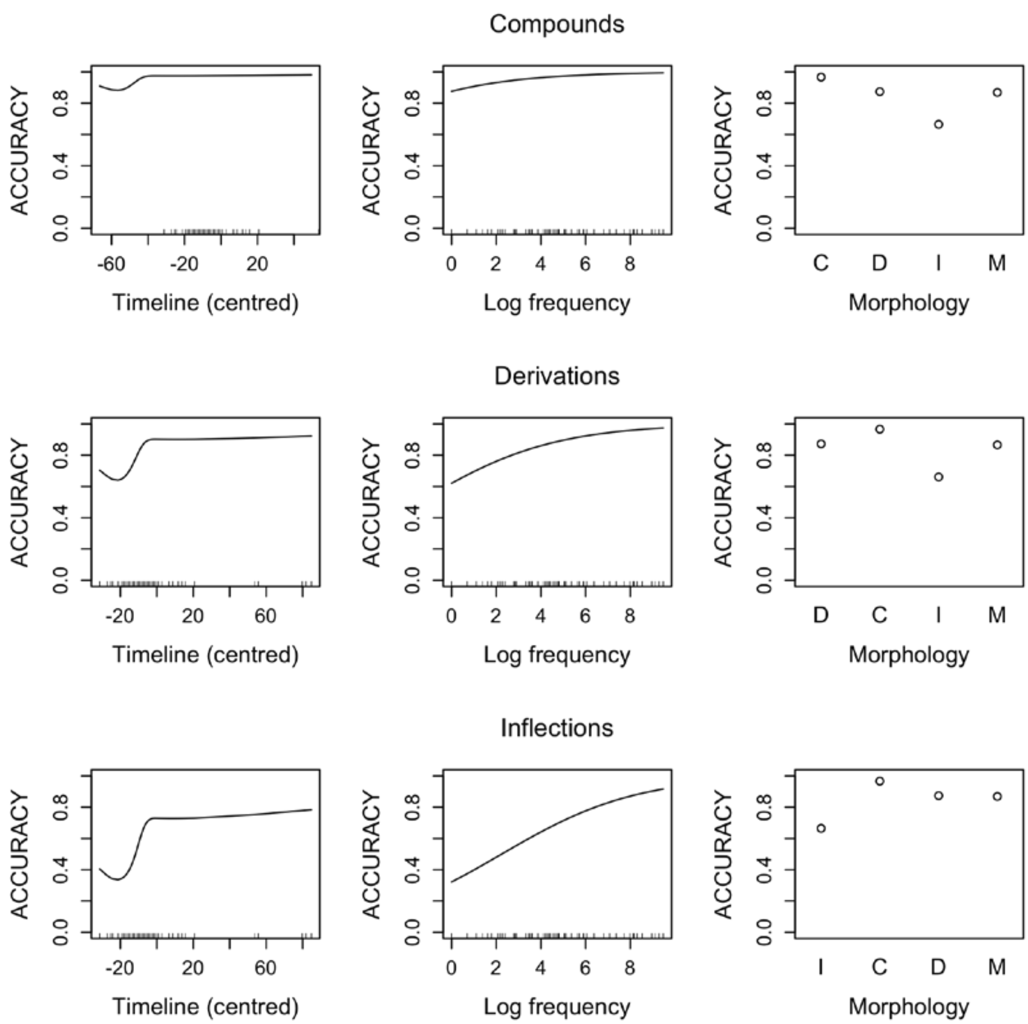

Figure 32. Partial effects of TIME (left), log-transformed FREQUENCY (centre), and MORPHOLOGY (right) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for control items – four patients. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

The model includes random by-subject slopes for TIME to allow for the differences in the effect of training observed for the individual patients. Inclusion of these random slopes was supported by a likelihood ratio test ($\chi^2(2) = 6.98$, $p < 0.03$, likelihood ratio test).

The effect of the FREQUENCY as displayed in the centre column (calibrated for the median day) also mirrors the effect of the FREQUENCY of the trained words. Words with higher frequencies received higher accuracy scores. The right-most column illustrates the accuracy score for the distinct morphological domains at the median of FREQUENCY and TIME.

PATIENT and ITEM were included as random effect factors. The estimated deviation for the random intercepts for PATIENT was 1.0279. The estimated deviation for the random intercepts for ITEM was 2.1488, while the estimated standard deviation for the by-subject slopes for TIME was 0.0084.

4.4.3. New words - joint analysis

The coefficients of the logistic regression model fitted to the longitudinal data set of new words for the group are listed in Table 29[9]. MORPHOLOGY is listed as a significant predictor of reading-aloud improvement as well as TIME. It should be noted that the new words were not presented to the patients during the training phase. As a consequence, the nonlinear steep improvement in performance that was present for the trained and control words is absent here: Day is modeled as a linear predictor of accuracy (on the logit scale), no restricted cubic spline is required.

As before, monomorphemic words and compounds side together against the derived and inflected words at day one. Figure 33[10] shows that accuracy increased for all complex words. The compound words reached the ceiling level of accuracy while the derived words increased their accuracy rate to over 80 percent by the time of the three-month post-therapy maintenance testing. The accuracy for inflected words also improved during therapy and continued to improve up to the

[9] Models and partial effects for new words for the individual patients are shown in Appendices AS-BH.

[10] Figure 33 represents three analyses. Please refer to Appendix AQ for the model of the derived words and Appendix AR for the model of the inflected words.

time of the three-month post-therapy testing. FREQUENCY was not selected as a significant predictor to the reading aloud improvement for control words (Table 29).

Table 29

Fixed-effect coefficients in a mixed-effects model fitted to reading-aloud accuracy for new words with compounds on the intercept in a longitudinal analysis.

	Estimate	Std. Error	Z value	P value
(INTERCEPT)	2.0789	0.4366	4.761	<0.0001
MORPHOLOGY : Contrast C↔ D	-1.0906	0.4529	-2.408	0.0160
MORPHOLOGY : Contrast C↔ I	-2.0177	0.5087	-3.967	<0.0001
MORPHOLOGY : Contrast C↔ M	0.4192	0.8299	0.505	0.6134
Slope log(FREQUENCY)	0.0794	0.1050	0.757	0.4491
TIME (cDay)	0.0152	0.0042	3.579	0.0003

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words; TIME: rcs = restricted cubic spline, cDay = centred day)

PATIENT and ITEM were included as random effect factors. The estimated standard deviation for the random intercepts for PATIENT was 0.4400. The estimated standard deviation for the random intercepts for ITEM was 0.9112, while the by-patient random slopes for TIME was 0.0069.

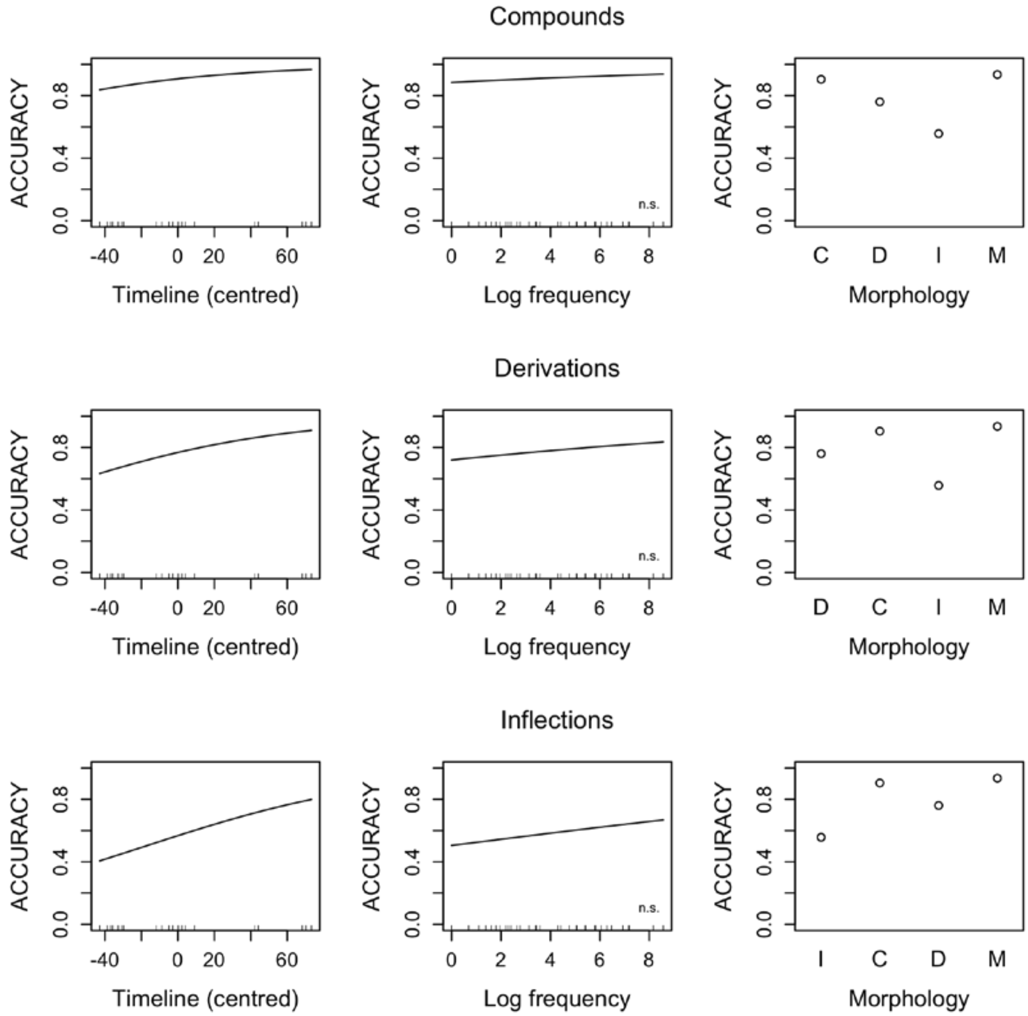

Figure 33. Partial effects of TIME (left column), log-transformed FREQUENCY (centre column), and MORPHOLOGY (right column) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for new items – four patients. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

4.4.4. Discussion

The three longitudinal analyses of joint data indicate that therapy effects were maintained up to the three-month post-therapy testing session. Indeed, the modeling of nonlinear trends of the trained and control analyses showed that accuracy scores improved during the maintenance phase, even after training was finished. In all three analyses, reading words with bound morphemes was significantly more difficult at the first testing day than reading compound words.

In addition, the reading of monomorphemic words was significantly more difficult before therapy than that of compound words for the analysis of control words.

In the next section, a final comprehensive longitudinal analyses that included WORD TYPE (trained, control, and new words) as a fixed-effect factor is presented.

4.5. Final analysis

A final comprehensive mixed model was fitted to the data of all word types, all patients, and all days of testing, in all, 6571 observations. Table 30 presents the fixed-effect coefficients and their statistics.

Main effects of MORPHOLOGY, WORD TYPE, and FREQUENCY are observed. Interactions between these predictors did not reach significance. Development over TIME was captured by means of a restricted cubic spline with five knots. Differences in the longitudinal development of PATIENTS were brought into the model by means of random slopes for (linear) TIME (modeled with centred day).

Table 30
Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for all words with a timeline of three months for four patients.

	Estimate	Std. Error	Z value	P value
(INTERCEPT)	-0.9052	0.6104	-1.483	0.1380
MORPHOLOGY: Contrast M↔ C	0.4204	0.4433	0.948	0.3430
MORPHOLOGY: Contrast M↔ D	-0.8044	0.3893	-2.066	0.0388
MORPHOLOGY: Contrast M↔ I	-1.9204	0.3529	-5.442	<0.0001
Slope log(FREQUENCY)	0.2384	0.0517	4.611	<0.0001
TIME (rcs(cDay, 5)cDay)	-0.0332	0.0129	-2.559	0.0105
TIME (rcs(cDay, 5)cDay')	2.1943	0.2368	9.264	<0.0001
TIME (rcs(cDay, 5)cDay'')	-14.6895	1.4516	-10.120	<0.0001
TIME (rcs(cDay, 5)cDay''')	20.2259	1.9992	10.117	<0.0001
WORD TYPE: Control↔ New	-0.1373	0.1756	-0.782	0.4344
WORD TYPE: Control↔ Trained	-0.2119	0.0818	-2.592	0.0095

(MORPHOLOGY: C = compound words, D = derived words, I = inflected words, M = monomorphemic words; TIME: rcs = restricted cubic spline, cDay = centred day)

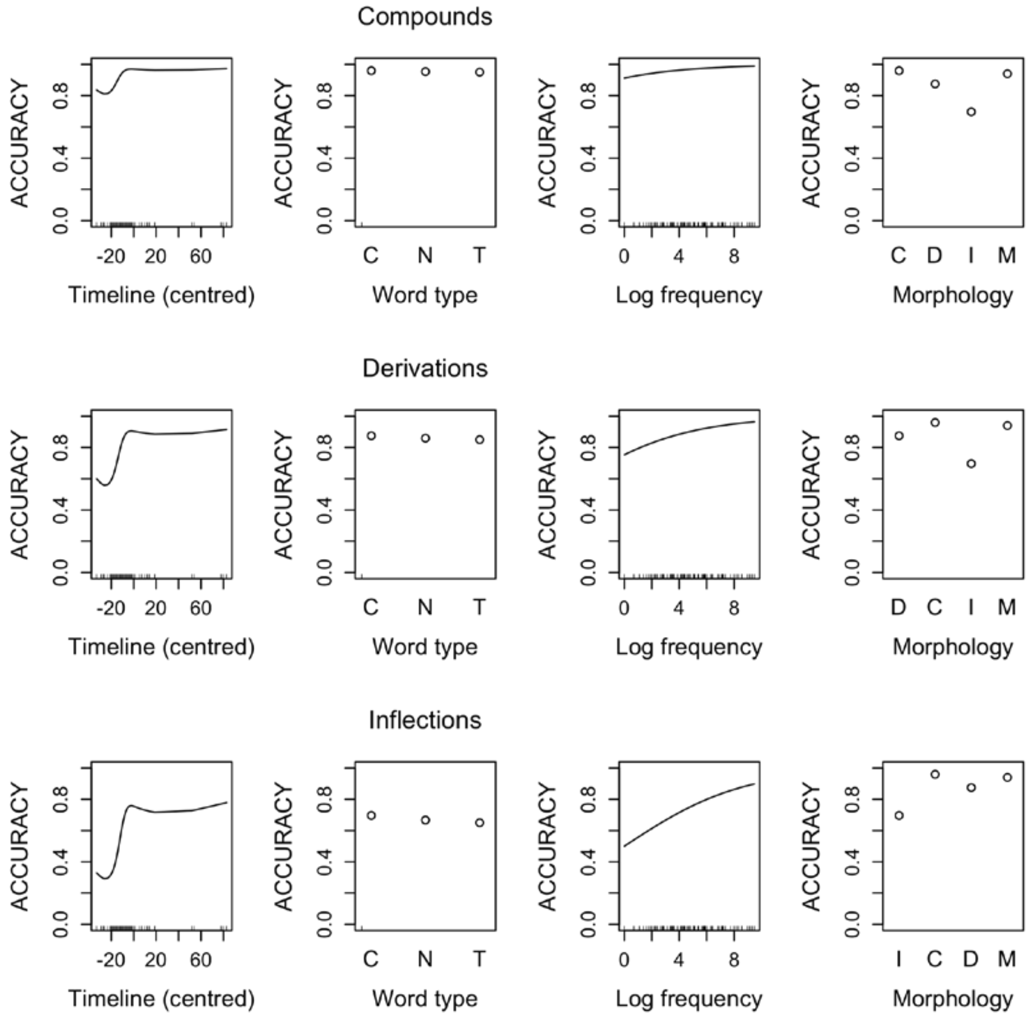

Figure 34. Partial effects for reading-aloud accuracy of TIME (left column), WORD TYPE (left centre column), log-transformed FREQUENCY (right centre column), and MORPHOLOGY (right column) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for four patients. Word Type: C = control words, N = new words, T= trained words; Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words. Panels show results for control words.

Results are well in line with those obtained in the analyses of parts of the data. Note that at Day 1, the words to receive training elicited significantly fewer correct responses, unsurprisingly: I selected for training those word families that patients had most difficulties with. As can be seen in the panels in the leftmost column of Figure 34[11], the patterns of improvement over time are very similar to those observed in the partial analyses and support persistence of the beneficial effect of therapy post training.

In this analysis, PATIENT and ITEM were included as random effect factors. The estimated standard deviation for the random intercepts for PATIENT was 0.3580. The estimated standard deviation for the random intercepts for ITEM was 0.8599, while the standard deviation of the by-patient random slopes for TIME was 0.0068.

I conclude this series of analyses of covariance with two methodological comments. First, in aphasiology there is a strong trend to consider each patient as unique. The present analyses support differences between patients. In the comprehensive analysis, these differences are captured by the random intercepts for PATIENTS in combination with the by-patient random slopes for TIME. Within the mixed modeling framework, justice can be done to both the differences and the commonalities between patients.

Second, in order to assess the importance of the different predictors in a strictly non-parametric way, I have made use of a random forest of conditional inference trees (`party` package, Hothorn, Hornik, & Zeileis, 2006). The trees are fitted to random subsets of observations and predictors and jointly vote for the most likely value of the accuracy measure. The importance of a predictor is gauged by comparing classification accuracy for the subsets of trees with and without the predictor.

[11] Figure 34 represents three analyses. Please refer to Appendix BI, BJ, and BK for the models of the compounds, the derived words, and the inflected words.

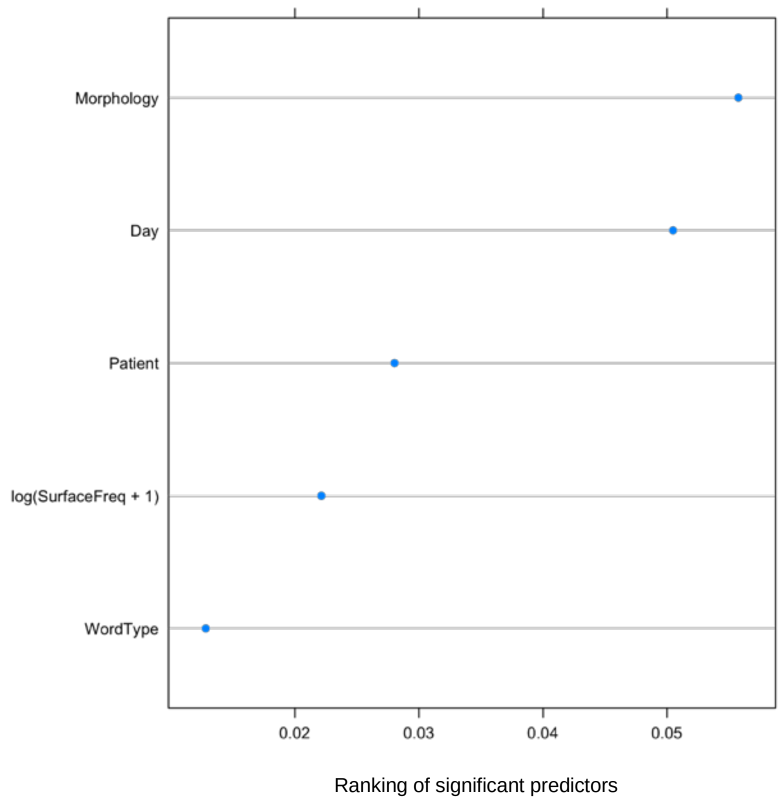

Figure 35. Random forest ranking of significant predictors for reading-aloud accuracy.

As can be seen in Figure 35, MORPHOLOGY is the most important predictor. When MORPHOLOGY is not available as a predictor, prediction accuracy is most severely impacted. The least important of the significant predictors is WORD TYPE. The low ranking of WORD TYPE supports my claim that there is good generalization from the trained words to the control and new words. The variable importance of PATIENT is intermediate in line with our conclusion above that there are both commonalities and differences between patients.

4.6. Post-therapy ALFAB results

4.6.1. Patient DR

Table 31 lists the pre-therapy versus post-therapy comparison of the ALFAB administrations for patient DR. Patient DR improved in many subtests of the ALFAB. The post-therapy accuracy scores that are at least 1 z-score higher than the pre-therapy scores are presented in bold font. These include scores that are grouped with Section A, the low level input and production repetition (both monomorphemic and multimorphemic words), Section B, the orthographic and phonological processing (reading), Section D, the semantic access (multimorphemic word-picture matching, visual and auditory synonym judgment, multimorphemic semantic decision, and Section E, auditory sentence comprehension. Note, however, that in the pre-therapy versus post-therapy comparison data not all subtests showed improvement with therapy. Notably, DR's spelling score, the subtest that is at least 1 z-score lower after therapy in comparison to before therapy is presented in bold italic font. Her pre-therapy spelling ability was 100%, after therapy, the score dropped down to 20%. Interestingly, both DR's visual and auditory lexical decision scores that are part of the orthographic and phonological processing subtests did not differ substantially from their pre-therapy scores.

Table 31

ALFAB Subtests Summary Table: Comparison pre-therapy versus post-therapy – Patient DR

	Pre-therapy results		Post-therapy results	
A.) Low level input & production				
Phoneme Discrimination:	98.9%	0.8z	96.6%	0.3z
Monomorphemic Repetition:	46.9%	-9.6z	**53.1%**	**-8.4z**
Multimorphemic Repetition:	48.7%	-9.3z	**57.7%**	**-7.5z**
B.) Orthographic & phonological processing				
Visual Lexical Decision:	90.1%	-1z	93%	-0.4z
Auditory Lexical Decision:	90.1%	-1z	89.4%	-1.1z
Rhyme Judgment:	N/A		N/A	
Reading:	27%	-13.6z	**33.3%**	**-12.3z**
Spelling:	100%	1z	***20%***	***-15z***
C) Fluency				
Oral:	0 words	-18.8z	3 words	-18.4z
Written:	2 words	-18.6z	2 words	-18.6z
Multimorphemic:	4 words	-18.2z	4 words	-18.2z
D.) Semantic access				
Word-picture matching				
Visual:	96.7%	0.3z	98.4%	0.7z
Auditory:	95.1%	0z	96.7%	0.3z
Multimorphemic:	93.9%	-0.2z	**100%**	**1z**
Synonym judgment				
Visual:	72.5%	-4.5z	**77.5%**	**-3.5z**
Auditory:	72.5%	-4.5z	**85%**	**-2z**
Semantic decision				
Visual:	75%	-4z	N/A	
Auditory:	81.3%	-2.7z	83.8%	-2.2z
Multimorphemic:	86.5%	-1.7z	**94.2%**	**-0.2z**
Picture naming				
Oral:	34.1%	-12.2z	38.6%	-11.3z
Written:	25%	-14z	27.3%	-13.5z
E) Sentence processing				
Visual comprehension:	67.9%	-5.4z	N/A	
Auditory comprehension:	60.7%	-6.9z	**83.9%**	**-4z**
Idiom judgment:	N/A		N/A	
Production:	8%	-17.4z	8%	-17.4z

4.6.2. Patient DP

Table 32 shows the pre-therapy and post-therapy comparisons of the ALFAB subtests for patient DP. Patient DP improved in individual subtests in all sections except in Section C, fluency. Post-therapy results that are at least 1 z-score higher than pre-therapy scores are presented in bold font and highlighted here. With respect to the low level input & production, Section A, DP improved both his monomorphemic and his multimorphemic repetition, he improved his visual lexical decision and his reading ability in Section B, Section D, which measures semantic access, visual word-picture matching, auditory synonym judgment, visual semantic decision, and oral picture naming improved, and in Section E, sentence processing, visual and auditory comprehension improved. Sentence production is included in Table 33 even though no pre-therapy measurement was attained, but the perfect score of 100% for sentence production should not be ignored. Similar to patient DR, some pre-therapy and post-therapy subtest comparison results (i.e., phoneme discrimination, fluency, and auditory semantic decision) showed slightly lower scores after therapy.

Only one comparison resulted in a post-therapy score that was at a least 1 z-score lower than its pre-therapy score (presented in bold italic font). In Section B, the auditory lexical decision dropped from 81% to 72.5% correct.

Table 32

ALFAB Subtests Summary Table: Comparison pre-therapy versus post-therapy – Patient DP

	Pre-therapy results		Post-therapy results	
A.) Low level input & production				
Phoneme Discrimination:	95.5%	0.1z	90.9%	-0.8z
Monomorphemic Repetition:	26.6%	-13.7z	**36.5%**	**-11.7z**
Multimorphemic Repetition:	33.8%	-12.2z	**57.7%**	**-7.5z**
B.) Orthographic & phonological processing				
Visual Lexical Decision:	73.2%	-4.4z	**78.2%**	**-3.4z**
Auditory Lexical Decision:	81%	-2.8z	***72.5%***	***-4.5z***
Rhyme Judgment:	N/A		N/A	
Reading:	20.7%	-14.9z	**39.6%**	**-11.1z**
Spelling:	100%	1z	N/A	
C) Fluency				
Oral:	1 words	-18.8z	0 words	-19z
Written:	1 words	-18.8z	2 words	-18.6z
Multimorphemic:	9 words	-17.2z	9 words	-17.2z
D.) Semantic access				
Word-picture matching				
Visual:	44.3%	-10.1z	**88.5%**	**-1.3z**
Auditory:	98.4%	0.7z	98.4%	0.7z
Multimorphemic:	84.8%	-2z	93.9%	-0.2z
Synonym judgment				
Visual:	65%	-6z	65%	-6z
Auditory:	22.5%	-14.5z	**40%**	**-11z**
Semantic decision				
Visual:	62.5%	-6.5z	**76.3%**	**-3.7z**
Auditory:	67.5%	-5.5z	66.3%	-5.7z
Multimorphemic:	50%	-9z	51.9%	-8.6z
Picture naming				
Oral:	20.5%	-14.9z	**34.1%**	**-12.2z**
Written:	27.3%	-13.5z		
E) Sentence processing				
Visual comprehension:	75%	-4z	**80.4%**	**-2.9z**
Auditory comprehension:	62.5%	-6.5z	**75%**	**-4z**
Idiom judgment:	N/A		N/A	
Production:	N/A		100%	1z

4.6.3. Patient PH

The ALFAB pre-therapy versus post-therapy subtest comparisons for patient PH are listed in Table 33. As PH did not wish to participate in many of the pre-therapy subtests due to personal reasons, he did not complete many subtests prior to the therapy administrations. Accordingly, not many comparisons are available. The subtests components for which a score increase of at least one z-score was obtained after the MTP administration are listed in bold font. In Section A, the score of monomorphemic and multimorphemic repetition increased. Within the semantic access component in Section D, multimorphemic word-picture matching, visual synonym judgment, and multimorphemic semantic decision scores increased as well. Sentence production in Section E was also included in Table 33 even though no comparison to pre-therapy scores was available, but the high score of 84% is impressive.

The two available comparisons with a lower post-therapy score are phoneme discrimination in Section A and auditory sentence comprehension in Section E. However, they did not reach a difference of at least 1 z-score.

Table 33

ALFAB Subtests Summary Table: Comparison pre-therapy versus post-therapy – Patient PH

	Pre-therapy results		Post-therapy results	
A.) Low level input & production				
Phoneme Discrimination:	55.7%	-7.9z	54.5%	-8.1z
Monomorphemic Repetition:	46.9%	-9.6z	**57.8%**	**-7.4z**
Multimorphemic Repetition:	59%	-7.2z	**80.8%**	**-2.8z**
B.) Orthographic & phonological processing				
Visual Lexical Decision:	N/A		93%	-0.4z
Auditory Lexical Decision:	N/A		76.8%	-3.6z
Rhyme Judgment:	N/A		N/A	
Reading:	N/A		57.7%	-7.5z
Spelling:	N/A		40%	-11z
C) Fluency				
Oral:	N/A		5 words	-18z
Written:	N/A		7 words	-17.6z
Multimorphemic:	6 words	-17.8z	9 words	-17.2z
D.) Semantic access				
Word-picture matching				
Visual:	N/A		95.1%	0z
Auditory:	N/A		96.7%	0.3z
Multimorphemic:	90.9%	-0.8z	**100%**	**1**
Synonym judgment				
Visual:	60%	-7z	**85%**	**-2z**
Auditory:	N/A		37.5%	-11.5z
Semantic decision				
Visual:	N/A		81.3%	-2.7z
Auditory:	N/A		73.8%	-4.2z
Multimorphemic:	76.9%	-3.6z	**86.5%**	**-1.7z**
Picture naming				
Oral:	N/A		61.4%	-6.7z
Written:	N/A		65.9%	-5.8z
E) Sentence processing				
Visual comprehension:	N/A		58.9%	-7.2
Auditory comprehension:	57.1%	-7.6z	55.4%	-7.9z
Idiom judgment:	N/A		N/A	
Production:	N/A		84%	-2.2z

4.6.4. Patient JN

Table 34 reports the comparison of the pre- and post-therapy results of the ALFAB for patient JN. Post-therapy results that are at least one z-score higher than pre-therapy scores are shown in bold font. JN's score comparison shows that he improved in several subtests by more than one z-score. However, he also received two post-therapy results with lower z-scores of at least one z-score (shown in bold italic font) and numerous lower results that did not reach a minimum difference of one z-score.

In Section A, both the monomorphemic and multimorphemic repetition score improved with therapy. Section B reveals that reading and spelling received higher accuracy scores in the post-therapy administration of the ALFAB. Visual word-picture matching, visual synonym judgment , and multimorphemic semantic decision received higher accuracy scores after the MTP (Section D). Sentence processing, shown in Section E, improved in several components. Auditory comprehension, idiom judgment, and importantly, sentence production had a good accuracy increase after the MTP administration.

As previously indicated, patient JN also showed a slight worsening in some subtest results after therapy. The subtests for multimorphemic word-picture matching, auditory synonym judgment, and oral picture naming (all in Section D) faired the worst after therapy (their respective z-scores drops are 1 z-score, 4 z-scores, and 2 z-scores).

Table 34

ALFAB Subtests Summary Table: Comparison pre-therapy versus post-therapy – Patient JN

	Pre-therapy results		Post-therapy results	
A.) Low level input & production				
Phoneme Discrimination:	88.6%	-1.3z	87.5%	-1.5z
Monomorphemic Repetition:	42.2%	-10.6z	**51.6%**	**-8.7z**
Multimorphemic Repetition:	70.5%	-4.9z	**79.5%**	**-3.1z**
B.) Orthographic & phonological processing				
Visual Lexical Decision:	85.2%	-2z	84.5%	-2.1z
Auditory Lexical Decision:	76.1%	-3.8z	***70.4%***	***-4.9z***
Rhyme Judgment:	69.8%	-5z	69.8%	-5z
Reading:	45.9%	-9.8z	**52.3%**	**-8.5z**
Spelling:	5.5%	-17.9z	**10.9%**	**-16.8z**
C) Fluency				
Oral:	1 words	-18.8z	0words	-19z
Written:	0 words	-19z	1 words	-18.8z
Multimorphemic:	1 words	-18.8z	3 words	-18.4z
D.) Semantic access				
Word-picture matching				
Visual:	88.5%	-1.3z	**95.1%**	**0z**
Auditory:	95.1%	0z	N/A	N/A
Multimorphemic:	84.8%	-2z	***78.8%***	***-3.2z***
Synonym judgment				
Visual:	55%	-8z	**62.5%**	**-6.5z**
Auditory:	57.5%	-7.5z	***37.5%***	***-11.5z***
Multimorphemic:	N/A		64.6%	-6.1z
Semantic decision				
Visual:	63.8%	-6.2z	N/A	N/A
Auditory:	68.8%	-5.2z	70%	-5z
Multimorphemic:	40.4%	-10.9z	**69.2%**	**-5.2z**
Picture naming				
Oral:	52.3%	-8.5z	***43.2%***	***-10.4z***
Written:	N/A		4.5%	-18.1z
E) Sentence processing				
Visual comprehension:	58.9%	-7.2z	60.7%	-6.9z
Auditory comprehension:	39.3%	-11.1z	**60.7%**	**-6.9z**
Idiom judgment:	58%	-7.4z	**68.2%**	**-5.4z**
Production:	32%	-12.6z	**64%**	**-6.2z**

Chapter 5

Concluding remarks

5.0. Introduction

This dissertation investigated whether a morphological therapy, the MTP, that specifically addresses morphological deficits in aphasia can help remediate the impairment. Morphological deficits such as omission and substitution of morphemes are present in all morphological domains in individuals with non-fluent aphasia. However, even though this study finds that these deficits are ubiquitous in complex words with bound morphemes, the MTP focuses on morphological processing in all domains.

The study design included three weekly baseline measurements in which 105 words were probed. The 105 words were made up of 15 word families. Each word family consisted of one identity word and two inflected words, two derived words, and two compound words. Across each word family, the identity word was kept constant (e.g., LOCK in *locked*, *locks*, *lockable*, *locker*, *locknut*, and *door lock*). The individual patient's results from these spontaneous naming tests determined the training set for each patient. The individualized training sets consisted of the five word families that were most difficult for each patient; the ten remaining word families were randomly assigned to the control set and to the set of words with limited exposure (new words). In addition, the Alberta Language Function Assessment Battery (ALFAB; Westbury, 2007) was administered as part of the baseline measurement.

During the treatment phase probes, of reading performance, similar to those conducted during baseline, were completed at the beginning of each session prior to treatment. Probes during the treatment phase included the set of training words (35 items), control words (35 items), and 50 filler items.

The maintenance of the reading aloud of trained words was measured during three weekly post-training sessions. Follow-up probes were conducted at two and three months post-training. Probes during the maintenance phase included the set of training words (35 items), control words (35 items), new words (35 items), and 75 fillers. The ALFAB was re-administered as part of the maintenance testing.

Training consisted of four computer-assisted word game tasks. Their aim was to reveal to the patients components that make up our morphological ability. These components include the nature of composition and decomposition of complex words as well as the morphological rules (i.e., selectional restrictions) that apply to morphemes. The four tasks built upon each other in terms of complexity. The twelve training days were divided into three modules, one for each domain of morphological complex words: inflected, derived, and compound words.

5.1. Experimental design of treatment

The investigation was based on joint analyses and individual patients' analyses of three sets of words: trained words, control words, and words with limited exposure. The analyses of trained words investigated whether a training effect is realized with the training set, the words that the patients were actually trained on and with which they practiced repeatedly during the training phase. The analyses of control words determined whether the practice received for the training words transferred to words with which they had not practiced, but that they had read aloud throughout the training phase. The analyses of the new words (with limited exposure) investigated whether a training effect transfer generalized to words that they had not encountered during the training phase. First, the analyses of the short-term comparison of the aggregate pre-therapy data and the aggregate post-therapy data were carried out, then the joint analysis of the longitudinal effects of the aggregate pre-therapy data to the follow-up maintenance data (three months post therapy) were carried out. In addition, a mega-analysis of the joint data with all words and all patients included was analyzed with comparisons for the aggregate pre-therapy data to the follow-up maintenance data.

5.2. Summary of experimental results

Logistic mixed-effects analyses showed that the MTP resulted in a considerable improvement in performance. Reading of words after therapy improved significantly as compared to reading prior to therapy. The training effect was maintained over a three-month post-therapy maintenance phase. Morphological training that specifically addresses a morphological deficit by revealing the decompositional nature of complex words and the covert compositional procedures of composing the complex words with its individual parts improved not only the trained words, but also the control and the new words. The training effect observed in the final comprehensive analysis is in line with those observed in the partial analyses. The random forest modeling of significant predictors to the reading-aloud accuracy of complex words revealed that the predictor WORD TYPE is low ranked in comparison to the other predictors (MORPHOLOGY, PATIENTS, TIME, and FREQUENCY; see Figure 3B), supporting my claim that there is good generalization from trained words to the control and new words. This finding of generalization to untrained words is in contrast to the findings of Wambaugh and Ferguson (2007) and Rider et al. (2008). In Wambaugh and Ferguson's semantic treatment, the exposure to stimulus items without training resulted in unstable and temporary naming accuracy increases whereas no generalization to untrained words was found in Rider and colleagues' study.

The final analysis showed that the accuracy of monomorphemic words and compound words patterned together before and after therapy and the accuracy of derived and inflected words patterned together before and after therapy. Derivational morphology is generally less affected by aphasia, however, in this group of patients, derivational morphology seems to be more difficult (before and after therapy) than for the average individual with aphasia. The monomorphemic words and compound words started off with higher accuracy scores leaving less room for improvement whereas the derived and inflected words started off with lower accuracy scores and therefore had the chance for greater improvement. Proportionally, the inflected words improved the most, followed by the derived words (see Figure 32). A limitation of this study is that I was not able to investigate whether differentiated training times for the morphological domains would have positively influenced words with bound morphemes to attain the same accuracy levels as monomorphemic and compound words with the current study design.

As the MTP was based on the premise that morphological constituents matter, these results are in line with previous research that gives evidence that not only constituents of inflected and compound words are important, but also constituents of derived words (e.g., Feldman et al., 2009; Longtin et al., 2003; Meunier & Longtin, 2007; Marslen-Wilson, 2007; Marslen-Wilson & Bozic, 2008; Rastle & Davis, 2008). The accuracy score improvement of the inflected words as a result of the MTP rejects a purely syntactic account of this deficit and certainly supports an account that allows for involvement of morphological constituents in all morphologically complex words.

All patients improved their reading-aloud of complex and simple words. However, patient JN showed inhibition at the comparison of the pre-therapy phase and the immediate post-therapy phase, but his reading-aloud ability improved to levels similar to the other patients during the long-term maintenance phase.

The comprehensive analysis and most of the other analyses reveal that whole-word word frequency plays a significant role in morphological processing of these individuals with aphasia. Words with higher frequencies afforded higher accuracy scores both before and after the MTP administration. In healthy individuals, who display (mostly) effortless and errorless morphological processing of complex words, frequency is also an important factor in morphological processing. Faster lexical decision times are correlated with high-frequency words that are stored as wholes whereas slower reaction times are correlated with low-frequency words that are more likely to undergo a decompositional process in word recognition, in dual-route models of processing. The obtained frequency effect suggests that training with the MTP might (re)activate the links of the representations of individual constituents with the whole-word representations or strengthen and (re)activating covert morphological combinatorial mechanisms thus achieving higher accuracy scores for high-frequency words.

5.3. Interpretation of ALFAB pre- and post-therapy comparison

The comparison of the data obtained from pre- and post-therapy ALFAB administrations across four patients showed that noteworthy improvements were obtained in four of the five sections of the ALFAB.

Section A: Low level input and production

All patients improved in monomorphemic and multimorphemic word repetition. The smallest accuracy rate increase after therapy was represented by a z-score increase of 1.8; the highest increase was represented by a z-score difference of 5.2. All patients repeated words with higher frequency values more accurately than words with lower frequency values.

Section B: Orthographic and phonological processing

Three of the five subtests that test access to orthographic and phonological lexical forms improved for some of the patients. Reading improved for three patients (PH did not do the pre-therapy reading test, thus reading could not be verified for him). Improvements in pre- and post-therapy reading covered a difference between 1.3 to 3.8 z-scores for the three patients. Visual lexical decision improved for patient DR by a z-score difference of 1.3. Spelling improved for patient JN by a z-score difference of 1.1.

Section C: Word fluency

No improvement was found as measured by at least one z-score between pre- and post-therapy assessments.

Section D: Semantic access

These subtests measured the ability to access word meanings. The results from most subtests indicated an improvement of at least one z-score by no less than one patient. Visual word-picture matching (choosing which of two pictures matches a printed word) improved for three patients. The z-score improvements ranged from 1.3 to 2.8. Visual synonym judgment (which of two visually-presented words is most similar in meaning to a third visually-presented word) also differed between the two ALFAB administrations for three patients. The z-score improvements for visual synonym judgments were between 1 to 5 z-scores. Auditory synonym judgment (which of two spoken words is similar in meaning to a third spoken word) and multimorphemic synonym judgment (whether a description is a plausible definition of a multimorphemic word) scores improved for two patients each. Multimorphemic word-picture matching (which of two written words corresponds to a presented picture), visual semantic decision (whether a visually-presented sentence is both sensible and true) and multimorphemic semantic decisions (which morpheme of a multimorphemic word is most important to the meaning of the whole word), and oral picture naming each improved for one patient.

Section E: Sentence processing

The auditory sentence comprehension task that required the patient to decide whether a spoken sentence correctly described a short animated film improved for three patients in the post-therapy ALFAB administration. The accuracy of the visual comprehension task that required the patients to decide whether a spoken sentence correctly described a short animated film improved by 1.1 z-scores for one patient. The idiom judgment that required the patients to decide whether a sentence could have a literal interpretation also improved for one patient. The sentence production task required the patients to produce a sentence that corresponded to a short animated movie. Only one complete comparison was available. Patient JN improved by 6.4 z-scores between the pre- and post-therapy assessments. In addition, patient DP achieved 100% accuracy on his sentence production task after therapy; unfortunately, he did not complete this task prior to therapy. Patient PH, who also did not complete this task before therapy, achieved an accuracy rate of 84% for sentence production.

However, the comparison of the data obtained from pre- and post-therapy ALFAB administrations across four patients also showed that deterioration in post-therapy comparisons scores of at least one z-score difference were found in two sections of the ALFAB.

Section B: Orthographic and phonological processing

One patient, DR, showed a decline in her spelling ability of 14 z-scores. Prior to therapy, she scored 100% correct whereas after therapy she scored only 20% correct. Patient DP received a lower accuracy score for his auditory lexical decision test. His accuracy score dropped from 81% to 72.5%, a z-scores drop of 1.7 z-scores.

Section D: Semantic access

The results of the pre-therapy and post-therapy comparisons indicate that for one patient, JN, three semantic access subtest z-scores dropped after therapy. His multimorphemic word-picture matching score lowered by 1.2 z-scores, his auditory synonym judgment score lowered by 4 z-scores, and his oral picture naming score lowered by 1.9 z-scores.

Thus, the ALFAB comparisons show that, overall, the patients did not only improve their morphological processing, but also their phonological and semantic processing after having completed the MTP (with the exceptions noted above). This is in contrast to the widely accepted hypothesis that states that each level of breakdown in word production should be remediated by a different kind of treatment (e.g., Hillis & Caramazza, 1994; Micelli, Amitrano, Capasso, & Caramazza, 1996). These patients had difficulties in complex words that previous to this morphological therapy warranted treatment with phonological, semantic, and syntactic therapies. In addition, with respect to semantic and phonological treatments, improvements seem to be mostly item specific and in addition, semantic treatments are only effective when the word form is also provided (e.g., Drew & Thompson, 1999; Hillis & Caramazza, 1994; Miceli et al., 1996; Nettleton & Lesser, 1991; Nickels, 2002). In contrast, the whole-word form is not provided as part of the MTP treatment and importantly, MTP treatment effects generalize to untreated items.

Previous studies do not clearly indicate which method or therapy will guarantee positive results. As L. Nickels (2002) explained:

> It has been clearly demonstrated that therapy for word-retrieval and production disorders can be effective. However, we still cannot predict which therapy will work for which impairment – this is a conclusion that has been drawn several times in the past (e.g., Hillis, 1993; Nickels & Best, 1996), and is likely to remain for several years to come (p. 959).

The findings of this dissertation, however, indicate that a therapy that specifically addresses morphological deficits by using morphological tasks might remediate an underlying functional impairment as diverse language aspects (e.g., morphology, semantics, phonology, and to a limited extend syntax) improve. The semantic and phonological therapies do not appear to treat an underlying functional deficit. These therapies seem to be symptomatic treatments. Support for syntactic improvement, however, is limited in this dissertation, due to insufficient data. Nevertheless, the sentence-production comparison data for one patient illustrate that he improved his sentence production considerably after MTP administration. Further analysis of speech samples should help to show that patient DP, for whom only post-therapy assessment scores for sentence production were obtained, also improved his sentence production notably, especially in light of his perfect sentence production score of 100% after the MTP administration.

It is to note, however, that it is possible that in addition to the MTP administration other practice factors (e.g., more familiarity with the ALFAB at the second testing) could have contributed to the magnitude of the attained effect.

5.4. Discussion

In conclusion, a morphological therapy seems to be able to help remediate the multimorphemic word production difficulty exhibited by neurologically impaired individuals. In light of the fact, that even in English, a language that is considered to be morphologically poor, the majority of words are multimorphemic (Libben, 2006), an inability to access and process multimorphemic forms easily poses a major disability. The MTP addresses morphological deficits that present with morpheme substitution and morpheme omission errors with a therapy that reveals the individual parts of complex words and exposes the covert combinatorial process of word formation. The result of the MTP treatment suggests better processing of words and less difficulty with lexical access after treatment in these four individuals with aphasia. Especially the reading out loud of complex words with bound morphemes that present with more challenges than simple or compound words is substantially helped by the MTP. The interesting question, of course, is how is this improvement achieved? I can only speculate, as the answer to this question requires information about neural activities that is not obtainable with the paradigm used here.

It is clear that the cognitive system, more precisely, the mental lexicon is responsible for lexical activity including implicit knowledge. Furthermore, individuals with aphasia simply cannot access this implicit knowledge for lexical activity or it is gone as evidenced by the difficulty of processing linguistic information in comparison to healthy individuals. In addition, the processing of monomorphemic words and compound words is relatively stable in comparison to that of words with bound morphemes. What is the basic principle of the MTP? Beginning with metalinguistic awareness, the MTP teaches the patients a new skill that allows them to read out loud morphologically complex words. This skill is practiced over and over again until it becomes a kind of unconsciously, well practiced knowledge. After enough practice this skill becomes automatic. The MTP takes something very explicit and gives the patients a heuristic to hold on to that acquired skill until it becomes internalized.

One possibility is that the skill the MTP teaches rebuilds some of the links in a neural network that do not function anymore due to the stroke, specifically the connections from form to meaning. In this connectionist approach, the new connections are replacing the old, severely damaged connections. As the network receives input from the MTP, it adapts and the weights of the new connections are adjusted in order to improve spoken output. The repetitively practiced skill of combining strings of letters that result in complex words generate similar patterns of neural activity within appropriate processing units. Thus, repeated combination of strings of letters that have a meaning with other strings of letters that also have a meaning allows for abstraction of these repeated patterns. The form-meaning connections for monomorphemic words and for compound words seem to be strong, but get even stronger with practice suggesting that perhaps only the weights need adjusting. However, it is likely that the connections for inflected and derived words need to be newly built as they might be severely damaged. It is possible that longer practice periods for words with bound morphemes might be needed in order to influence the specific values of the connection weights between units. It is possible that both the old and the new network exist in parallel. In this case, the new network may correct for a potential deficit in plasticity in the old network. Thus with respect to connectionist models, improvement is achieved by rebuilding new neural connections to form links between form and meaning processing units without any explicit parsing or any presupposed morphological representations.

An alternative hypothesis is based on the assumption that everything gets decomposed (e.g., Taft & Forster, 1975). Within this full-parsing model, the result of the MTP application suggests that the representations of stems and affixes is intact as patients can access the representations of stems and affixes and produce either in isolation even when a complex word is desired. In this model, stems might benefit from the parsing of the whole words as multiple multimorphemic words containing a particular stem are presented in the reading aloud testing sessions. Stem frequency, which is correlated with decompositional representations, however, did not reach significance in the logistic mixed-effects analyses. It is not clear whether the representations of the combination of the stems and the affixes are intact. In this model, a possible explanation for the improvement of multimorphemic-word reading is that the MTP rebuilds the skill to build morphologically complex representations.

Another hypothesis is based on dual or multi-route models that allow for representations of stems, representations of affixes, and representations of whole words (e.g., Allen & Badecker, 2002; Baayen & Schreuder, 1999; Schreuder & Baayen, 1995; Baayen & Schreuder, 2000). Similarly to the full-parsing model, the stems might benefit from the parsing of the whole words. For the production of compounds, the stems need to be accessed and put into the correct sequence. The limited amount of reversal errors (only three errors before therapy) suggests that this combinatory process is relatively easy. It is possible that the frequency effect seen for compounds is in fact a frequency effect that indicates how well these particular constituents combine and thus represent the frequency of a combinatorial rule. One explanation could be that the representations are intact and the knowledge of the morphological rule is intact, but that the trauma imposes a lot of noise so that the system does not attain a stable state for words with bound morphemes. This instability causes the high rate of morpheme substitutions for derived words and the high rate of morpheme omission in inflected words prior to therapy. Another explanation for the dissociation of compound-word production and bound-morpheme production could be that the combinatorial process may not be as straight forward for the inflected and derived words. For instance, I did not control for CVC complexity, therefore multimorphemic representations for words with bound morphemes may be more complex than the original constituent representations. The patients still have all representations, but the links of how to get from the concepts that are tightly linked to particular phonological and orthographic representations to the right complex forms is difficult. In this case, the MTP is rebuilding how these concepts are combined, the combinatorial rules.

Essentially, the MTP is teaching the conventionalized ways of expressing certain concepts. The improvement of multimorphemic words is then due to the automatization of these rules.

Thus, although the precise mechanism of the improvement process is not clear, I propose that the observed improvement reflects either a connectionist model of processing or a dual- or multi-route model of processing.

In summary, the results of this dissertation show that the MTP successfully remediates the difficulty of reading out loud monomorphemic and morphologically complex words. The therapy effect was maintained over a three-month post-therapy maintenance phase. Furthermore, the MTP independent assessment of other aspects of language with the Alberta Language Function Assessment Battery indicates that multimorphemic word access has improved in these patients and that facets of semantic access, phonology, and to a limited extend also syntax seem to have improved after the MTP administration.

Importantly, when we turn to the practical application of the language gains obtained with the MTP, it is to note that the patients state in post-therapy interviews that they feel more at ease communicating with others after this therapy. It also seems to me that they have gained more confidence in their linguistic abilities as at least two patients now report talking with more ease on the phone than previously. Caregivers, friends, and family members have also noted a definite communication improvement in these patients.

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Appendix A

The Alberta Language Function Assessment Battery: Results for patient DR

The Alberta Language Function Assessment Battery (ALFAB) is a comprehensive computerized battery designed as a research instrument to test the integrity of the language system from its lowest-level components (phoneme discrimination) to its highest-level components (sentence production).

D.R.'s results are summarized in the table on the next page. ALFAB scores are reported in terms of z-scores, which are a standardized way of reporting results with respect to normal performance. Using this system, a score less than -2z would be considered significantly impaired (these scores are indicated in bold text). Because of ceiling effects (most normal subjects score highly on most ALFAB tests), ALFAB z-scores are less meaningful when they are attached to high scores: very high scores may have fairly small z-scores. The two columns after each subtest name give the actual score and the z-score equivalent of that score. In this case D.R.'s z-scores may tend to be low (that is, fast in normalized terms) because she is considerably younger (age: 39) than the average age of the subjects used to norm the ALFAB.

ALFAB Subtests Summary Table - DR

Age: 39 Gender: female Handedness: right Education: 12

A. Low level input & production

Phoneme Discrimination:	98.9%	0.8z
Monomorphemic Repetition:	46.9%	-9.6z
Multimorphemic Repetition:	48.7%	-9.3z

B. Orthographic & phonological processing

Visual Lexical Decision:	90.1%	-1z
Auditory Lexical Decision:	90.1%	-1z
Rhyme Judgment:	N/A	N/A
Reading:	27%	-13.6z
Spelling:	100%	1z

C. Fluency

Oral:	[Error] words	[Error]z
Written:	2 words	-18.6z
Multimorphemic:	4 words	-18.2z

D. Semantic access

Word-picture matching	Visual	96.7%	0.3z
	Auditory	95.1%	0z
	Multimorphemic	93.9%	-0.2z
Synonym judgment	Visual	72.5%	-4.5z
	Auditory	72.5%	-4.5z
Semantic decision	Visual	75%	-4z
	Auditory	81.3%	-2.7z
	Multimorphemic	86.5%	-1.7z
Picture naming	Oral	34.1%	-12.2z
	Written	25%	-14z

E. Sentence processing

Visual comprehension	67.9%	-5.4z
Auditory comprehension	60.7%	-6.9z
Idiom judgment	N/A	N/A
Production	8%	-17.4z

Analysis - DR

A. Low level input & production

The first three subtests are Phoneme Discrimination, Repetition of simple (monomorphemic) words, and Repetition of complex (multimorphemic) words. These tasks assess the integrity of low-level processes of auditory comprehension and verbal production. The processes tested are considered 'low-level' because they do not require explicit access to semantic or lexical information.

Phoneme Discrimination

The phoneme discrimination task is a test of auditory processing of speech segments that requires subjects to decide if two auditory strings (words and nonwords) are the same or different. Difficulty on this task may signify peripheral hearing problems, or damage in superior temporal lobe regions associated with phonological processing.

Repetition of monomorphemic words.

The repetition task requires subjects to repeat words and nonwords. The first test uses simple words composed of a single morpheme. Poor scores on this task may be due to difficulty with hearing or speech articulation. They may also indicate neurological damage either at the input side (Wernicke's area in the superior temporal lobe), the output side (Broca's area in the inferior frontal lobe), or in the connection between them (the arcuate fasciculus).

The following table shows the breakdown of D.R.'s repetition results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in her performance (as measured by a difference between factor levels of at least one z-score).

	Word frequency			
High		75%	-4z	4
Low		55%	-8z	
	Word Length			
	Nonword Length			
	Word phonological neighbourhood			
	Nonword phonological neighbourhood			

D.R. repeated high frequency words better than low frequency words. This is a common pattern.

Repetition of multimorphemic words.

The second repetition task requires subjects to repeat more complex words and nonwords that are composed of more than one morpheme. This task should not be considered to be simply a more difficult version of the first task, since long words can be easier to repeat than short words because they are less easily confused with other words. Poor performance in this task may be indicative of the same problems mentioned above. However, it may also indicate a particular problem in processing morphology.

D.R. is is impaired at repeating multimorphemic words (48.7%; -9.3z).

B. Orthographic and phonological processing

The five subtests in this section test access to orthographic and phonological lexical forms. The processes tested require explicit access to lexical information, but not to semantic information.

Visual Lexical Decision

The visual lexical decision task is a test of visual processing of word forms that requires subjects to decide if a string is a word or a nonword. Difficulty on this task may be associated with damage to visual word processing areas in a number of different regions of the brain.

The following table shows the breakdown of D.R.'s visual lexical decision results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in her performance (as measured by a difference between factor levels of at least 1 z-score).

Wordness				
Word Frequency				
	High frequency:	**95.2%**	**0z**	**4.5**
	Low frequency:	**72.5%**	**-4.5z**	
Length				
	Short:	**82.2%**	**-2.6z**	
Word Phonological Neighbourhood				
Nonword Phonological Neighbourhood				
Concreteness				
	Abstract:	**65.6%**	**-5.9z**	**-6.2**
	Concrete:	**96.6%**	**0.3z**	
Word Regularity				
	Regular:	**87.5%**	**-1.5z**	**3**
	Irregular:	**72.4%**	**-4.5z**	

Auditory Lexical Decision

The auditory lexical decision task is a test of auditory processing of word forms that requires subjects to decide if a spoken sound is a word or a nonword. Difficulty on this task may be associated with damage to auditory word processing areas in the temporal lobe.

The following table shows the breakdown of D.R.'s auditory lexical decision results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in her performance (as measured by a difference between factor levels of at least 1 z-score).

Wordness			
Word Frequency			
High frequency:	**100%**	**1z**	**2**
Low frequency:	**90%**	**-1z**	
Length			
Long:	93.8%	-0.2z	0.1
Short:	93.3%	-0.3z	
Phonological Neighbourhood			
High PN:	**89.7%**	**-1.1z**	**-1.4**
Low PN:	**96.6%**	**0.3z**	
Concreteness			
Abstract:	**90.6%**	**-0.9z**	**-1.2**
Concrete:	**96.6%**	**0.3z**	
Word Regularity			
Regular:	**96.9%**	**0.4z**	**1.5**
Irregular:	**89.7%**	**-1.1z**	

Rhyme Judgment

The rhyme judgment task is a test of orthographic to phonological processing that requires subjects to decide which of two written strings (words or nonwords) rhymes with a probe string. Difficulty on this task may be associated with damage to word processing areas in a number of different regions of the brain devoted to orthographic and phonological processing.

D.R. did not complete the rhyme judgment task.

Reading words and nonwords

The reading task asks subjects to read words and nonword strings aloud. Difficulty on this task may be associated with damage to visual word processing areas in a number of different regions of the brain, or with articulatory difficulties.

Spelling words and nonwords

The spelling task asks subjects to spell words and nonwords. Spelling words is complex, and subject to the influence of many different lexical variables. It requires coordinated processing in a number of different regions of the brain. Problems with spelling may therefore occur for many reasons and may be associated with many underlying neurological deficits.

D.R. scored within the normal range in spelling simple words (100%; 1z) and complex words (100%; 1z), as well as nonwords (100%; 1z). Reaction times in this task are approximate because the administrator enters the response, but significantly long reaction times would normally only be seen if the subject was very slow at spelling. D.R. was slow at spelling simple words (21699.3 ms 4320.9z), complex words (31081.1 ms 6197.2z), and nonwords (13011.8 ms; 2583.4z). This suggests that she may have moderate difficulty in translating from phonology to orthography. D.R. is worse at spelling phonologically complex words than phonologically simple words. This is a common pattern.

C. Word fluency

The three-word fluency tests in the ALFAB test the ability to retrieve words along specific dimensions (first letter or final morpheme). Word fluency tests are sensitive to the integrity of functioning of the frontal lobes.

Oral word fluency

The oral word fluency test asks subjects to orally produce words beginning with the letter 's'.

D.R. produced [Error] 's' words in 60 seconds ([Error] words per second). This is in the normal range ([Error]z).

Written word fluency

The oral word fluency test asks subjects to produce written words beginning with the letter 'c'.

D.R. produced 2 written 'c' words in 60 seconds (30 words per second). This is below the normal range (-18.6z).

Morphological word fluency

The morphological word fluency test asks subjects to orally produce words that end with specific morphemes.

Summary N	z	Words per second
'-er' Words: 0	**-19**	**[Error]**
'-ing' Words: 1	**-18.8**	**60**
'-ness' Words: 0	**-19**	**[Error]**
'-s' Words: 3	**-18.4**	**20**
Total Words: 4	**-18.2**	**60**

D.R. produced 4 affixed words in 240 seconds (60 words per second). This is below the normal range (-18.2z).

D. Semantic access

The semantic access subtests assess a person's ability to access word meanings. There are four sets of tests, each if which is tested in both the auditory and visual modalities. In addition, the three sets that test comprehension also compare monomorphemic word access with multimorphemic word access.

Word-picture matching: Visual

The visual word-picture matching task requires the subject to choose which of two pictures corresponds to a printed word.

Overall, D.R. was able to pick the correctly matching picture for visually presented words (96.7%; 0.3z). However, she was significantly slow at making her responses (4068.4 ms; 794.7z), suggesting that she may have trouble accessing meaning from printed words.

Word-picture matching: Auditory

The auditory word-picture matching task requires the subject to choose which of two pictures corresponds to a spoken word.

Overall, D.R. was able to pick the correctly matching picture for auditorily presented words (95.1%; 0z). However, she was significantly slow at making her responses (2264.6 ms; 433.9z), suggesting that she may have trouble accessing meaning from spoken words.

Word-picture matching: Morphological

The morphological word-picture matching task is different from the other two word-picture matching tasks because it uses two words and one picture, requiring the subject to choose which of the two written words corresponds to the picture. This allows the use of morphological foils.

D.R. was able to pick the correct multimorphemic name for a picture (93.9%; -0.2z). However, she was significantly slow at making her responses (4434.9 ms; 868z).

Synonym judgment: Visual

The visual synonym judgment task requires the subject to choose which of two visually-presented words is most similar in meaning to a third visually-presented word.

D.R. was impaired at choosing synonyms of visually presented words (72.5%; -4.5z), suggesting that she has trouble accessing meaning from written words.

The following table shows the breakdown of D.R.'s visual synonym results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in her performance (as measured by a difference between factor levels of at least 1 z-score).

Foil type for Concrete words			
Phonological:	**90%**	**-1z**	**6**
Semantic:	**60%**	**-7z**	
Foil type for Abstract words			
Phonological:	**60%**	**-7z**	**-4**
Semantic:	**80%**	**-3z**	

Synonym judgment: Auditory

The auditory synonym judgment task requires the subject to choose which of two spoken words is most similar in meaning to a third spoken word.

D.R. was impaired at choosing synonyms of auditorily presented words (72.5%; -4.5z), suggesting that she has trouble accessing meaning from spoken words.

The following table shows the breakdown of D.R.'s auditory synonym results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in her performance (as measured by a difference between factor levels of at least 1 z-score).

Concreteness			
Concrete:	**85%**	**-2z**	**5**
Abstract:	**60%**	**-7z**	
Foil type			
Phonological:	**95%**	**0z**	**9**
Semantic:	**50%**	**-9z**	
Foil type for Concrete words			
Phonological:	**100%**	**1z**	**6**
Semantic:	**70%**	**-5z**	
Foil type for Abstract words			
Phonological:	**90%**	**-1z**	**12**
Semantic:	**30%**	**-13z**	

Synonym judgment: Morphological

The morphological synonym judgment task requires the subject to decide whether a description is a plausible definition of a multimorphemic word.

Semantic Decision: Visual

The visual semantic decision task requires the subject to decide whether or not a visually presented sentence is both sensible and true.

D.R. was impaired at making sensibility judgments about written sentences (75%; -4z), suggesting that she has trouble accessing meaning from written sentences.

Semantic Decision: Auditory

The auditory semantic decision task requires the subject to decide whether or not a spoken sentence is both sensible and true.

D.R. was impaired at making sensibility judgments about spoken sentences (81.3%; -2.7z), suggesting that she has trouble accessing meaning from spoken sentences.

Semantic Decision: Morphological

The morphological semantic decision task requires the subject to decide which part (morpheme) of a multimorphemic word is most important to the meaning of the whole word. Performance on this task is a measure of a subject's ability to recognize the meanings of the constituents of a multimorphemic word.

D.R. was able to make semantic judgments about the components of multimorphemic words (86.5%; -1.7z). However, she was significantly slow at making her decisions (6697.8 ms; 1320.6z), suggesting that she may have trouble accessing meaning from morphology.

Picture naming: Oral

The oral picture-naming task requires the subject to name a pictured object or animal verbally. Since the test administrator scores the test by pressing a key to signal whether the response was correct, incorrect, or absent, the RTs on this test are not reliable. However, very long reaction times are indicative of a delayed response, which suggests that the subject had difficulty in accessing names.

D.R. was impaired at producing names for pictures (34.1%; -12.2z), suggesting that she has word-finding problems.

The following table shows the breakdown of D.R.'s oral picture naming results by semantic category. Bold text is used to highlight categories that are significantly impaired (as measured by a z-score less than -2z).

Semantic Category		
Animals:	**12.5%**	**-16.5z**
Fruits:	**25%**	**-14z**
Tools:	**62.5%**	**-6.5z**
Music:	**12.5%**	**-16.5z**
Miscellaneous:	**50%**	**-9z**

Picture naming: Written

The written picture-naming task requires the subject to name a pictured object or animal by writing out its name. Since the subject must write out each response and the test administrator scores the test by pressing a key to signal whether the response was correct, incorrect, or absent, the RTs on this test are not reliable. However, very long reaction times are indicative of a delayed response, which suggests that the subject had difficulty in accessing names.

D.R. was impaired at writing names for pictures (25%; -14z), suggesting that she has word-finding problems.

The following table shows the breakdown of D.R.'s written picture naming results by semantic category. Bold text is used to highlight categories that are significantly impaired (as measured by a z-score less than -2z).

Semantic Category		
Animals:	**62.5%**	**-6.5z**
Fruits:	**0%**	**-19z**
Tools:	**0%**	**-19z**
Music:	**12.5%**	**-16.5z**
Miscellaneous:	**41.7%**	**-10.7z**

E.) Sentence processing

The sentence processing tests assess production and comprehension of sentences.

Sentence Processing: Visual Comprehension

The visual sentence comprehension task requires the subject to decide whether a written sentence correctly describes a short animated film.

D.R. was impaired at deciding if written sentences correctly described a short animation (67.9%; -5.4z), suggesting that she has trouble accessing meaning from printed sentences.

The following table shows the breakdown of D.R.'s visual sentence comprehension results by type of syntactic structure. Bold text is used to highlight structures that are significantly impaired (as measured by a z-score less than -2z).

Syntactic structure

Active:	100%	1z	(E.g., 'The cat chases the dog.' Foils reverse agent and patient.)
Passive:	**25%**	**-14z**	**(E.g., 'The dog is bitten by the cat.' Foils reverse agent and patient.)**
Verb:	100%	1z	(E.g., 'The man kicks.' Foils use different action.)
Preposition:	87.5%	-1.5z	(E.g., 'The man walks down the stairs.' Foils change preposition.)
Particle:	**25%**	**-14z**	**(E.g., 'The man turned on the TV.' Foils use different verb particle.)**
Dative passive:	**62.5%**	**-6.5z**	**(E.g., 'The flower was given to the woman by the boy.' Foils reverse agent and patient.)**
Subject object relative:	**75%**	**-4z**	**(E.g., 'The boy the girl kicked hugged the man.' Foils reverse agent and patient or change main verb action.)**

Sentence Processing: Auditory Comprehension

The auditory sentence comprehension task requires the subject to decide whether a spoken sentence correctly describes a short animated film.

D.R. was impaired at deciding if spoken sentences correctly described a short animation (60.7%; -6.9z), suggesting that she has trouble accessing meaning from spoken sentences.

The following table shows the breakdown of D.R.'s auditory sentence comprehension results by type of syntactic structure. Bold text is used to highlight structures that are significantly impaired (as measured by a z-score less than -2z).

Syntactic structure

Active:	**62.5%**	**-6.5z**	**(E.g., 'The cat chases the dog.' Foils reverse agent and patient.)**
Passive:	**37.5%**	**-11.5z**	**(E.g., 'The dog is bitten by the cat.' Foils reverse agent and patient.)**
Verb:	**50%**	**-9z**	**(E.g., 'The man kicks.' Foils use different action.)**
Preposition:	**62.5%**	**-6.5z**	**(E.g., 'The man walks down the stairs.' Foils change preposition.)**
Particle:	**50%**	**-9z**	**(E.g., 'The man turned on the TV.' Foils use different verb particle.)**
Dative passive:	87.5%	-1.5z	(E.g., 'The flower was given to the woman by the boy.' Foils reverse agent and patient.)
Subject object relative:	**75%**	**-4z**	**(E.g., 'The boy the girl kicked hugged the man.' Foils reverse agent and patient or change main verb action.)**

Sentence Processing: Idiom Comprehension

The idiom comprehension task requires the subject to decide whether or not a written sentence could have a literal interpretation.

D.R. did not complete the idiom comprehension task.

Sentence Processing: Production

The sentence production task requires the subject to produce a sentence that describes a short animation. Constraints in the task force the production of different forms of sentences. Subjects may produce sentences orally or in written form. Because of the complex nature of the response, reaction times have little meaning for this task.

D.R. was impaired at producing constrained sentences (8%; -17.4z).

The following table shows the breakdown of D.R.'s sentence production results by type of syntactic structure. Bold text is used to highlight structures that are significantly impaired (as measured by a z-score less than -2z).

Syntactic structure

Active:	**40%**	**-11z**	**(E.g., 'The boy kicks the woman.')**
Passive:	**0%**	**-19z**	**(E.g., 'The woman is carried by the man.')**
Dative:	**0%**	**-19z**	**(E.g., 'The girl puts the cushion on the bed.')**
Dative passive:	**0%**	**-19z**	**(E.g., 'The ball is given to the baby by the man.')**
Subject object relative:	**0%**	**-19z**	**(E.g., 'The man with the phone points at the girl.')**

Appendix B
The Alberta Language Function Assessment Battery: Results for patient DP

ALFAB Subtests Summary Table - DP

A.) Low-level input & production		
Phoneme Discrimination:	95.5%	0.1z
Monomorphemic Repetition:	**26.6%**	**-13.7z**
Multimorphemic Repetition:	**33.8%**	**-12.2z**
B.) Orthographic & phonological processing		
Visual Lexical Decision:	**73.2%**	**-4.4z**
Auditory Lexical Decision:	**81%**	**-2.8z**
Rhyme Judgment:	**N/A**	
Reading:	**20.7%**	**-14.9z**
Spelling:	100%	1z
C) Fluency		
Oral:	**1 words**	**-18.8z**
Written:	**1 words**	**-18.8z**
Multimorphemic:	**9 words**	**-17.2z**
D.) Semantic access		
Word-picture matching		
Visual:	**44.3%**	**-10.1z**
Auditory:	98.4%	0.7z
Multimorphemic:	84.8%	-2z
Synonym judgment		
Visual:	**65%**	**-6z**
Auditory:	**22.5%**	**-14.5z**
Semantic decision		
Visual:	**62.5%**	**-6.5z**
Auditory:	**67.5%**	**-5.5z**
Multimorphemic:	**50%**	**-9z**
Picture naming		
Oral:	**20.5%**	**-14.9z**
Written:	**27.3%**	**-13.5z**
E) Sentence processing		
Visual comprehension:	**75%**	**-4z**
Auditory comprehension:	**62.5%**	**-6.5z**
Idiom judgment:	**N/A**	
Production:	**N/A**	

Analysis - DP

A.) Low-level input & production
For detailed explanation, please refer to Appendix A.

Phoneme Discrimination
For detailed explanation, please refer to Appendix A.

Repetition of monomorphemic words.
For detailed explanation, please refer to Appendix A.

The following table shows the breakdown of D.P.'s repetition results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in his performance (as measured by a difference between factor levels of at least one z-score).

Word frequency			
High:	**41.7%**	**-10.7z**	**2.3**
Low:	**30%**	**-13z**	
Word Length			
Nonword Length			
Word phonological neighbourhood			
Nonword phonological neighbourhood			

D.P. repeated high frequency words better than low frequency words. This is a common pattern.

Repetition of multimorphemic words.
For detailed explanation, please refer to Appendix A.

D.P. is impaired at repeating multimorphemic words (33.8%; -12.2z).

B.) Orthographic and phonological processing
For detailed explanation, please refer to Appendix A.

Visual Lexical Decision
The following table shows the breakdown of D.P.'s visual lexical decision results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in his performance (as measured by a difference between factor levels of at least 1 z-score).

Wordness			
Word Frequency			
High frequency:	**100%**	**1z**	**1.5**
Low frequency:	**92.5%**	**-0.5z**	

Length			
Long:	**87.5%**	**-1.5z**	**-2.1**
Short:	**97.8%**	**0.6z**	
Word Phonological Neighbourhood			
Nonword Phonological Neighbourhood			
Concreteness			
Abstract:	93.8%	-0.2z	-0.5
Concrete:	96.6%	0.3z	
Word Regularity			
Regular:	**90.6%**	**-0.9z**	**-1.9**
Irregular:	**100%**	**1z**	

Auditory Lexical Decision
For detailed explanation, please refer to Appendix A.

The following table shows the breakdown of D.P.'s auditory lexical decision results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in his performance (as measured by a difference between factor levels of at least 1 z-score).

Wordness			
Word Frequency			
High frequency:	**100%**	**1z**	**1.5**
Low frequency:	**92.5%**	**-0.5z**	
Length			
Long:	**100%**	**1z**	**1.3**
Short:	**93.3%**	**-0.3z**	
Phonological Neighbourhood			
High PN:	**76.9%**	**-3.6z**	**-2.9**
Low PN:	**91.4%**	**-0.7z**	
Concreteness			
Abstract:	**90.6%**	**-0.9z**	**-1.9**
Concrete:	**100%**	**1z**	
Word Regularity			
Regular:	96.9%	0.4z	0.8
Irregular:	93.1%	-0.4z	

Rhyme Judgment
For detailed explanation, please refer to Appendix A.

D.P. did not complete the rhyme judgment task.

Reading words and nonwords
For detailed explanation, please refer to Appendix A.

Spelling words and nonwords

For detailed explanation, please refer to Appendix A.

D.P. scored within the normal range in spelling simple words (100%; 1z) and complex words (100%; 1z), as well as nonwords (100%; 1z).

D.P. is worse at spelling phonologically complex words than phonologically simple words. This is a common pattern.

C.) Word fluency

For detailed explanation, please refer to Appendix A.

Oral word fluency

The oral word fluency test asks subjects to orally produce words beginning with the letter 's'.

D.P. produced 1 's' words in 60 seconds (60 words per second). This is below the normal range (-18.8z).

Written word fluency

The oral word fluency test asks subjects to produce written words beginning with the letter 'c'.

D.P. produced 2 written 'c' words in 60 seconds (30 words per second). This is below the normal range (-18.8z).

Morphological word fluency

The morphological word fluency test asks subjects to orally produce words that end with specific morphemes.

Summary N	z	Words per second
'-er' Words: 3	**-18.4**	**20**
'-ing' Words: 2	**-18.6**	**30**
'-ness' Words: 1	**-18.8**	**60**
'-s' Words: 3	**-18.4**	**20**
Total Words: 9	**-17.2**	**26.7**

D.P. produced 9 affixed words in 240 seconds (26.7 words per second). This is below the normal range (-17.2z).

D.) Semantic access

For detailed explanation, please refer to Appendix A.

Word-picture matching: Visual

For detailed explanation, please refer to Appendix A.

D.P. was impaired at picking the correctly matching picture for visually presented words (44.3%; -10.1z), suggesting that he has trouble accessing meaning from printed words.

Word-picture matching: Auditory
For detailed explanation, please refer to Appendix A.

Overall, D.P. was able to pick the correctly matching picture for auditorily presented words (98.4%; 0.7z).

Word-picture matching: Morphological
For detailed explanation, please refer to Appendix A.

D.P. was able to pick the correct multimorphemic name for a picture (84.8%; -2z).

Synonym judgment: Visual
For detailed explanation, please refer to Appendix A.

D.P. was impaired at choosing synonyms of visually presented words (65%; -6z), suggesting that he has trouble accessing meaning from written words.

The following table shows the breakdown of D.P.'s visual synonym results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in his performance (as measured by a difference between factor levels of at least 1 z-score).

Concreteness			
Concrete:	**60%**	**-7z**	**-2**
Abstract:	**70%**	**-5z**	
Foil type			
Phonological:	**80%**	**-3z**	**6**
Semantic:	**50%**	**-9z**	
Foil type for Concrete words			
Phonological:	**80%**	**-3z**	**8**
Semantic:	**40%**	**-11z**	
Foil type for Abstract words			
Phonological:	**80%**	**-3z**	**4**
Semantic:	**60%**	**-7z**	

D.P. showed an unusual advantage for selecting synonyms of abstract words. Although abstract word sparing is not unheard of, it is very rare. It may be interesting to follow up this finding more closely.

Synonym judgment: Auditory
For detailed explanation, please refer to Appendix A.

D.P. was impaired at choosing synonyms of auditorily presented words (22.5%; -14.5z), suggesting that he has trouble accessing meaning from spoken words.

The following table shows the breakdown of D.P.'s auditory synonym results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in his performance (as measured by a difference between factor levels of at least 1 z-score).

Concreteness			
Concrete:	**15%**	**-16z**	**-3**
Abstract:	**30%**	**-13z**	
Foil type			
Phonological:	**15%**	**-16z**	**-3**
Semantic:	**30%**	**-13z**	
Foil type for Concrete words			
Phonological:	**0%**	**-19z**	**-6**
Semantic:	**30%**	**-13z**	
Foil type for Abstract words			
Phonological:	30%	-13z	0
Semantic:	30%	-13z	

D.P. showed an unusual advantage for selecting synonyms of abstract words. Although abstract word sparing is not unheard of, it is very rare. It may be interesting to follow up this finding more closely.

Synonym judgment: Morphological
For detailed explanation, please refer to Appendix A.

Semantic Decision: Visual
For detailed explanation, please refer to Appendix A.

D.P. was impaired at making sensibility judgments about written sentences (62.5%; -6.5z), suggesting that he has trouble accessing meaning from written sentences.

Semantic Decision: Auditory
For detailed explanation, please refer to Appendix A.

D.P. was impaired at making sensibility judgments about spoken sentences (67.5%; -5.5z), suggesting that he has trouble accessing meaning from spoken sentences.

Semantic Decision: Morphological
For detailed explanation, please refer to Appendix A.

D.P. was impaired at making semantic judgments about the components of multimorphemic words (50%; -9z), suggesting that he has trouble accessing meaning from morphology.

Picture naming: Oral
For detailed explanation, please refer to Appendix A.

D.P. was impaired at producing names for pictures (20.5%; -14.9z), suggesting that he has word-finding problems.

The following table shows the breakdown of D.P.'s oral picture naming results by semantic category. Bold text is used to highlight categories that are significantly impaired (as measured by a z-score less than -2z).

Semantic Category		
Animals:	**12.5%**	**-16.5z**
Fruits:	**25%**	**-14z**
Tools:	**37.5%**	**-11.5z**
Music:	**0%**	**-19z**
Miscellaneous:	**25%**	**-14z**

Picture naming: Written

For detailed explanation, please refer to Appendix A.

D.P. was impaired at writing names for pictures (27.3%; -13.5z), suggesting that he has word-finding problems.

The following table shows the breakdown of D.P.'s written picture naming results by semantic category. Bold text is used to highlight categories that are significantly impaired (as measured by a z-score less than -2z).

Semantic Category		
Animals:	**25%**	**-14z**
Fruits:	**25%**	**-14z**
Tools:	**37.5%**	**-11.5z**
Music:	**12.5%**	**-16.5z**
Miscellaneous:	**33.3%**	**-12.3z**

E.) Sentence processing

For detailed explanation, please refer to Appendix A.

Sentence Processing: Visual Comprehension

For detailed explanation, please refer to Appendix A.

D.P. was impaired at deciding if written sentences correctly described a short animation (75%; -4z), suggesting that he has trouble accessing meaning from printed sentences.

The following table shows the breakdown of D.P.'s visual sentence comprehension results by type of syntactic structure. Bold text is used to highlight structures that are significantly impaired (as measured by a z-score less than -2z).

Syntactic structure			
Active:	87.5%	-1.5z	(E.g., 'The cat chases the dog.' Foils reverse agent and patient.)
Passive:	**62.5%**	**-6.5z**	**(E.g., 'The dog is bitten by the cat.' Foils reverse agent and patient.)**
Verb:	100%	1z	(E.g., 'The man kicks.' Foils use different action.)
Preposition:	**50%**	**-9z**	**(E.g., 'The man walks down the stairs.' Foils change preposition.)**
Particle:	87.5%	-1.5z	(E.g., 'The man turned on the TV.' Foils use different verb particle.)
Dative passive:	**50%**	**-9z**	**(E.g., 'The flower was given to the woman**

			by the boy.' Foils reverse agent and patient.)
Subject object relative:	87.5%	-1.5z	(E.g., 'The boy the girl kicked hugged the man.' Foils reverse agent and patient or change main verb action.)

Sentence Processing: Auditory Comprehension

For detailed explanation, please refer to Appendix A.

D.P. was impaired at deciding if spoken sentences correctly described a short animation (62.5%; -6.5z), suggesting that he has trouble accessing meaning from spoken sentences.

The following table shows the breakdown of D.P.'s auditory sentence comprehension results by type of syntactic structure. Bold text is used to highlight structures that are significantly impaired (as measured by a z-score less than -2z).

Syntactic structure			
Active:	**75%**	**-4z**	**(E.g., 'The cat chases the dog.' Foils reverse agent and patient.)**
Passive:	**25%**	**-14z**	**(E.g., 'The dog is bitten by the cat.' Foils reverse agent and patient.)**
Verb:	**62.5%**	**-6.5z**	**(E.g., 'The man kicks.' Foils use different action.)**
Preposition:	**50%**	**-9z**	**(E.g., 'The man walks down the stairs.' Foils change preposition.)**
Particle:	**62.5%**	**-6.5z**	**(E.g., 'The man turned on the TV.' Foils use different verb particle.)**
Dative passive:	87.5%	-1.5z	(E.g., 'The flower was given to the woman by the boy.' Foils reverse agent and patient.)
Subject object relative:	**75%**	**-4z**	**(E.g., 'The boy the girl kicked hugged the man.' Foils reverse agent and patient or change main verb action.)**

Sentence Processing: Idiom Comprehension

For detailed explanation, please refer to Appendix A.

D.P. did not complete the idiom comprehension task.

Sentence Processing: Production

For detailed explanation, please refer to Appendix A.

D.P. did not complete the sentence production task.

Appendix C

The Alberta Language Function Assessment Battery: Results for patient PH

ALFAB Subtests Summary Table - PH

A.) Low-level input & production		
Phoneme Discrimination:	**55.7%**	**-7.9z**
Monomorphemic Repetition:	**46.9%**	**-9.6z**
Multimorphemic Repetition:	**59%**	**-7.2z**
B.) Orthographic & phonological processing		
Visual Lexical Decision:	**N/A**	
Auditory Lexical Decision:	**N/A**	
Rhyme Judgment:	**N/A**	
Reading:	**N/A**	
Spelling:	**N/A**	
C) Fluency		
Oral:	**N/A**	
Written:	**N/A**	
Multimorphemic:	**6 words**	**-17.8z**
D.) Semantic access		
Word-picture matching		
Visual: N/A		
Note: -% of the data was below the minimum RT cut-off (0).		
Auditory: N/A		
Note: -% of the data was below the minimum RT cut-off (0).		
Multimorphemic:	90.9%	-0.8z
Synonym judgment		
Visual:	**60%**	**-7z**
Auditory:	**N/A**	
Semantic decision		
Visual:	**N/A**	
Auditory:	**N/A**	
Multimorphemic:	**76.9%**	**-3.6z**
Picture naming		
Oral:	**N/A**	
Written:	**N/A**	
E) Sentence processing		
Visual comprehension:	**N/A**	
Auditory comprehension:	**57.1%**	**-7.6z**
Idiom judgment:	**N/A**	
Production:	**N/A**	

Analysis - PH

A.) Low-level input & production
For detailed explanation, please refer to Appendix A.

Phoneme Discrimination
For detailed explanation, please refer to Appendix A.

Repetition of monomorphemic words.
For detailed explanation, please refer to Appendix A.

The following table shows the breakdown of P.H.'s repetition results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in his performance (as measured by a difference between factor levels of at least one z-score).

Word frequency			
High:	**83.3%**	**-2.3z**	**3.7**
Low:	**65%**	**-6z**	
Word Length			
Nonword Length			
Word phonological neighbourhood			
Nonword phonological neighbourhood			

P.H. repeated high frequency words better than low frequency words. This is a common pattern.

Repetition of multimorphemic words.
For detailed explanation, please refer to Appendix A.

P.H. is impaired at repeating multimorphemic words (59%; -7.2z).

B.) Orthographic and phonological processing
For detailed explanation, please refer to Appendix A.

Visual Lexical Decision
For detailed explanation, please refer to Appendix A.

P.H. did not complete the visual lexical decision task.

Auditory Lexical Decision
For detailed explanation, please refer to Appendix A.

P.H. did not complete the auditory lexical decision task.

Rhyme Judgment
For detailed explanation, please refer to Appendix A.

P.H. did not complete the rhyme judgment task.

Reading words and nonwords

For detailed explanation, please refer to Appendix A.

P.H. did not complete the reading task. This may be due to an inability to read at all.

Spelling words and nonwords

For detailed explanation, please refer to Appendix A.

P.H. did not complete the spelling task. This may be due to an inability to spell at all.

C.) Word fluency

For detailed explanation, please refer to Appendix A.

Oral word fluency

For detailed explanation, please refer to Appendix A.

P.H. did not complete the oral word fluency task.

Written word fluency

For detailed explanation, please refer to Appendix A.

P.H. did not complete the written word fluency task.

Morphological word fluency

For detailed explanation, please refer to Appendix A.

Summary N	z	Words per second
'-er' Words: 1	**-18.8**	**60**
'-ing' Words: 1	**-18.8**	**60**
'-ness' Words: 0	**-19**	**[Error]**
'-s' Words: 4	**-18.2**	**15**
Total Words: 6	**-17.8**	**40**

P.H. produced 6 affixed words in 240 seconds (40 words per second). This is below the normal range (-17.8z).

D.) Semantic access

For detailed explanation, please refer to Appendix A.

Word-picture matching: Visual

For detailed explanation, please refer to Appendix A.

Word-picture matching: Auditory

For detailed explanation, please refer to Appendix A.

P.H. did not complete the auditory word-picture matching task.

Word-picture matching: Morphological

For detailed explanation, please refer to Appendix A.

P.H. was able to pick the correct multimorphemic name for a picture (90.9%; -0.8z).

Synonym judgment: Visual
For detailed explanation, please refer to Appendix A.

P.H. was impaired at choosing synonyms of visually presented words (60%; -7z), suggesting that he has trouble accessing meaning from written words.

The following table shows the breakdown of P.H.'s visual synonym results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in his performance (as measured by a difference between factor levels of at least 1 z-score).

Concreteness			
Concrete:	60%	-7z	0
Abstract:	60%	-7z	
Foil type			
Phonological:	**70%**	**-5z**	**4**
Semantic:	**50%**	**-9z**	
Foil type for Concrete words			
Phonological:	**70%**	**-5z**	**4**
Semantic:	**50%**	**-9z**	
Foil type for Abstract words			
Phonological:	**70%**	**-5z**	**4**
Semantic:	**50%**	**-9z**	

Synonym judgment: Auditory
For detailed explanation, please refer to Appendix A.

P.H. did not complete the auditory synonym judgment task.

Synonym judgment: Morphological
For detailed explanation, please refer to Appendix A.

Semantic Decision: Visual
For detailed explanation, please refer to Appendix A.

P.H. did not complete the visual semantic decision task.

Semantic Decision: Auditory
For detailed explanation, please refer to Appendix A.

P.H. did not complete the auditory semantic decision task.

Semantic Decision: Morphological
For detailed explanation, please refer to Appendix A.

P.H. was impaired at making semantic judgments about the components of multimorphemic words (76.9%; -3.6z), suggesting that he has trouble accessing meaning from morphology.

Picture naming: Oral
For detailed explanation, please refer to Appendix A.

P.H. did not complete the oral picture-naming task.

Picture naming: Written
For detailed explanation, please refer to Appendix A.

P.H. did not complete the written picture-naming task.

E.) Sentence processing
For detailed explanation, please refer to Appendix A.

Sentence Processing: Visual Comprehension
For detailed explanation, please refer to Appendix A.

P.H. did not complete the written sentence comprehension task.

Sentence Processing: Auditory Comprehension
For detailed explanation, please refer to Appendix A.

P.H. was impaired at deciding if spoken sentences correctly described a short animation (57.1%; -7.6z), suggesting that he has trouble accessing meaning from spoken sentences.

The following table shows the breakdown of P.H.'s auditory sentence comprehension results by type of syntactic structure. Bold text is used to highlight structures that are significantly impaired (as measured by a z-score less than -2z).

Syntactic structure			
Active:	87.5%	-1.5z	(E.g., 'The cat chases the dog.' Foils reverse agent and patient.)
Passive:	**25%**	**-14z**	**(E.g., 'The dog is bitten by the cat.' Foils reverse agent and patient.)**
Verb:	**50%**	**-9z**	**(E.g., 'The man kicks.' Foils use different action.)**
Preposition:	**62.5%**	**-6.5z**	**(E.g., 'The man walks down the stairs.' Foils change preposition.)**
Particle:	**75%**	**-4z**	**(E.g., 'The man turned on the TV.' Foils use different verb particle.)**
Dative passive:	**50%**	**-9z**	**(E.g., 'The flower was given to the woman by the boy.' Foils reverse agent and patient.)**
Subject object relative:	**50%**	**-9z**	**(E.g., 'The boy the girl kicked hugged the man.' Foils reverse agent and patient or change main verb action.)**

Sentence Processing: Idiom Comprehension

P.H. did not complete the idiom comprehension task.

Sentence Processing: Production
P.H. did not complete the sentence production task.

Appendix D
The Alberta Language Function Assessment Battery: Results for patient JN

ALFAB Subtests Summary Table - JN

A.) Low-level input & production		
Phoneme Discrimination:	88.6%	-1.3z
Monomorphemic Repetition:	**42.2%**	**-10.6z**
Multimorphemic Repetition:	**70.5%**	**-4.9z**
B.) Orthographic & phonological processing		
Visual Lexical Decision:	85.2%	-2z
Auditory Lexical Decision:	**76.1%**	**-3.8z**
Rhyme Judgment:	**69.8%**	**-5z**
Reading:	**45.9%**	**-9.8z**
Spelling:	**5.5%**	**-17.9z**
C) Fluency		
Oral:	**1 words**	**-18.8z**
Written:	**0 words**	**-19z**
Multimorphemic:	**1 words**	**-18.8z**
D.) Semantic access		
Word-picture matching		
Visual:	88.5%	-1.3z
Auditory:	95.1%	0z
Multimorphemic:	84.8%	-2z
Synonym judgment		
Visual:	**55%**	**-8z**
Auditory:	**57.5%**	**-7.5z**
Semantic decision		
Visual:	**63.8%**	**-6.2z**
Auditory:	**68.8%**	**-5.2z**
Multimorphemic:	**40.4%**	**-10.9z**
Picture naming		
Oral:	**52.3%**	**-8.5z**
E) Sentence processing		
Visual comprehension:	**58.9%**	**-7.2z**
Auditory comprehension:	**39.3%**	**-11.1z**
Idiom judgment:	**58%**	**-7.4z**
Production:	**32%**	**-12.6z**

Analysis - JN

A.) Low-level input & production
For detailed explanation, please refer to Appendix A.

Phoneme Discrimination
For detailed explanation, please refer to Appendix A.

Repetition of monomorphemic words.
For detailed explanation, please refer to Appendix A.

The following table shows the breakdown of J.N.'s repetition results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in his performance (as measured by a difference between factor levels of at least one z-score).

Word frequency			
High:	**58.3%**	**-7.3z**	**2.7**
Low:	**45%**	**-10z**	
Word Length			
Nonword Length			
Word phonological neighbourhood			
Nonword phonological neighbourhood			

J.N. repeated high frequency words better than low frequency words. This is a common pattern.

Repetition of multimorphemic words.
For detailed explanation, please refer to Appendix A.
J.N. is impaired at repeating multimorphemic words (70.5%; -4.9z).

B.) Orthographic and phonological processing
For detailed explanation, please refer to Appendix A.

Visual Lexical Decision
For detailed explanation, please refer to Appendix A.

The following table shows the breakdown of J.N.'s visual lexical decision results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in his performance (as measured by a difference between factor levels of at least 1 z-score).

Wordness			
Length			
Long:	100%	1z	0.9
Short:	95.6%	0.1z	
Word Phonological Neighbourhood			

Nonword Phonological Neighbourhood			
Concreteness			
Abstract:	**93.8%**	**-0.2z**	**-1.2**
Concrete:	**100%**	**1z**	
Word Regularity			
Regular:	**100%**	**1z**	**1.4**
Irregular:	**93.1%**	**-0.4z**	

Auditory Lexical Decision

For detailed explanation, please refer to Appendix A.

The following table shows the breakdown of J.N.'s auditory lexical decision results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in his performance (as measured by a difference between factor levels of at least 1 z-score).

Wordness			
Word Frequency			
High frequency:	**95.2%**	**0z**	**2**
Low frequency:	**85%**	**-2z**	
Length			
Long:	87.5%	-1.5z	-0.3
Short:	88.9%	-1.2z	
Phonological Neighbourhood			
High PN:	**61.5%**	**-6.7z**	**-4.9**
Low PN:	**86.2%**	**-1.8z**	
Concreteness			
Abstract:	**81.3%**	**-2.7z**	**-3**
Concrete:	**96.6%**	**0.3z**	
Word Regularity			
Regular:	**93.8%**	**-0.2z**	**2.2**
Irregular:	**82.8%**	**-2.4z**	

Rhyme Judgment

For detailed explanation, please refer to Appendix A.

J.N. scored below the normal range on this task for both words (78.3%; -3.3z) and nonwords (60%; -7z).

The following table shows the breakdown of J.N.'s rhyme judgment results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in his performance (as measured by a difference between factor levels of at least 1 z-score).

Wordness			
Word:	**78.3%**	**-3.3z**	**3.7**
Nonword:	**60%**	**-7z**	
Phonological Neighbourhood			

Target relation			
Response choices			
Nonwords:	**50%**	**-9z**	**-4**
Pseudohomophones:	**70%**	**-5z**	

Reading words and nonwords
For detailed explanation, please refer to Appendix A.

Spelling words and nonwords
For detailed explanation, please refer to Appendix A.

J.N. was below the normal range in spelling both simple words (12.5%; -16.5z) and complex words (6.3%; -17.7z). He was better at spelling high frequency words (18.8%; -15.2z) than low frequency words (0%; -19z). He could not spell a single nonword (0%; -19z). He is having severe difficulty in translating from phonology to orthography.

The following table shows the breakdown of J.N.'s spelling results by the factors that were manipulated. Bold text is used to highlight factors that appear to be significantly implicated in his performance (as measured by a difference between factor levels of at least 1 z-score).

Word frequency			
High:	**18.8%**	**-15.2z**	**3.8**
Low:	**0%**	**-19z**	
Concreteness			
Concrete:	**12.5%**	**-16.5z**	**1.2**
Abstract:	**6.3%**	**-17.7z**	
Orthographic transparency			
Transparent:	**6.3%**	**-17.7z**	**-1.2**
Opaque:	**12.5%**	**-16.5z**	
Phonological complexity			
Complex:	**6.3%**	**-17.7z**	**-1.2**
Simple:	**12.5%**	**-16.5z**	

J.N. spelled high frequency words better than low frequency words. This is a common pattern. J.N. showed an advantage for spelling concrete over abstract words. It is striking to note that J.N. is better at spelling opaque words (like 'yacht') than transparent words (like 'scarf'). This suggests that he may have damage to the phonological assembly route (which can only be used to spell transparent words and nonwords) but have intact access to the look-up route. This is consistent with his poor performance at spelling nonwords.

C.) Word fluency
For detailed explanation, please refer to Appendix A.

Oral word fluency
For detailed explanation, please refer to Appendix A.

J.N. produced 1 's' words in 60 seconds (60 words per second). This is below the normal range (-18.8z).

Written word fluency

For detailed explanation, please refer to Appendix A.

J.N. produced 0 written 'c' words in 60 seconds ([Error] words per second). This is below the normal range (-19z).

For detailed explanation, please refer to Appendix A.

Morphological word fluency

For detailed explanation, please refer to Appendix A.

Summary N	z	Words per second
'-er' Words: 0	**-19**	**[Error]**
'-ing' Words: 0	**-19**	**[Error]**
'-ness' Words: 0	**-19**	**[Error]**
'-s' Words: 1	**-18.8**	**60**
Total Words: 1	**-18.8**	**240**

J.N. produced 1 affixed word in 240 seconds (240 words per second). This is below the normal range (-18.8z).

D.) Semantic access

For detailed explanation, please refer to Appendix A.

Word-picture matching: Visual

For detailed explanation, please refer to Appendix A.

Overall, J.N. was able to pick the correctly matching picture for visually presented words (88.5%; -1.3z).

Word-picture matching: Auditory

For detailed explanation, please refer to Appendix A.

Overall, J.N. was able to pick the correctly matching picture for auditorily presented words (95.1%; 0z).

Word-picture matching: Morphological

For detailed explanation, please refer to Appendix A.

J.N. was able to pick the correct multimorphemic name for a picture (84.8%; -2z).

Synonym judgment: Visual

For detailed explanation, please refer to Appendix A.

J.N. was impaired at choosing synonyms of visually presented words (55%; -8z), suggesting that he has trouble accessing meaning from written words.

The following table shows the breakdown of J.N.'s visual synonym results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in his performance (as measured by a difference between factor levels of at least 1 z-score).

Concreteness			
Concrete:	**75%**	**-4z**	**8**
Abstract:	**35%**	**-12z**	
Foil type			
Phonological:	**60%**	**-7z**	**2**
Semantic:	**50%**	**-9z**	
Foil type for Concrete words			
Phonological:	**80%**	**-3z**	**2**
Semantic:	**70%**	**-5z**	
Foil type for Abstract words			
Phonological:	**40%**	**-11z**	**2**
Semantic:	**30%**	**-13z**	

Synonym judgment: Auditory

For detailed explanation, please refer to Appendix A.

J.N. was impaired at choosing synonyms of auditorily presented words (57.5%; -7.5z), suggesting that he has trouble accessing meaning from spoken words.

The following table shows the breakdown of J.N.'s auditory synonym results by the factors that were manipulated. Bold text is used to highlight factors that seem significantly implicated in his performance (as measured by a difference between factor levels of at least 1 z-score).

Concreteness			
Concrete:	**45%**	**-10z**	**-5**
Abstract:	**70%**	**-5z**	
Foil type for Concrete words			
Phonological:	**50%**	**-9z**	**2**
Semantic:	**40%**	**-11z**	
Foil type for Abstract words			
Phonological:	**60%**	**-7z**	**-4**
Semantic:	**80%**	**-3z**	

J.N. showed an unusual advantage for selecting synonyms of abstract words. Although abstract word sparing is not unheard of, it is very rare. It may be interesting to follow up this finding more closely.

Synonym judgment: Morphological

The morphological synonym judgment task requires the subject to decide whether a description is a plausible definition of a multimorphemic word.

Semantic Decision: Visual

The visual semantic decision task requires the subject to decide whether or not a visually presented sentence is both sensible and true.

J.N. was impaired at making sensibility judgments about written sentences (63.8%; -6.2z), suggesting that he has trouble accessing meaning from written sentences.

Semantic Decision: Auditory

The auditory semantic decision task requires the subject to decide whether or not a spoken sentence is both sensible and true.

J.N. was impaired at making sensibility judgments about spoken sentences (68.8%; -5.2z), suggesting that he has trouble accessing meaning from spoken sentences.

Semantic Decision: Morphological

For detailed explanation, please refer to Appendix A.

J.N. was impaired at making semantic judgments about the components of multimorphemic words (40.4%; -10.9z), suggesting that he has trouble accessing meaning from morphology.

Picture naming: Oral

For detailed explanation, please refer to Appendix A.

J.N. was impaired at producing names for pictures (52.3%; -8.5z), suggesting that he has word-finding problems.

The following table shows the breakdown of J.N.'s oral picture naming results by semantic category. Bold text is used to highlight categories that are significantly impaired (as measured by a z-score less than -2z).

Semantic Category		
Animals:	**50%**	**-9z**
Fruits:	**25%**	**-14z**
Tools:	**62.5%**	**-6.5z**
Music:	**25%**	**-14z**
Miscellaneous:	**83.3%**	**-2.3z**

Picture naming: Written

For detailed explanation, please refer to Appendix A.

The following table shows the breakdown of J.N.'s written picture naming results by semantic category. Bold text is used to highlight categories that are significantly impaired (as measured by a z-score less than -2z).

Semantic Category

E.) Sentence processing
For detailed explanation, please refer to Appendix A.

Sentence Processing: Visual Comprehension
For detailed explanation, please refer to Appendix A.

J.N. was impaired at deciding if written sentences correctly described a short animation (58.9%; -7.2z), suggesting that he has trouble accessing meaning from printed sentences.

The following table shows the breakdown of J.N.'s visual sentence comprehension results by type of syntactic structure. Bold text is used to highlight structures that are significantly impaired (as measured by a z-score less than -2z).

Syntactic structure			
Active:	**62.5%**	**-6.5z**	**(E.g., 'The cat chases the dog.' Foils reverse agent and patient.)**
Passive:	**37.5%**	**-11.5z**	**(E.g., 'The dog is bitten by the cat.' Foils reverse agent and patient.)**
Verb:	**75%**	**-4z**	**(E.g., 'The man kicks.' Foils use different action.)**
Preposition:	**62.5%**	**-6.5z**	**(E.g., 'The man walks down the stairs.' Foils change preposition.)**
Particle:	**62.5%**	**-6.5z**	**(E.g., 'The man turned on the TV.' Foils use different verb particle.)**
Dative passive:	**50%**	**-9z**	**(E.g., 'The flower was given to the woman by the boy.' Foils reverse agent and patient.)**
Subject object relative:	**62.5%**	**-6.5z**	**(E.g., 'The boy the girl kicked hugged the man.' Foils reverse agent and patient or change main verb action.)**

Sentence Processing: Auditory Comprehension
For detailed explanation, please refer to Appendix A.

J.N. was impaired at deciding if spoken sentences correctly described a short animation (39.3%; -11.1z), suggesting that he has trouble accessing meaning from spoken sentences.

The following table shows the breakdown of J.N.'s auditory sentence comprehension results by type of syntactic structure. Bold text is used to highlight structures that are significantly impaired (as measured by a z-score less than -2z).

Syntactic structure			
Active:	**25%**	**-14z**	**(E.g., 'The cat chases the dog.' Foils reverse agent and patient.)**
Passive:	**62.5%**	**-6.5z**	**(E.g., 'The dog is bitten by the cat.' Foils reverse agent and patient.)**
Verb:	**50%**	**-9z**	**(E.g., 'The man kicks.' Foils use different**

			action.)
Preposition:	**37.5%**	**-11.5z**	**(E.g., 'The man walks down the stairs.' Foils change preposition.)**
Particle:	**37.5%**	**-11.5z**	**(E.g., 'The man turned on the TV.' Foils use different verb particle.)**
Dative passive:	**37.5%**	**-11.5z**	**(E.g., 'The flower was given to the woman by the boy.' Foils reverse agent and patient.)**
Subject object relative:	**25%**	**-14z**	**(E.g., 'The boy the girl kicked hugged the man.' Foils reverse agent and patient or change main verb action.)**

Sentence Processing: Idiom Comprehension

For detailed explanation, please refer to Appendix A.

J.N. was impaired at deciding if written sentences had a literal interpretation (58%; -7.4z).

Sentence Processing: Production

For detailed explanation, please refer to Appendix A.

J.N. was impaired at producing constrained sentences (32%; -12.6z).

The following table shows the breakdown of J.N.'s sentence production results by type of syntactic structure. Bold text is used to highlight structures that are significantly impaired (as measured by a z-score less than -2z).

Syntactic structure			
Active:	**60%**	**-7z**	**(E.g., 'The boy kicks the woman.')**
Passive:	**0%**	**-19z**	**(E.g., 'The woman is carried by the man.')**
Dative:	100%	1z	(E.g., 'The girl puts the cushion on the bed.')
Dative passive:	**0%**	**-19z**	**(E.g., 'The ball is given to the baby by the man.')**
Subject object relative:	**0%**	**-19z**	**(E.g., 'The man with the phone points at the girl.')**

Appendix E

Critical word stimuli list

Identity word	Inflection1	Inflection 2	Derivation 1	Derivation 2	Compound1	Compound2
BACK	backed	backs	backing	backer	backbone	backdoor
BOOK	booked	books	bookish	booklet	cookbook	bookplate
HAND	handed	hands	handful	handsome	handbag	handgun
HEAD	headed	heads	heading	header	headstone	arrowhead
HORN	horned	horns	hornless	hornlike	shoehorn	hornpipe
HOUSE	housed	houses	housing	houseful	houseboat	housefly
LEAF	leafed	leaves	leafy	leafless	bayleaf	leafmould
LIGHT	lighted	lights	lighter	lighting	taillight	lightbulb
LOCK	locked	locks	lockable	locker	locknut	doorlock
NEST	nested	nests	nestling	nestle	nest-egg	birdnest
PAINT	painted	paints	painter	repaint	oilpaint	paintbrush
PAPER	papered	papers	papery	repaper	toilet-paper	paperclip
POCKET	pocketed	pockets	pocketing	pocketful	pocket-money	pocket-knife
POT	potted	pots	potter	potting	coffeepot	flowerpot
SAIL	sailed	sails	sailing	sailor	sailboat	sailcloth

Appendix F

Distracter word stimuli list

Identity word	Distracter words				
	Monomorphemic words		Multimorphemic words		
	Related	Unrelated	Inflection	Compound	Derivation
BACK	chest	wind	chested	whirlwind	windy
BOOK	shelf	girl	shelved	girlfriend	shelfful
HAND	mouth	king	mouthed	kingcup	mouthful
HEAD	eye	school	schooled	schoolboard	schooling
HORN	cow	seal	sealed	cowbell	sealer
HOUSE	garage	bottle	bottled	bottlecap	garageful
LEAF	tree	nose	treed	nose-ring	nosy
LIGHT	atom	lamp	lamped	lamppost	lamping
LOCK	safe	hen	saved	hencoop	safer
NEST	feather	sword	feathered	swordfish	feathering
PAINT	frame	bread	framed	gingerbread	reframe
PAPER	letter	baby	lettered	letterpress	reletter
POCKET	shirt	bill	billed	shirtsleeve	shirting
POT	cup	camera	cupped	camera-phone	cupping
SAIL	mast	drum	drummed	drumline	drumming

Appendix G

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term joint analysis (derived words on the intercept)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + log(SurfaceFreq + 1) + rcs(cDay, 5) + (1 + cDay | Patient) + (1 | ITEM)
Data: datTRAINED

AIC	BIC	logLik	deviance
2220	2297	-1097	2194

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
ITEM	(Intercept)	1.0757842	1.037200	
Patient	(Intercept)	2.6401588	1.624857	
	cDay	0.0006549	0.025591	0.971

Number of obs: 2731, groups: ITEM, 70; Patient, 4

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-4.64135	1.54273	-3.009	0.002625	**
DC	1.58611	0.39997	3.966	7.32e-05	***
DI	-1.19640	0.37170	-3.219	0.001287	**
DM	1.20376	0.58327	2.064	0.039037	*
log(SurfaceFreq)	0.29410	0.07672	3.834	0.000126	***
rcs(cDay, 5)cDay	-0.04785	0.02461	-1.944	0.051904	.
rcs(cDay, 5)cDay'	3.38863	0.40319	8.405	< 2e-16	***
rcs(cDay, 5)cDay''	-34.24003	3.77560	-9.069	< 2e-16	***
rcs(cDay, 5)cDay'''	51.21944	5.69991	8.986	< 2e-16	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix H

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term joint analysis (inflected words on the intercept)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + log(SurfaceFreq + 1) + rcs(cDay, 5) + (1 + cDay | Patient) + (1 | ITEM)
Data: datTRAINED

AIC	BIC	logLik	deviance
2220	2297	-1097	2194

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
ITEM	(Intercept)	1.07578551	1.037201	
Patient	(Intercept)	2.64008294	1.624833	
	cDay	0.00065488	0.025591	0.971

Number of obs: 2731, groups: ITEM, 70; Patient, 4

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-5.83773	1.56391	-3.733	0.000189	***
IC	2.78251	0.44521	6.250	4.11e-10	***
ID	1.19640	0.37170	3.219	0.001287	**
IM	2.40016	0.53882	4.455	8.41e-06	***
log(SurfaceFreq)	0.29410	0.07672	3.834	0.000126	***
rcs(cDay, 5)cDay	-0.04785	0.02461	-1.944	0.051905	.
rcs(cDay, 5)cDay'	3.38863	0.40319	8.405	< 2e-16	***
rcs(cDay, 5)cDay''	-34.23999	3.77560	-9.069	< 2e-16	***
rcs(cDay, 5)cDay'''	51.21938	5.69991	8.986	< 2e-16	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix I

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term analysis patient DR (compound words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + rcs(cDay, 5) + log(SurfaceFreq + 1) + (1 | ITEM)
Data: dat[dat$Patient == "D.R._4",]

AIC	BIC	logLik	deviance
405.6	451.1	-192.8	385.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	1.0767	1.0376

Number of obs: 700, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	5.18453	2.56504	2.021	0.043256	*
CD	-2.75180	0.69207	-3.976	7.00e-05	***
CI	-4.04881	0.80096	-5.055	4.30e-07	***
CM	-0.11578	1.34130	-0.086	0.931213	
rcs(Day, 5)cDay	0.10619	0.04662	2.278	0.022736	*
rcs(cDay, 5)cDay'	3.28801	1.19109	2.761	0.005771	**
rcs(cDay, 5)cDay''	-23.15104	9.36599	-2.472	0.013443	*
rcs(cDay, 5)cDay'''	30.59789	14.40691	2.124	0.033684	*
log(SurfaceFreq)	0.54964	0.15728	3.495	0.000475	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix J

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term analysis patient DR (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + rcs(cDay, 5) + log(SurfaceFreq + 1) + (1 | ITEM)
Data: dat[dat$Patient == "D.R._4",]

AIC	BIC	logLik	deviance
405.6	451.1	-192.8	385.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	1.0767	1.0376

Number of obs: 700, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	2.43274	2.55276	0.953	0.340600	
DC	2.75180	0.69207	3.976	7e-05	***
DI	-1.29702	0.59609	-2.176	0.029565	*
DM	2.63602	1.18806	2.219	0.026503	*
rcs(Day, 5)cDay	0.10619	0.04662	2.278	0.022736	*
rcs(cDay, 5)cDay'	3.28801	1.19109	2.761	0.005771	**
rcs(cDay, 5)cDay''	-23.15103	9.36600	-2.472	0.013443	*
rcs(cDay, 5)cDay'''	30.59788	14.40692	2.124	0.033684	*
log(SurfaceFreq)	0.54964	0.15728	3.495	0.000475	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix K

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term analysis patient DR (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + rcs(cDay, 5) + log(SurfaceFreq + 1) + (1 | ITEM)
Data: dat[dat$Patient == "D.R._4",]

AIC	BIC	logLik	deviance
405.6	451.1	-192.8	385.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	1.0767	1.0376

Number of obs: 700, groups: ITEM, 35

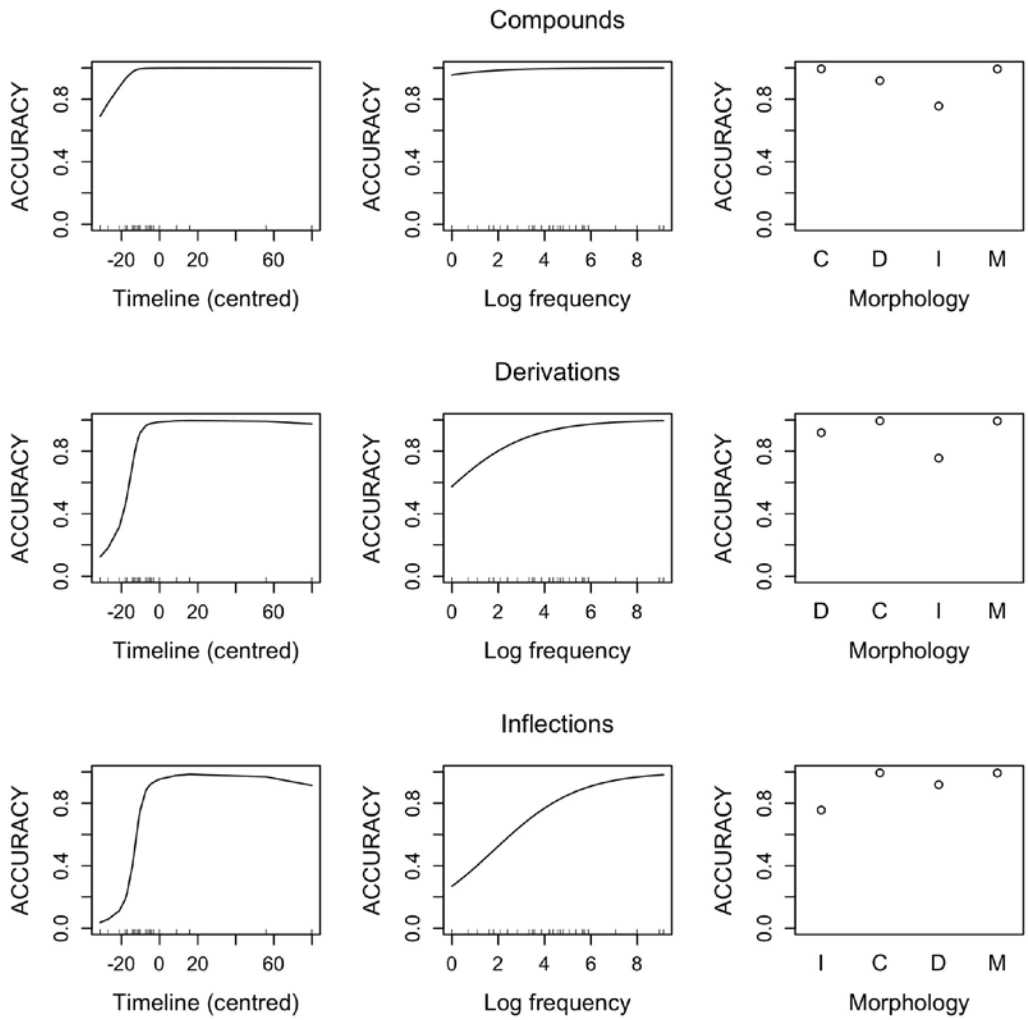
Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	1.13573	2.60679	0.436	0.663069	
IC	4.04881	0.80096	5.055	4.30e-07	***
IC	1.29702	0.59609	2.176	0.029565	*
IM	3.93304	1.14212	3.444	0.000574	***
rcs(Day, 5)cDay	0.10619	0.04662	2.278	0.022736	*
rcs(cDay, 5)cDay'	3.28801	1.19109	2.761	0.005771	**
rcs(cDay, 5)cDay''	-23.15102	9.36600	-2.472	0.013443	*
rcs(cDay, 5)cDay'''	30.59786	14.40692	2.124	0.033684	*
log(SurfaceFreq)	0.54964	0.15728	3.495	0.000475	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix L

Partial effects for trained words – Long-term analysis patient DR



Partial effects of TIME (left column), log-transformed FREQUENCY (centre column), and MORPHOLOGY (right column) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for trained items – patient DR. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

Appendix M

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term analysis patient DP (compound words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + rcs(cDay, 5) + log(SurfaceFreq + 1) + (1 | ITEM)

Data: datTRAINED[datTRAINED$Patient == "D.P._1",]

AIC	BIC	logLik	deviance
554.6	599.4	-267.3	534.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.9514	0.9754

Number of obs: 651, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-6.27995	1.15120	-5.455	4.89e-08	***
CD	-1.03544	0.60596	-1.709	0.0875	.
CI	-2.75027	0.69011	-3.985	6.74e-05	***
CM	-1.52810	1.00145	-1.526	0.1270	
rcs(Day, 5)cDay	-0.18641	0.04217	-4.421	9.82e-06	***
rcs(cDay, 5)cDay'	5.99859	0.83528	7.182	6.89e-13	***
rcs(cDay, 5)cDay''	-64.75209	9.51997	-6.802	1.03e-11	***
rcs(cDay, 5)cDay'''	116.76865	18.27690	6.389	1.67e-10	***
log(SurfaceFreq)	0.43561	0.10890	4.000	6.33e-05	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix N

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term analysis patient DP (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + rcs(cDay, 5) + log(SurfaceFreq + 1) + (1 | ITEM)

Data: datTRAINED[datTRAINED$Patient == "D.P._1",]

AIC	BIC	logLik	deviance
554.6	599.4	-267.3	534.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.9514	0.9754

Number of obs: 651, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-7.31537	1.24994	-5.853	4.84e-09	***
DC	1.03543	0.60596	1.709	0.08750	.
DI	-1.71482	0.54926	-3.122	0.00180	**
DM	-0.49265	0.81205	-0.607	0.54407	
rcs(Day, 5)cDay	-0.18641	0.04217	-4.421	9.82e-06	***
rcs(cDay, 5)cDay'	5.99859	0.83528	7.182	6.89e-13	***
rcs(cDay, 5)cDay''	-64.75211	9.51996	-6.802	1.03e-11	***
rcs(cDay, 5)cDay'''	116.76873	18.27689	6.389	1.67e-10	***
log(SurfaceFreq)	0.43561	0.10890	4.000	6.33e-05	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix O

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term analysis patient DP (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + rcs(cDay, 5) + log(SurfaceFreq + 1) + (1 | ITEM)

Data: datTRAINED[datTRAINED$Patient == "D.P._1",]

AIC	BIC	logLik	deviance
554.6	599.4	-267.3	534.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.9514	0.9754

Number of obs: 651, groups: ITEM, 35

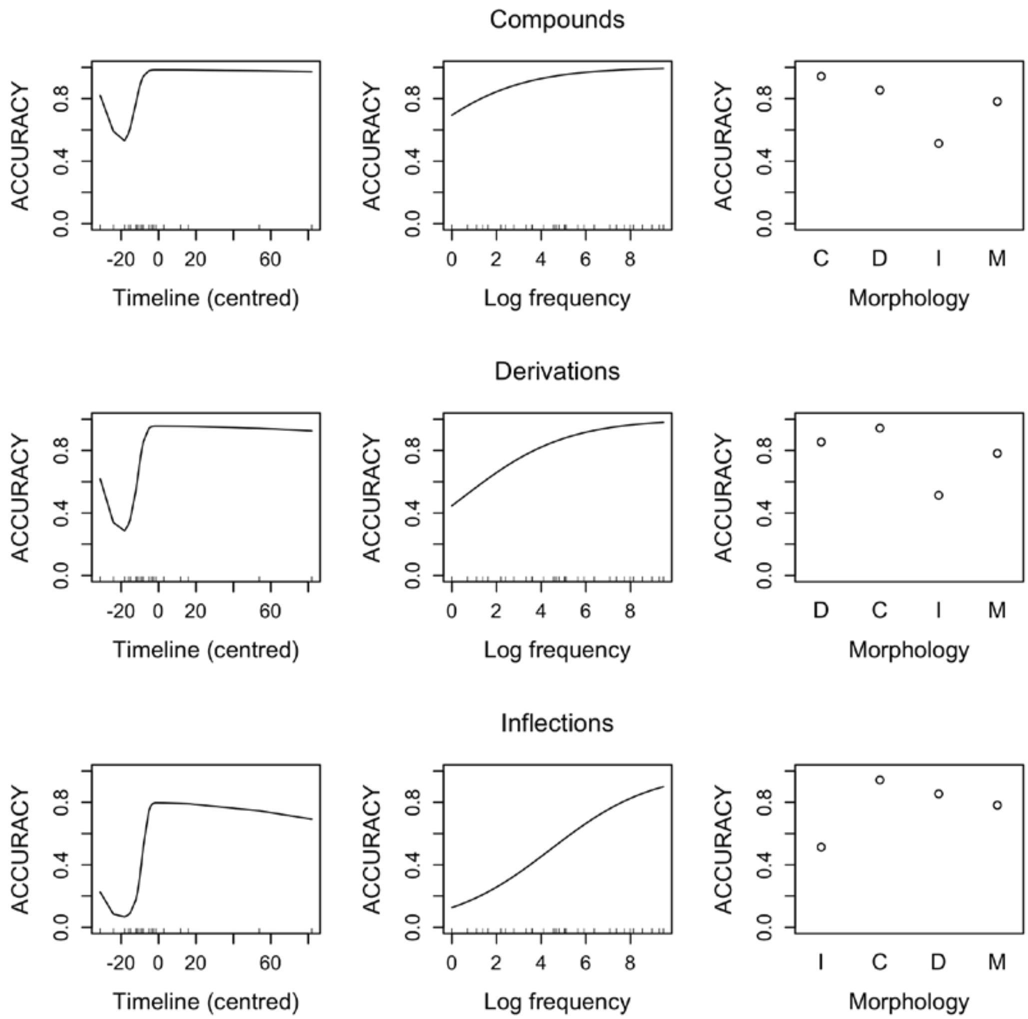
Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-9.03020	1.33209	-6.779	1.21e-11	***
IC	2.75026	0.69011	3.985	6.74e-05	***
ID	1.71482	0.54926	3.122	0.00180	**
IM	1.22217	0.74082	1.650	0.09899	.
rcs(Day, 5)cDay	-0.18641	0.04217	-4.421	9.82e-06	***
rcs(cDay, 5)cDay'	5.99859	0.83528	7.182	6.89e-13	***
rcs(cDay, 5)cDay''	-64.75211	9.51996	-6.802	1.03e-11	***
rcs(cDay, 5)cDay'''	116.76874	18.27688	6.389	1.67e-10	***
log(SurfaceFreq)	0.43561	0.10890	4.000	6.33e-05	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix P

Partial effects for trained words – Long-term analysis patient DP



Partial effects of TIME (left), FREQUENCY (centre), and MORPHOLOGY (right) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for trained items – patient DP. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

Appendix Q

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term analysis patient PH (compound words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + rcs(cDay, 5) + log(SurfaceFreq + 1) + (1 | ITEM)

Data: datTRAINED[datTRAINED$Patient == "P.H._2",]

AIC	BIC	logLik	deviance
494.5	539.7	-237.3	474.5

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	1.6314	1.2772

Number of obs: 680, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.26220	1.35235	-0.194	0.8463	
CD	-3.27051	0.78677	-4.157	3.23e-05	***
CI	-5.00465	0.85394	-5.861	4.61e-09	***
CM	-2.15699	1.27698	-1.689	0.0912	.
rcs(Day, 5)cDay	-0.08989	0.04881	-1.842	0.0655	.
rcs(cDay, 5)cDay'	3.83895	0.93152	4.121	3.77e-05	***
rcs(cDay, 5)cDay''	-33.67803	8.06341	-4.177	2.96e-05	***
rcs(cDay, 5)cDay'''	63.59469	15.98068	3.979	6.91e-05	***
log(SurfaceFreq)	0.26487	0.14940	1.773	0.0762	.

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix R

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term analysis patient PH (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + rcs(cDay, 5) + log(SurfaceFreq + 1) + (1 | ITEM)

Data: datTRAINED[datTRAINED$Patient == "P.H._2",]

AIC	BIC	logLik	deviance
494.5	539.7	-237.3	474.5

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	1.6314	1.2773

Number of obs: 680, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.53271	1.36839	-2.582	0.00983	**
DC	3.27051	0.78677	4.157	3.23e-05	***
DI	-1.73414	0.78677	-2.596	0.00944	**
DM	1.11353	1.09640	1.016	0.30981	
rcs(Day, 5)cDay	-0.08989	0.04881	-1.842	0.06551	.
rcs(cDay, 5)cDay'	3.83896	0.93152	4.121	3.77e-05	***
rcs(cDay, 5)cDay''	-33.67807	8.06341	-4.177	2.96e-05	***
rcs(cDay, 5)cDay'''	63.59478	15.98068	3.979	6.91e-05	***
log(SurfaceFreq)	0.26487	0.14940	1.773	0.07624	.

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix S

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term analysis patient PH (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + rcs(cDay, 5) + log(SurfaceFreq + 1) + (1 | ITEM)

Data: datTRAINED[datTRAINED$Patient == "P.H._2",]

AIC	BIC	logLik	deviance
494.5	539.7	-237.3	474.5

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	1.6314	1.2773

Number of obs: 680, groups: ITEM, 35

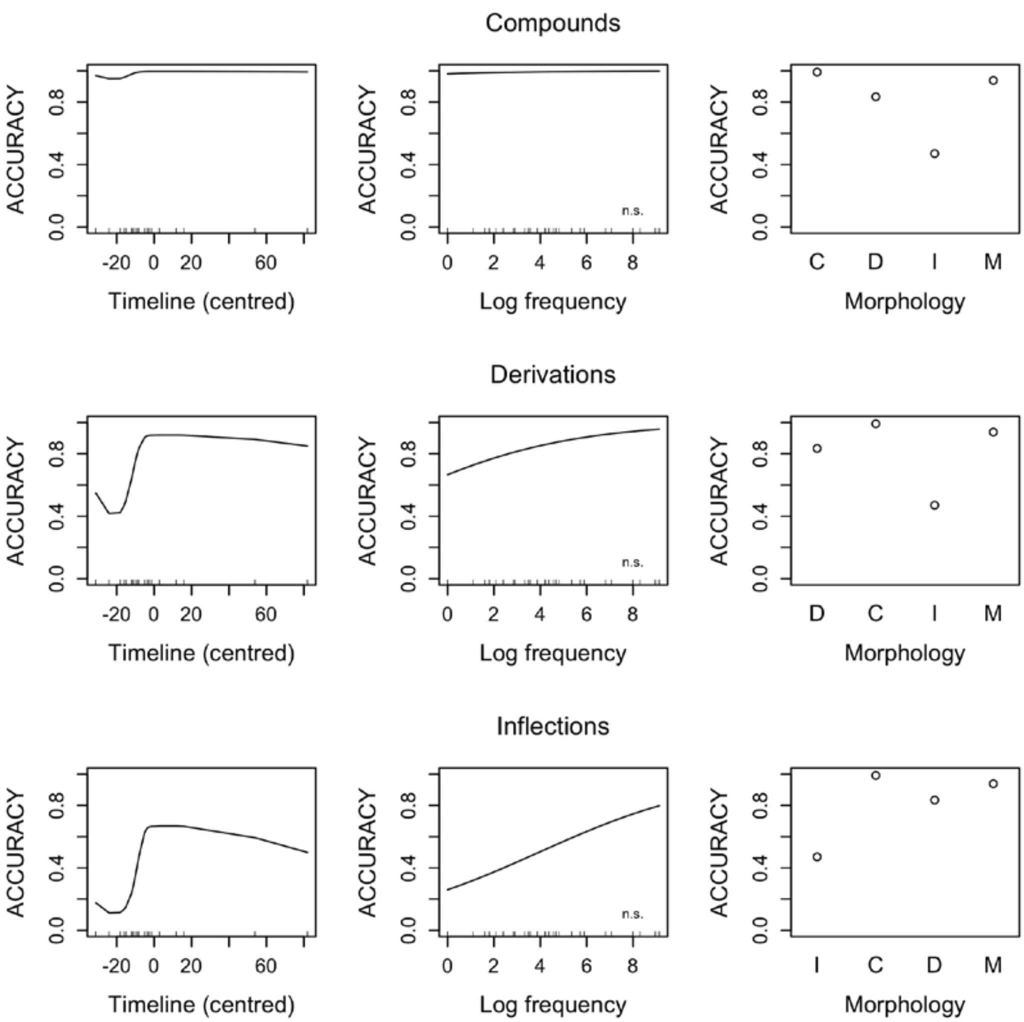
Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-5.26684	1.45934	-3.609	0.000307	***
IC	5.00465	0.85394	5.861	4.61e-09	***
ID	1.73414	0.66812	2.596	0.009444	**
IM	2.84767	0.98758	2.883	0.003933	**
rcs(Day, 5)cDay	-0.08989	0.04881	-1.842	0.065512	.
rcs(cDay, 5)cDay'	3.83895	0.93152	4.121	3.77e-05	***
rcs(cDay, 5)cDay"	-33.67802	8.06341	-4.177	2.96e-05	***
rcs(cDay, 5)cDay"'	63.59467	15.98068	3.979	6.91e-05	***
log(SurfaceFreq)	0.26487	0.14940	1.773	0.076241	.

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix T

Individual partial effects for trained words – Long-term analysis patient PH



Partial effects of TIME (left column), log-transformed FREQUENCY (centre column), and MORPHOLOGY (right column) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for trained items – patient PH. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

Appendix U

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term analysis patient JN (compound words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + rcs(cDay, 5) + log(SurfaceFreq + 1) + (1 | ITEM)

Data: datTRAINED[datTRAINED$Patient == "J.N._5",]

AIC	BIC	logLik	deviance
631.4	676.9	-305.7	611.4

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	2.3903	1.5460

Number of obs: 700, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	0.87626	0.96377	0.9092	0.36325	
CD	-1.97677	0.81804	-2.4165	0.01567	*
CI	-2.85739	0.95033	-3.0067	0.00264	**
CM	1.12010	1.55289	0.7213	0.47073	
rcs(Day, 5)cDay	0.01383	0.03473	0.3983	0.69043	
rcs(cDay, 5)cDay'	1.63647	0.74547	2.1952	0.02815	*
rcs(cDay, 5)cDay''	-11.66392	4.27845	-2.7262	0.00641	**
rcs(cDay, 5)cDay'''	17.09831	5.80534	2.9453	0.00323	**
log(SurfaceFreq)	0.24633	0.17696	1.3921	0.16390	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix V

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term analysis patient JN (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + rcs(cDay, 5) + log(SurfaceFreq + 1) + (1 | ITEM)

Data: datTRAINED[datTRAINED$Patient == "J.N._5",]

AIC	BIC	logLik	deviance
631.4	676.9	-305.7	611.4

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	2.3903	1.5460

Number of obs: 700, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.10051	1.05372	-1.0444	0.29630	
DC	1.97676	0.81804	2.4165	0.01567	*
DI	-0.88061	0.78619	-1.1201	0.26267	
DM	3.09688	1.36557	2.2678	0.02334	*
rcs(Day, 5)cDay	0.01383	0.03473	0.3983	0.69043	
rcs(cDay, 5)cDay'	1.63647	0.74547	2.1952	0.02815	*
rcs(cDay, 5)cDay''	-11.66390	4.27844	-2.7262	0.00641	**
rcs(cDay, 5)cDay'''	17.09828	5.80534	2.9453	0.00323	**
log(SurfaceFreq)	0.24633	0.17696	1.3920	0.16392	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix W

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for trained words – Long-term analysis patient JN (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + rcs(cDay, 5) + log(SurfaceFreq + 1) + (1 | ITEM)

Data: datTRAINED[datTRAINED$Patient == "J.N._5",]

AIC	BIC	logLik	deviance
631.4	676.9	-305.7	611.4

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	2.3903	1.5460

Number of obs: 700, groups: ITEM, 35

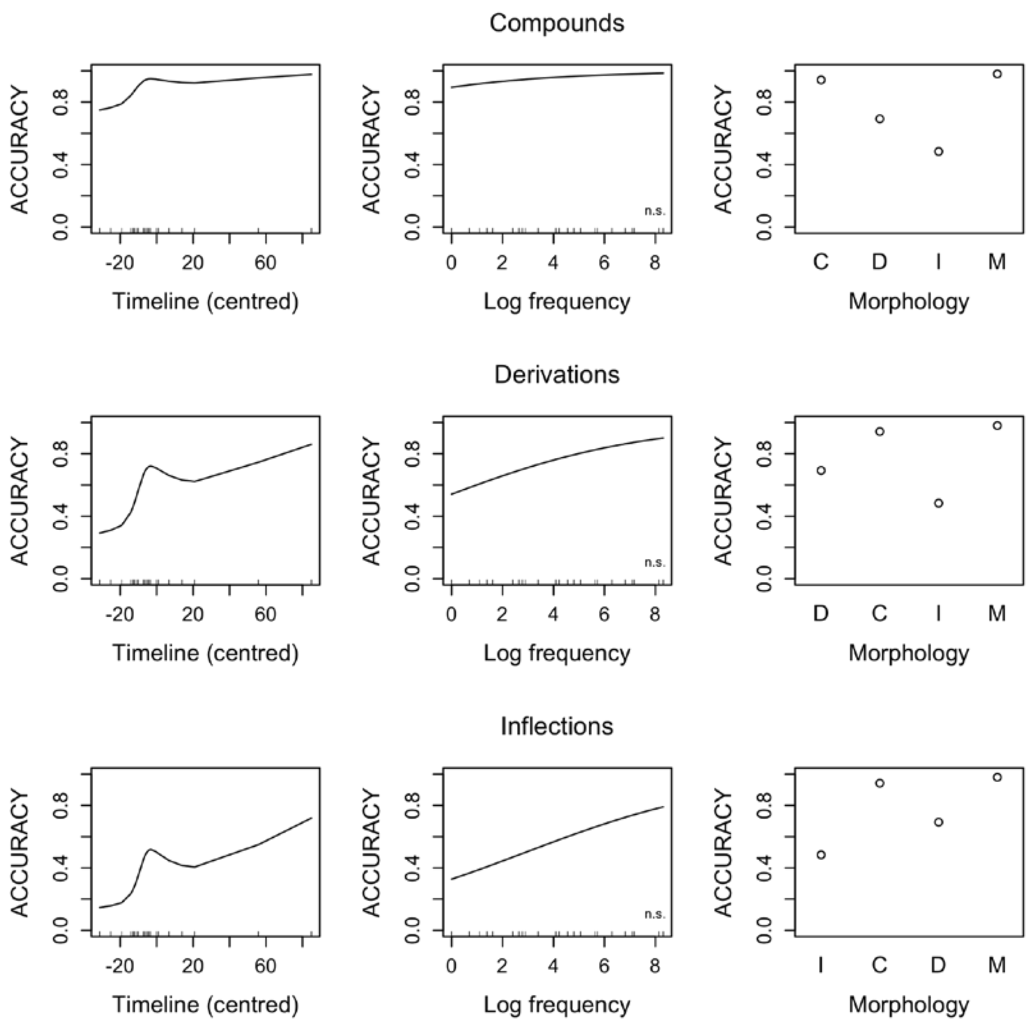
Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.98113	1.19267	-1.661	0.09670	.
IC	2.85738	0.95033	3.007	0.00264	**
ID	0.88061	0.78619	1.120	0.26267	
IM	3.97750	1.25527	3.169	0.00153	**
rcs(Day, 5)cDay	0.01383	0.03473	0.398	0.69043	
rcs(cDay, 5)cDay'	1.63647	0.74547	2.195	0.02815	*
rcs(cDay, 5)cDay"	-11.66391	4.27845	-2.726	0.00641	**
rcs(cDay, 5)cDay"'	17.09829	5.80534	2.945	0.00323	**
log(SurfaceFreq)	0.24633	0.17696	1.392	0.16391	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix X

Partial effects for trained words – Long-term analysis patient JN



Partial effects of TIME (left), log-transformed FREQUENCY (centre), and MORPHOLOGY (right) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for trained items – patient JN. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

Appendix Y

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis joint analysis (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + log(SurfaceFreq + 1) + rcs(cDay, 5) + (1 + cDay | Patient) + (1 | ITEM)

Data: datCONTROL

AIC	BIC	logLik	deviance
2260	2337	-1117	2234

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
ITEM	(Intercept)	1.0887e+00	1.0434e+00	
Patient	(Intercept)	1.7289e-13	4.1580e-07	
	cDay	5.8035e-05	7.6181e-03	0.000

Number of obs: 2722, groups: ITEM, 70; Patient, 4

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.98978	0.65409	-3.042	0.002350	**
DC	1.44473	0.39921	3.619	0.000296	***
DI	-1.25577	0.37273	-3.369	0.000754	***
DM	-0.05771	0.57081	-0.101	0.919468	
log(SurfaceFreq)	0.33251	0.07688	4.325	1.53e-05	***
rcs(Day, 5)cDay	-0.04540	0.02177	-2.085	0.037059	*
rcs(cDay, 5)cDay'	2.10062	0.39645	5.299	1.17e-07	***
rcs(cDay, 5)cDay''	-20.15858	3.66400	-5.502	3.76e-08	***
rcs(cDay, 5)cDay'''	29.52502	5.51005	5.358	8.40e-08	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix Z

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis joint analysis (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + log(SurfaceFreq + 1) + rcs(cDay, 5) + (1 + cDay | Patient) + (1 | ITEM)

Data: datCONTROL

AIC	BIC	logLik	deviance
2258	2335	-1116	2232

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
ITEM	(Intercept)	1.0566e+00	1.0279077	
Patient	(Intercept)	2.6639e-02	0.1632158	
	cDay	7.0574e-05	0.0084008	0.449

Number of obs: 2722, groups: ITEM, 70; Patient, 4

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.26737	0.69962	-4.670	3.01e-06	***
IC	2.69486	0.43142	6.246	4.20e-10	***
ID	1.25418	0.36807	3.407	0.000656	***
IM	1.20639	0.51657	2.335	0.019522	*
log(SurfaceFreq)	0.33119	0.07623	4.345	1.40e-05	***
rcs(Day, 5)cDay	-0.04652	0.02185	-2.129	0.033283	*
rcs(cDay, 5)cDay'	2.13504	0.39713	5.376	7.61e-08	***
rcs(cDay, 5)cDay''	-20.44705	3.66980	-5.572	2.52e-08	***
rcs(cDay, 5)cDay'''	29.92582	5.51754	5.424	5.83e-08	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AA

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis patient DR (compound words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + log(SurfaceFreq + 1) + cDay+ (1 | ITEM)

Data: datCONTROL[datCONTROL$Patient == "D.R._4",]

AIC	BIC	logLik	deviance
572.6	604.5	-279.3	558.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	2.3918	1.5465

Number of obs: 700, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	2.53612	0.65482	3.873	0.000108	***
CD	-1.22435	0.83942	-1.459	0.144686	
CI	-1.34518	0.90624	-1.484	0.137715	
CM	1.24123	1.53662	0.808	0.419226	
log(SurfaceFreq)	0.08040	0.15227	0.528	0.597482	
cDay	0.04444	0.00823	5.400	6.67e-08	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AB

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis patient DR (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + log(SurfaceFreq + 1) + cDay+ (1 | ITEM)

Data: datCONTROL[datCONTROL$Patient == "D.R._4",]

AIC	BIC	logLik	deviance
572.6	604.5	-279.3	558.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	2.3918	1.5465

Number of obs: 700, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	1.31175	0.81720	1.605	0.1085	
DC	1.22435	0.83942	1.459	0.1447	
DI	-0.12082	0.76709	-0.158	0.8748	
DM	2.46559	1.33529	1.846	0.0648	.
log(SurfaceFreq)	0.08041	0.15227	0.528	0.5975	
cDay	0.04444	0.00823	5.400	6.67e-08	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AC

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis patient DR (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + log(SurfaceFreq + 1) + cDay+ (1 | ITEM)

Data: datCONTROL[datCONTROL$Patient == "D.R._4",]

AIC	BIC	logLik	deviance
572.6	604.5	-279.3	558.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	2.3918	1.5465

Number of obs: 700, groups: ITEM, 35

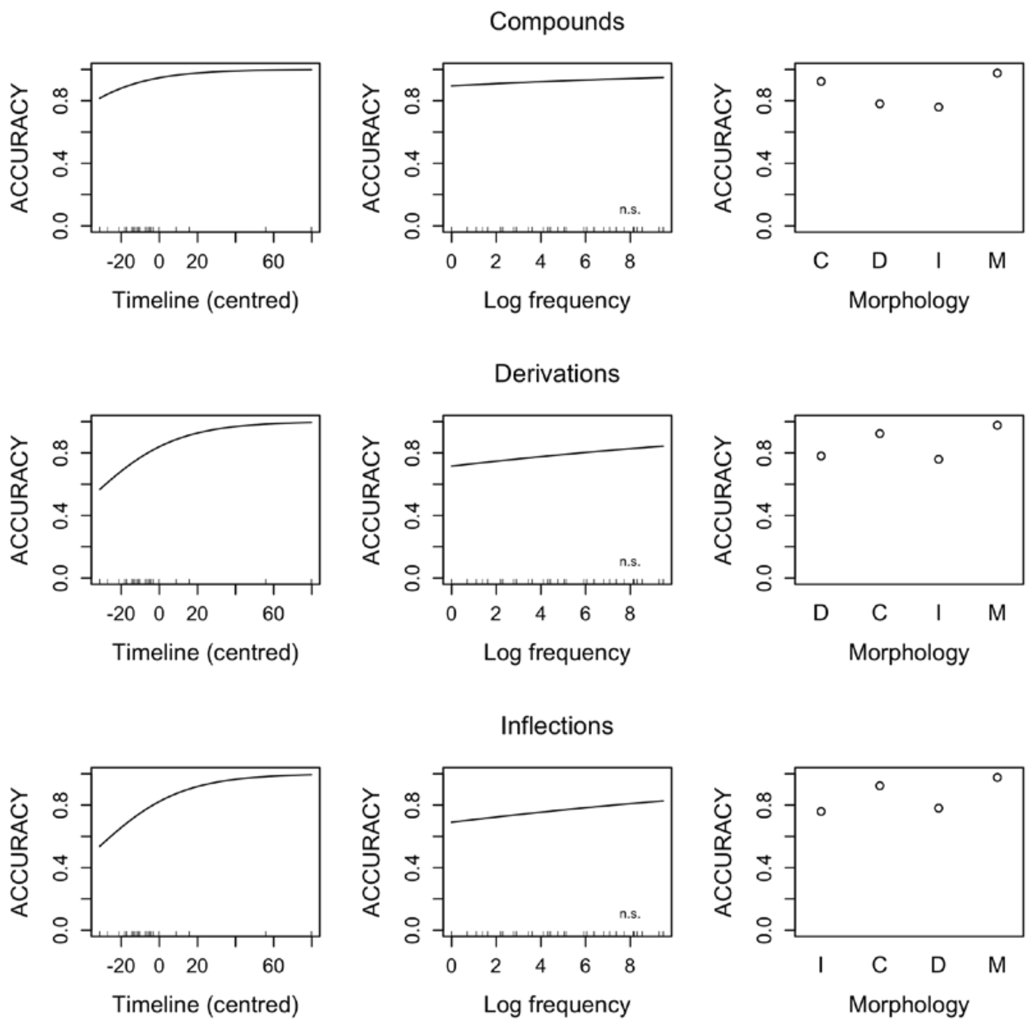
Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	1.19094	0.93867	1.269	0.2045	
IC	1.34518	0.90624	1.484	0.1377	
ID	0.12082	0.76709	0.158	0.8748	
IM	2.58641	1.25560	2.060	0.0394	*
log(SurfaceFreq)	0.08041	0.15227	10.528	0.5975	
cDay	0.04444	0.00823	5.400	6.67e-08	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AD

Individual partial effects for control words – Long-term analysis patient DR



Partial effects of TIME (left), log-transformed FREQUENCY (centre), and MORPHOLOGY (right) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for control items – patient DR. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

Appendix AE

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis patient DP (compound words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + log(SurfaceFreq + 1) + rcs(cDay, 5) + (1 | ITEM)

Data: datCONTROL[datCONTROL$Patient == "D.P._1",]

AIC	BIC	logLik	deviance
616.6	661.8	-298.3	596.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	1.9901	1.4107

Number of obs: 675, groups: ITEM, 36

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.79336	1.19562	-3.173	0.001510	**
CD	-1.82195	0.72497	-2.513	0.011966	*
CI	-2.58410	0.79534	-3.249	0.001158	**
CM	-2.25605	1.23655	-1.824	0.068082	.
log(SurfaceFreq)	0.42940	0.16513	2.600	0.009311	**
rcs(Day, 5)cDay	-0.14050	0.04264	-3.295	0.000983	***
rcs(cDay, 5)cDay'	4.14484	0.77578	5.343	9.15e-08	***
rcs(cDay, 5)cDay''	-42.69744	8.56895	-4.983	6.27e-07	***
rcs(cDay, 5)cDay'''	75.33347	16.31822	4.617	3.90e-06	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AF

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis patient DP (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + log(SurfaceFreq + 1) + rcs(cDay, 5) + (1 | ITEM)

Data: datCONTROL[datCONTROL$Patient == "D.P._1",]

AIC	BIC	logLik	deviance
616.6	661.8	-298.3	596.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	1.9901	1.4107

Number of obs: 675, groups: ITEM, 36

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-5.61530	1.28070	-4.385	1.16e-05	***
DC	1.82195	0.72497	2.513	0.011966	*
DI	-0.76216	0.71733	-1.062	0.288017	
DM	-0.43410	1.10882	-0.391	0.695430	
log(SurfaceFreq)	0.42940	0.16513	2.600	0.009312	**
rcs(Day, 5)cDay	-0.14050	0.04264	-3.295	0.000983	***
rcs(cDay, 5)cDay'	4.14484	0.77578	5.343	9.15e-08	***
rcs(cDay, 5)cDay''	-42.69744	8.56894	-4.983	6.27e-07	***
rcs(cDay, 5)cDay'''	75.33347	16.31821	4.617	6.27e-07	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AG

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis patient DP (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + log(SurfaceFreq + 1) + rcs(cDay, 5) + (1 | ITEM)

Data: datCONTROL[datCONTROL$Patient == "D.P._1",]

AIC	BIC	logLik	deviance
616.6	661.8	-298.3	596.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	1.9901	1.4107

Number of obs: 675, groups: ITEM, 36

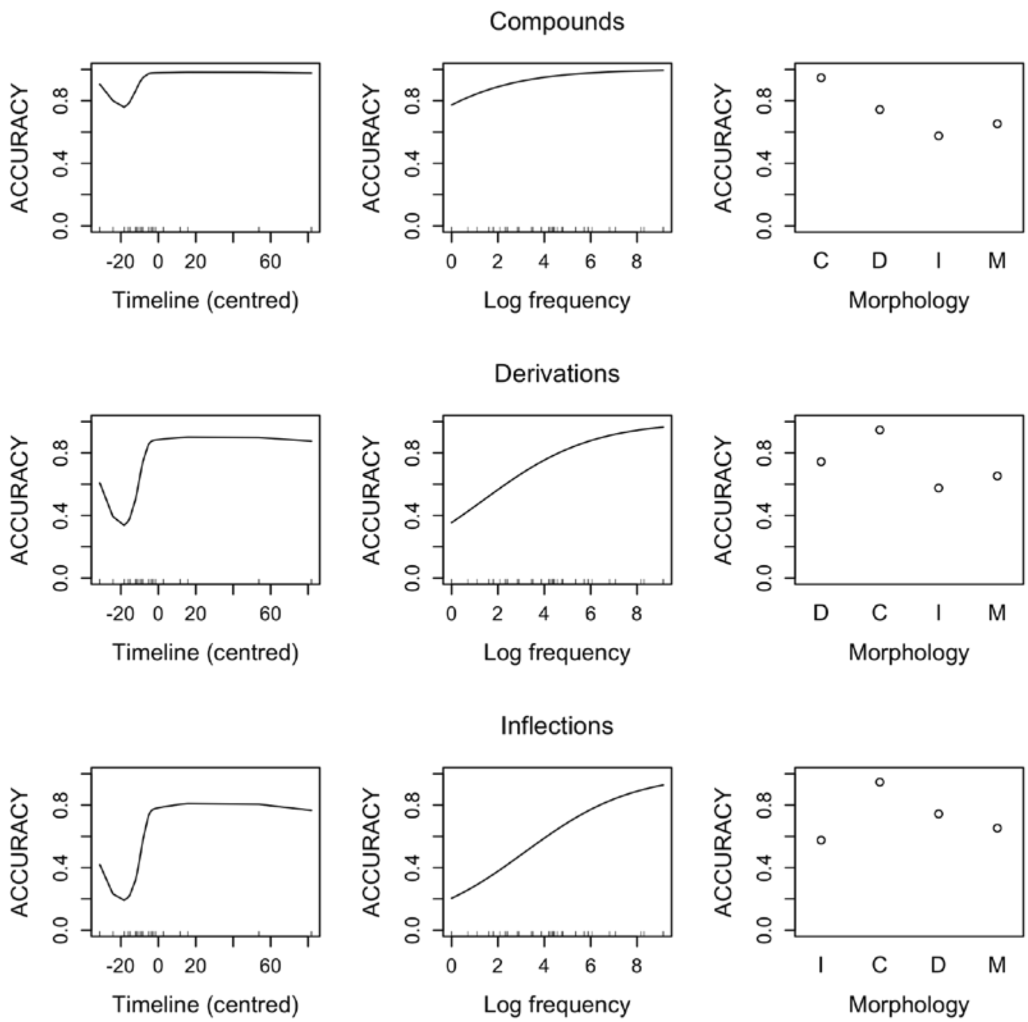
Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-6.37746	1.37173	-4.649	3.33e-06	***
IC	2.58410	0.79534	3.249	0.001158	**
ID	0.76216	0.71733	1.062	0.288015	
IM	0.32806	1.00727	0.326	0.744658	
log(SurfaceFreq)	0.42940	0.16513	2.600	0.009312	**
rcs(Day, 5)cDay	-0.14050	0.04264	-3.295	0.000983	***
rcs(cDay, 5)cDay'	4.14484	0.77578	5.343	9.15e-08	***
rcs(cDay, 5)cDay''	-42.69745	8.56894	-4.983	6.27e-07	***
rcs(cDay, 5)cDay'''	75.33348	16.31821	4.617	3.90e-06	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AH

Individual partial effects for control words – Long-term analysis patient DP



Partial effects of TIME (left), log-transformed FREQUENCY (centre), and MORPHOLOGY (right) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for control items – patient DP. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

Appendix AI

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis patient PH (compound words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + log(SurfaceFreq + 1) + cDay + (1 | ITEM)

Data: datCONTROL[datCONTROL$Patient == "P.H._2",]

AIC	BIC	logLik	deviance
401.3	432.6	-193.6	387.3

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.79072	0.88922

Number of obs: 647, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	2.053280	0.476337	4.311	1.63e-05	***
CD	-1.825643	0.711495	-2.566	0.01029	*
CI	-5.075860	0.808130	-6.281	3.36e-10	***
CM	-3.806721	1.245910	-3.055	0.00225	**
log(SurfaceFreq)	0.698287	0.137905	5.064	4.12e-07	***
cDay	0.015726	0.006113	2.573	0.01009	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AJ

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis patient PH (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + log(SurfaceFreq + 1) + cDay + (1 | ITEM)

Data: datCONTROL[datCONTROL$Patient == "P.H._2",]

AIC	BIC	logLik	deviance
401.3	432.6	-193.6	387.3

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.79072	0.88922

Number of obs: 647, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	0.227636	0.627730	0.363	0.7169	
DC	1.825644	0.711495	2.566	0.0103	*
DI	-3.250217	0.634041	-5.126	2.96e-07	***
DM	-1.981078	1.061835	-1.866	0.0621	.
log(SurfaceFreq)	0.698287	0.137905	5.064	4.12e-07	***
cDay	0.015726	0.006113	2.573	0.0101	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AK

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis patient PH (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + log(SurfaceFreq + 1) + cDay+ (1 | ITEM)

Data: datCONTROL[datCONTROL$Patient == "P.H._2",]

AIC	BIC	logLik	deviance
401.3	432.6	-193.6	387.3

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.79072	0.88923

Number of obs: 647, groups: ITEM, 35

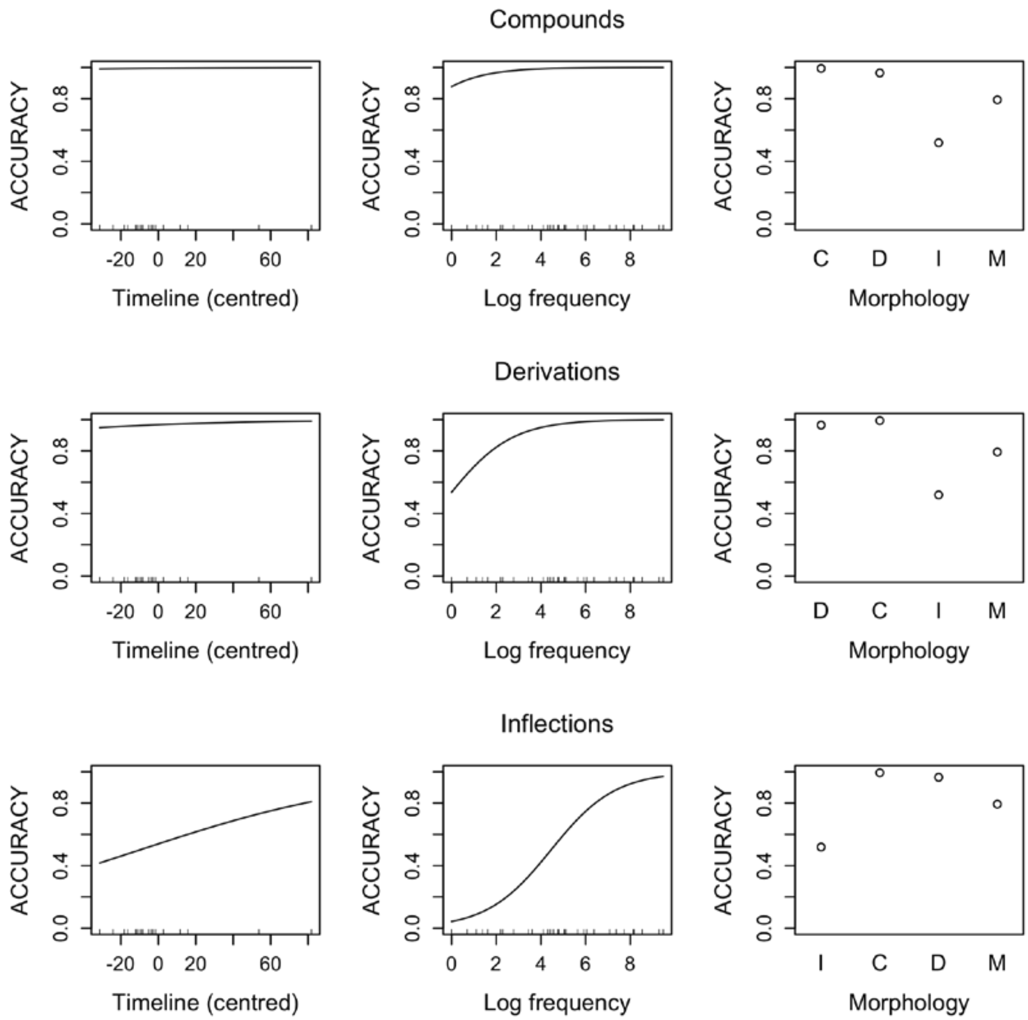
Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.022581	0.780904	-3.871	0.000109	***
IC	5.075859	0.808131	6.281	3.36e-10	***
ID	3.250217	0.634041	5.126	2.96e-07	***
IM	1.269133	0.902142	1.407	0.159487	
log(SurfaceFreq)	0.698287	0.137905	5.064	4.12e-07	***
cDay	0.015726	0.006113	2.573	0.010093	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AL

Individual partial effects for control words – Long-term analysis patient PH



Partial effects of TIME (left), log-transformed FREQUENCY (centre), and MORPHOLOGY (right) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for control items – patient PH. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

Appendix AM

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis patient JN (compound words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + log(SurfaceFreq + 1) + cDay + (1 | ITEM)

Data: datCONTROL[datCONTROL$Patient == "J.N._5",]

AIC	BIC	logLik	deviance
548.3	580.1	-267.1	534.3

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	1.1169	1.0568

Number of obs: 700, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	2.022323	0.514623	3.930	8.50e-05	***
CD	-0.520622	0.673830	-0.773	0.4397	
CI	-2.936038	0.707230	-4.151	3.30e-05	***
CM	-1.267589	1.086581	-1.167	0.2434	
log(SurfaceFreq)	0.221541	0.129223	1.714	0.0865	.
cDay	0.006631	0.004725	1.403	0.1606	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AN

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis patient JN (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + log(SurfaceFreq + 1) + cDay + (1 | ITEM)

Data: datCONTROL[datCONTROL$Patient == "J.N._5",]

AIC	BIC	logLik	deviance
548.3	580.1	-267.1	534.3

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	1.1169	1.0568

Number of obs: 700, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	1.501694	0.728560	2.061	0.0393	*
DC	0.520625	0.673828	0.773	0.4397	
DI	-2.415414	0.586449	-4.119	3.81e-05	***
DM	-0.746969	0.897954	-0.832	0.4055	
log(SurfaceFreq)	0.221542	0.129223	1.714	0.0865	.
cDay	0.006631	0.004725	1.403	0.1606	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AO

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for control words – Long-term analysis patient JN (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + log(SurfaceFreq + 1) + rcs(cDay, 5) + (1 | ITEM)

Data: datCONTROL[datCONTROL$Patient == "J.N._5",]

AIC	BIC	logLik	deviance
548.3	580.1	-267.1	534.3

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	1.1169	1.0568

Number of obs: 700, groups: ITEM, 35

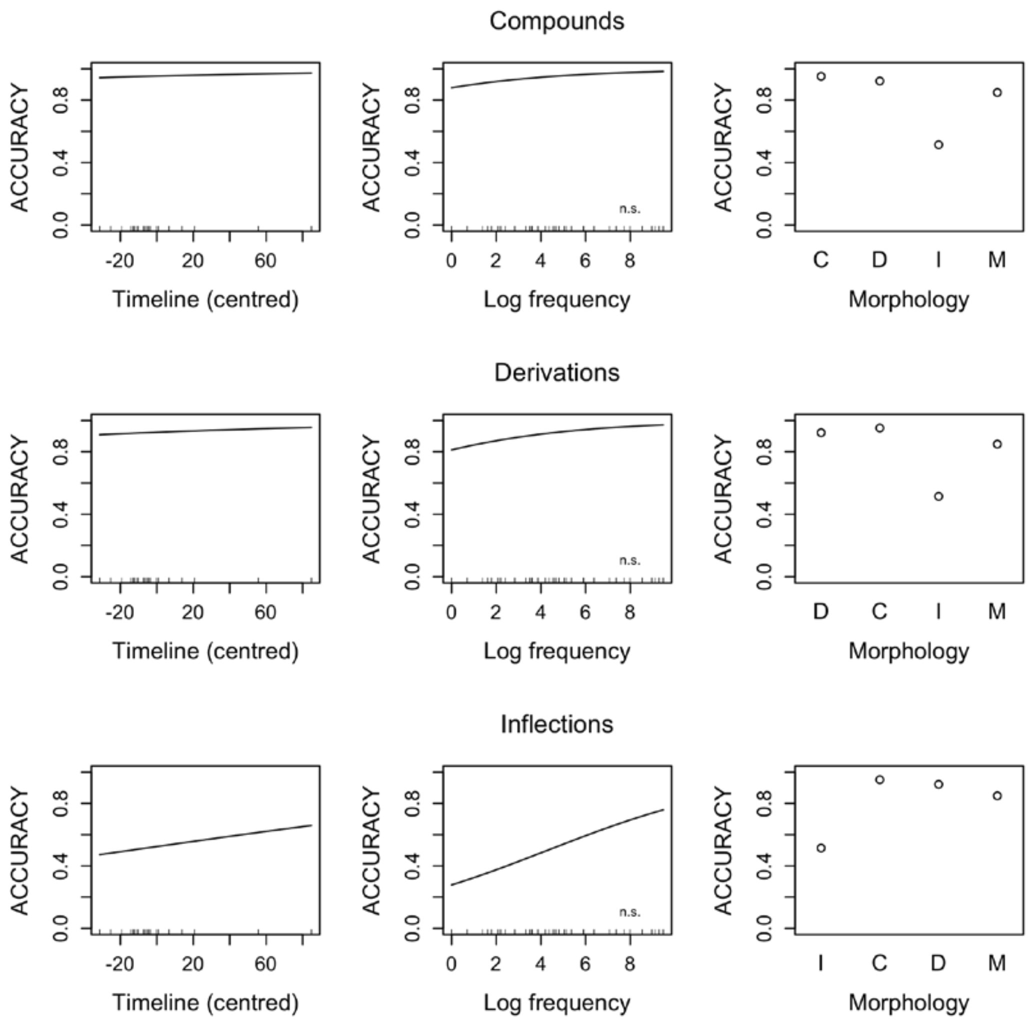
Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.913713	0.805514	-1.134	0.2567	
IC	2.936036	0.707230	4.151	3.30e-05	***
ID	2.415414	0.586451	4.119	3.81e-05	***
IM	1.668446	0.810293	2.059	0.0395	*
log(SurfaceFreq)	0.221541	0.129223	1.714	0.0865	.
cDay	0.006631	0.004725	1.403	0.1606	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AP

Individual partial effects for control words – Long-term analysis patient JN



Partial effects of TIME (left), log-transformed FREQUENCY (centre), and MORPHOLOGY (right) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for control items – patient JN. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

Appendix AQ

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term joint analysis (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + log(SurfaceFreq + 1) + cDay + (1 + cDay | Patient) + (1 | ITEM)

Data: datNEW

AIC	BIC	logLik	deviance
1050	1100	-515.1	1030

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
ITEM	(Intercept)	8.3032e-01	0.9112195	
Patient	(Intercept)	1.9364e-01	0.4400415	
	cDay	4.8402e-05	0.0069571	-0.070

Number of obs: 1119, groups: ITEM, 42; Patient, 4

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	0.988268	0.461636	2.141	0.032290	*
DC	1.090597	0.452875	2.408	0.016033	*
DI	-0.927060	0.456749	-2.030	0.042388	*
DM	1.509843	0.766340	1.970	0.048816	*
log(SurfaceFreq)	0.079448	0.104957	0.757	0.449074	
cDay	0.015164	0.004237	3.579	0.000345	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AR

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term joint analysis (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + log(SurfaceFreq + 1) + cDay + (1 + cDay | Patient) + (1 | ITEM)

Data: datNEW

AIC	BIC	logLik	deviance
1050	1100	-515.1	1030

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
ITEM	(Intercept)	8.3032e-01	0.9112189	
Patient	(Intercept)	1.9364e-01	0.4400420	
	cDay	4.8402e-05	0.0069572	-0.070

Number of obs: 1119, groups: ITEM, 42; Patient, 4

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	0.061220	0.572540	0.107	0.914846	
IC	2.017646	0.508661	3.967	7.29e-05	***
ID	0.927054	0.456749	2.030	0.042389	*
IM	2.436925	0.673272	3.620	0.000295	***
log(SurfaceFreq)	0.079445	0.104957	0.757	0.449089	
cDay	0.015164	0.004237	3.579	0.000345	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AS

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term analysis patient DR (compound words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + log(SurfaceFreq + 1) + cDay + (1 + cDay | Patient) + (1 | ITEM)

Data: datNEW[datNEW$Patient == "D.R._4",]

AIC	BIC	logLik	deviance
288.6	314.0	-137.3	274.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.99072	0.99535

Number of obs: 280, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	1.693660	0.517385	3.274	0.00106	**
CD	-1.092288	0.619146	-1.764	0.07770	.
CI	-1.766083	0.694636	-2.542	0.01101	*
CM	0.661020	1.302320	0.508	0.61175	
log(SurfaceFreq)	0.159496	0.143312	1.113	0.26574	
cDay	0.010434	0.004431	2.355	0.01853	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AT

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term analysis patient DR (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + log(SurfaceFreq + 1) + cDay + (1 | ITEM)

Data: datNEW[datNEW$Patient == "D.R._4",]

AIC	BIC	logLik	deviance
288.6	314.0	-137.3	274.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.99073	0.99535

Number of obs: 280, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	0.601371	0.527704	1.140	0.2545	
DC	1.092286	0.619146	1.764	0.0777	.
DI	-0.673797	0.624773	-1.079	0.2808	
DM	1.753304	1.235406	1.419	0.1558	
log(SurfaceFreq)	0.159496	0.143312	1.113	0.2657	
cDay	0.010434	0.004431	2.355	0.0185	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AU

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term analysis patient DR (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + log(SurfaceFreq + 1) + cDay + (1 | ITEM)

Data: datNEW[datNEW$Patient == "D.R._4",]

AIC	BIC	logLik	deviance
288.6	314.0	-137.3	274.6

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.99073	0.99535

Number of obs: 280, groups: ITEM, 35

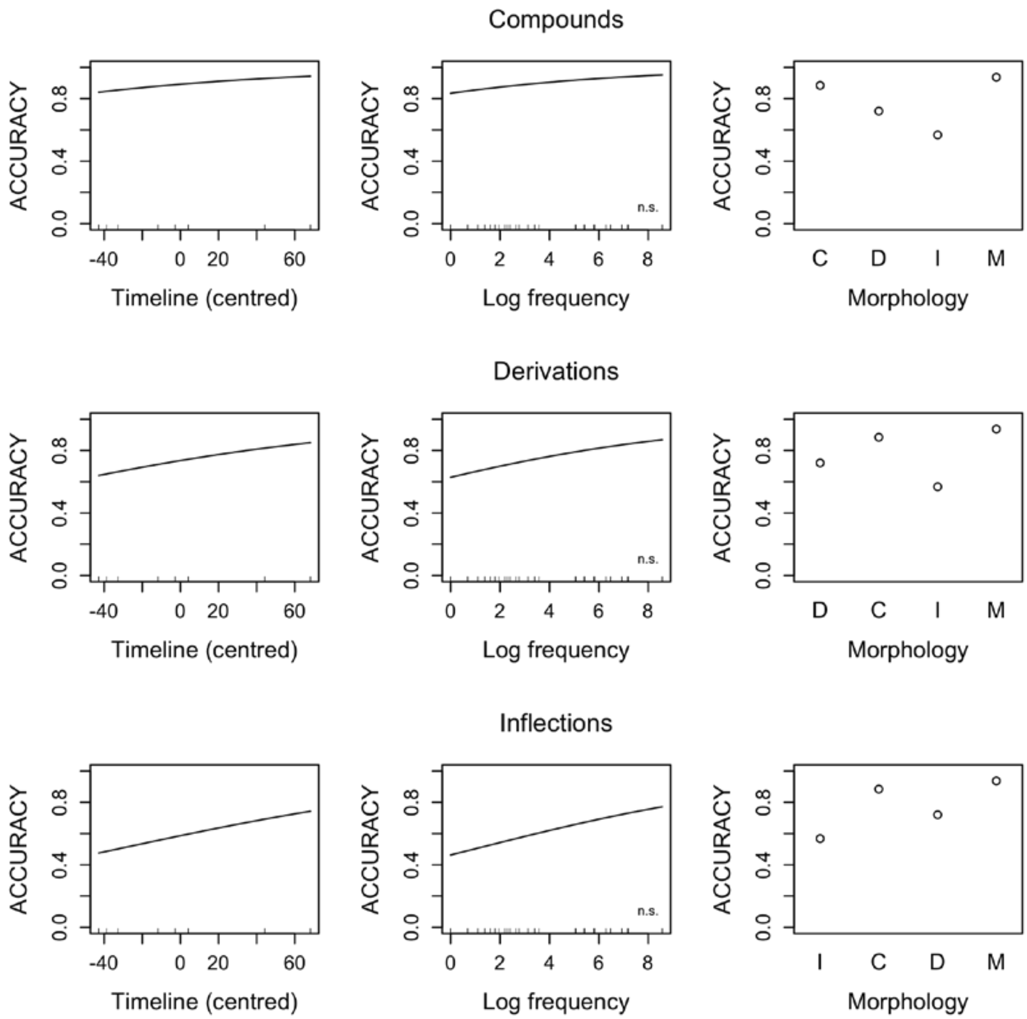
Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.072450	0.700607	-0.1034	0.9176	
IC	1.766103	0.694637	2.5425	0.0110	*
ID	0.673811	0.624773	1.0785	0.2808	
IM	2.427067	1.124323	2.1587	0.0309	*
log(SurfaceFreq)	0.159501	0.143313	1.1130	0.2657	
cDay	0.010434	0.004431	2.3548	0.0185	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AV

Individual partial effects for new words – Long-term analysis patient DR



Partial effects of TIME (left column), log-transformed FREQUENCY (centre column), and MORPHOLOGY (right column) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for new items – Patient DR. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

Appendix AW

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term analysis patient DP (compound words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + log(SurfaceFreq + 1) + cDay + (1 | ITEM)

Data: datNEW[datNEW$Patient == "D.P._1",]

AIC	BIC	logLik	deviance
306	331.4	-146	292

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.57987	0.76149

Number of obs: 279, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	1.171345	0.422691	2.771	0.00559	**
CD	-0.529689	0.519956	-1.019	0.30834	
CI	-1.320486	0.588522	-2.244	0.02485	*
CM	0.694449	0.999996	0.694	0.48740	
log(SurfaceFreq)	0.108813	0.121519	0.895	0.37055	
cDay	0.025863	0.004993	5.180	2.22e-07	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AX

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term analysis patient DP (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + log(SurfaceFreq + 1) + cDay + (1 | ITEM)

Data: datNEW[datNEW$Patient == "D.P._1",]

AIC	BIC	logLik	deviance
306	331.4	-146	292

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.57987	0.76149

Number of obs: 279, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	0.641655	0.458432	1.400	0.162	
DC	0.529687	0.519957	1.019	0.308	
DI	-0.790795	0.539646	-1.465	0.143	
DM	1.224138	0.939781	1.303	0.193	
log(SurfaceFreq)	0.108813	0.121519	0.895	0.371	
cDay	0.025863	0.004993	5.180	2.22e-07	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix AY

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term analysis patient DP (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + log(SurfaceFreq + 1) + cDay+ (1 | ITEM)

Data: datNEW[datNEW$Patient == "D.P._1",]

AIC	BIC	logLik	deviance
306	331.4	-146	292

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.57987	0.76149

Number of obs: 279, groups: ITEM, 35

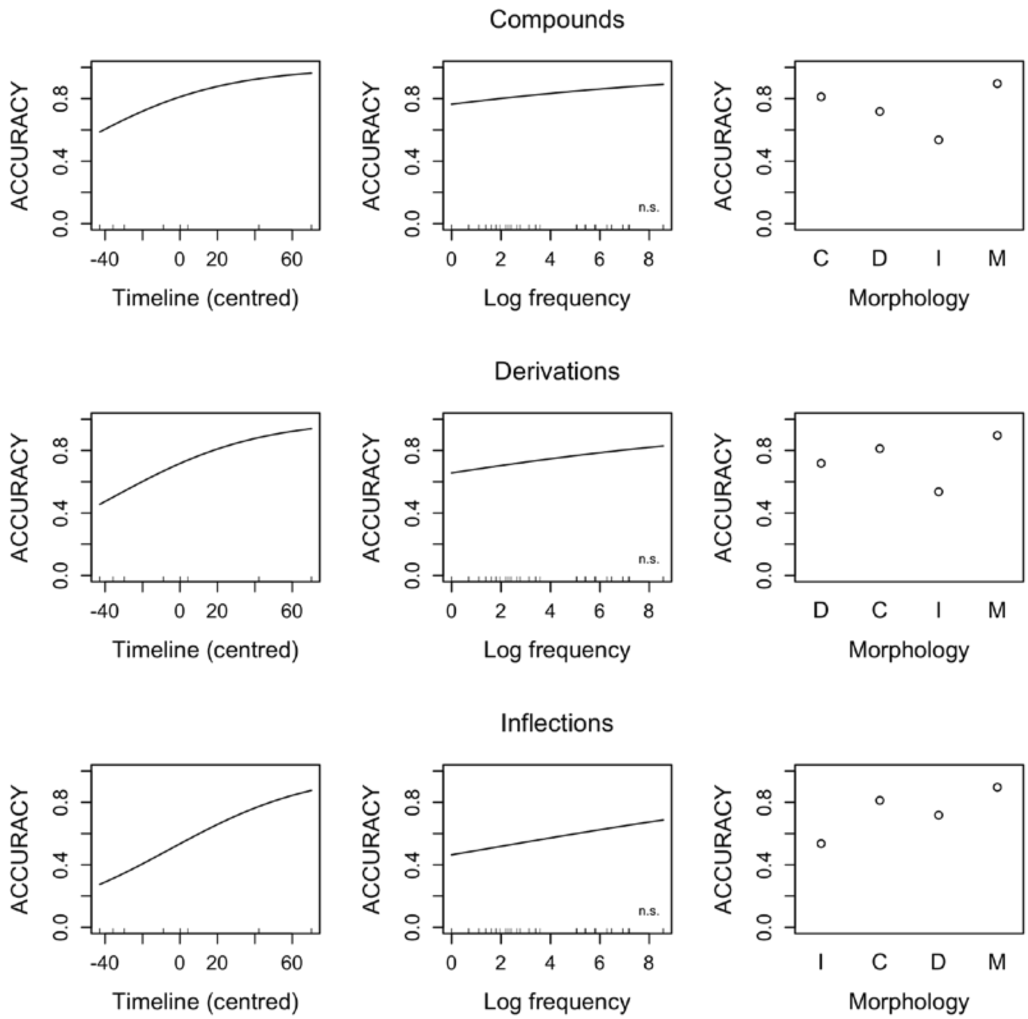
Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.149144	0.602126	-0.248	0.8044	
IC	1.320488	0.588522	2.244	0.0248	*
ID	0.790798	0.539646	1.465	0.1428	
IM	2.014935	0.830523	2.426	0.0153	*
log(SurfaceFreq)	0.108813	0.121519	0.895	0.3706	
cDay	0.025863	0.004993	5.180	2.22e-07	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Appendix AZ

Individual partial effects for new words – Long-term analysis patient DP



Partial effects of TIME (left column), log-transformed FREQUENCY (centre column), and MORPHOLOGY (right column) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for new items – Patient DP. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

Appendix BA

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term analysis patient PH (compound words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + log(SurfaceFreq + 1) + cDay+ (1 | ITEM)

Data: datNEW[datNEW$Patient == "P.H._2",]

AIC	BIC	logLik	deviance
211.8	237.2	-98.88	197.8

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.85265	0.92339

Number of obs: 280, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	3.15388	0.69641	4.529	5.93e-06	***
CD	-1.53061	0.79506	-1.925	0.05421	.
CI	-2.57270	0.84158	-3.057	0.00224	**
CM	-1.49678	1.33019	-1.125	0.26049	
log(SurfaceFreq)	0.19139	0.15431	1.240	0.21488	
cDay	0.01922	0.00646	2.975	0.00293	**

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix BB

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term analysis patient PH (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + log(SurfaceFreq + 1) +cDay+ (1 | ITEM)

Data: datNEW[datNEW$Patient == "P.H._2",]

AIC	BIC	logLik	deviance
211.8	237.2	-98.88	197.8

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.85265	0.92339

Number of obs: 280, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	1.62327	0.57483	2.8239	0.00474	**
DC	1.53061	0.79506	1.9251	0.05421	.
DI	-1.04209	0.65268	-1.5966	0.11034	
DM	0.03383	1.17219	0.0289	0.97698	
log(SurfaceFreq)	0.19139	0.15431	1.2403	0.21488	
cDay	0.01922	0.00646	2.9747	0.00293	**

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix BC

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term analysis patient PH (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + log(SurfaceFreq + 1) + cDay + (1 | ITEM)

Data: datNEW[datNEW$Patient == "P.H._2",]

AIC	BIC	logLik	deviance
211.8	237.2	-98.88	197.8

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	0.85265	0.92339

Number of obs: 280, groups: ITEM, 35

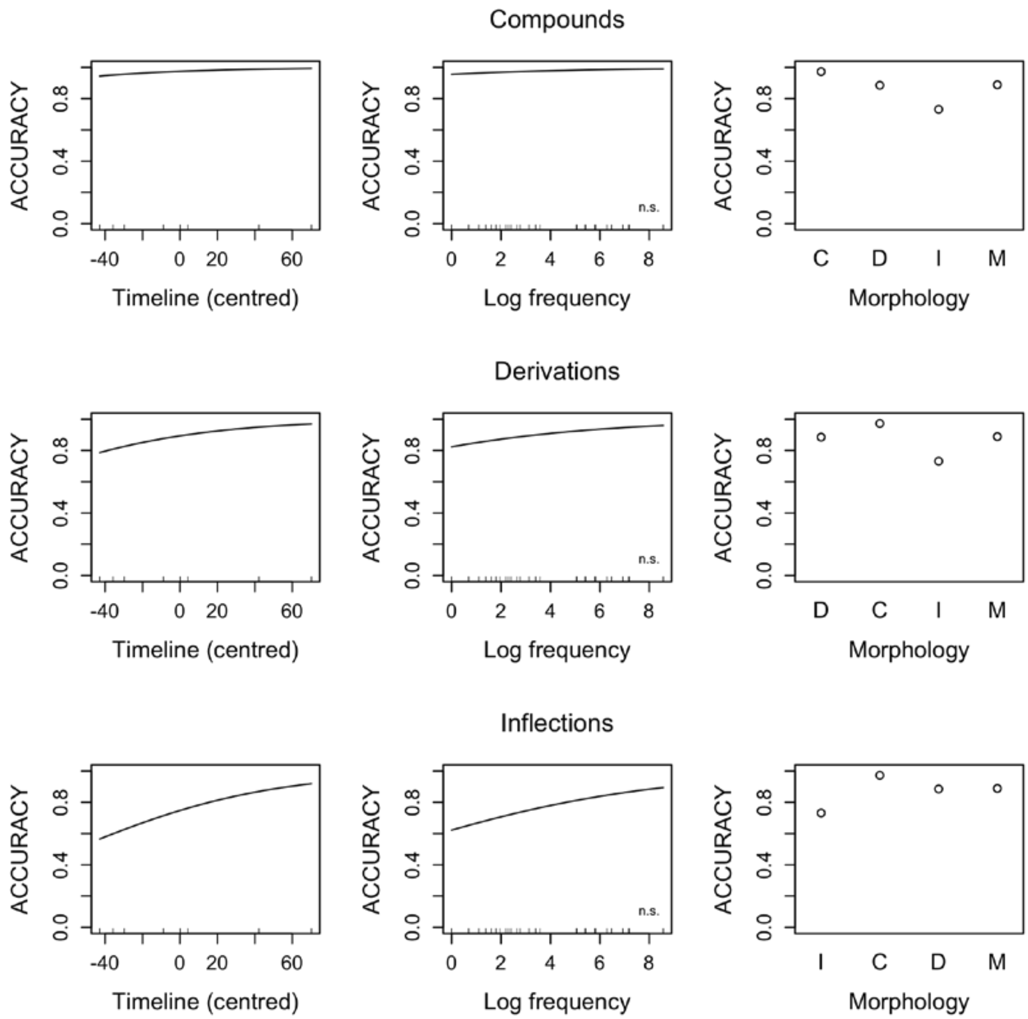
Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	0.58118	0.71496	0.8129	0.41628	
IC	2.57270	0.84158	3.0570	0.00224	**
ID	1.04209	0.65268	1.5966	0.11035	
IM	1.07592	1.02219	1.0526	0.29254	
log(SurfaceFreq)	0.19139	0.15431	1.2403	0.21488	
cDay	0.01922	0.00646	2.9747	0.00293	**

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix BD

Individual partial effects for new words – Long-term analysis patient PH



Partial effects of TIME (left column), log-transformed FREQUENCY (centre column), and MORPHOLOGY (right column) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for new items – Patient PH. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

Appendix BE

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term analysis patient JN (compound words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + log(SurfaceFreq + 1) + cDay+ (1 | ITEM)

Data: datNEW[datNEW$Patient == "J.N._5",]

AIC	BIC	logLik	deviance
265.3	290.8	-125.7	251.3

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	2.1286	1.4590

Number of obs: 280, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	3.351806	0.805108	4.163	3.14e-05	***
CD	-2.044869	0.880107	-2.323	0.0202	*
CI	-2.575669	0.972851	-2.648	0.0081	**
CM	1.549439	1.655243	0.936	0.3492	
log(SurfaceFreq)	-0.173041	0.196969	-0.879	0.3797	
cDay	0.007201	0.004525	1.591	0.1116	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix BF

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term analysis patient JN (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + log(SurfaceFreq + 1) + cDay + (1 | ITEM)

Data: datNEW[datNEW$Patient == "J.N._5",]

AIC	BIC	logLik	deviance
265.3	290.8	-125.7	251.3

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	2.1286	1.4590

Number of obs: 280, groups: ITEM, 35

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	1.306933	0.740429	1.7651	0.0775	.
DC	2.044864	0.880109	2.3234	0.0202	*
DI	-0.530801	0.824718	-0.6436	0.5198	
DM	3.594288	1.535130	2.3414	0.0192	*
log(SurfaceFreq)	-0.173037	0.196970	-0.8785	0.3797	
cDay	0.007201	0.004525	1.5913	0.1116	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix BG

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for new words – Long-term analysis patient JN (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + log(SurfaceFreq + 1) + cDay+ (1 | ITEM)

Data: datNEW[datNEW$Patient == "J.N._5",]

AIC	BIC	logLik	deviance
265.3	290.8	-125.7	251.3

Random effects:

Groups	Name	Variance	Std.Dev.
ITEM	(Intercept)	2.1286	1.4590

Number of obs: 280, groups: ITEM, 35

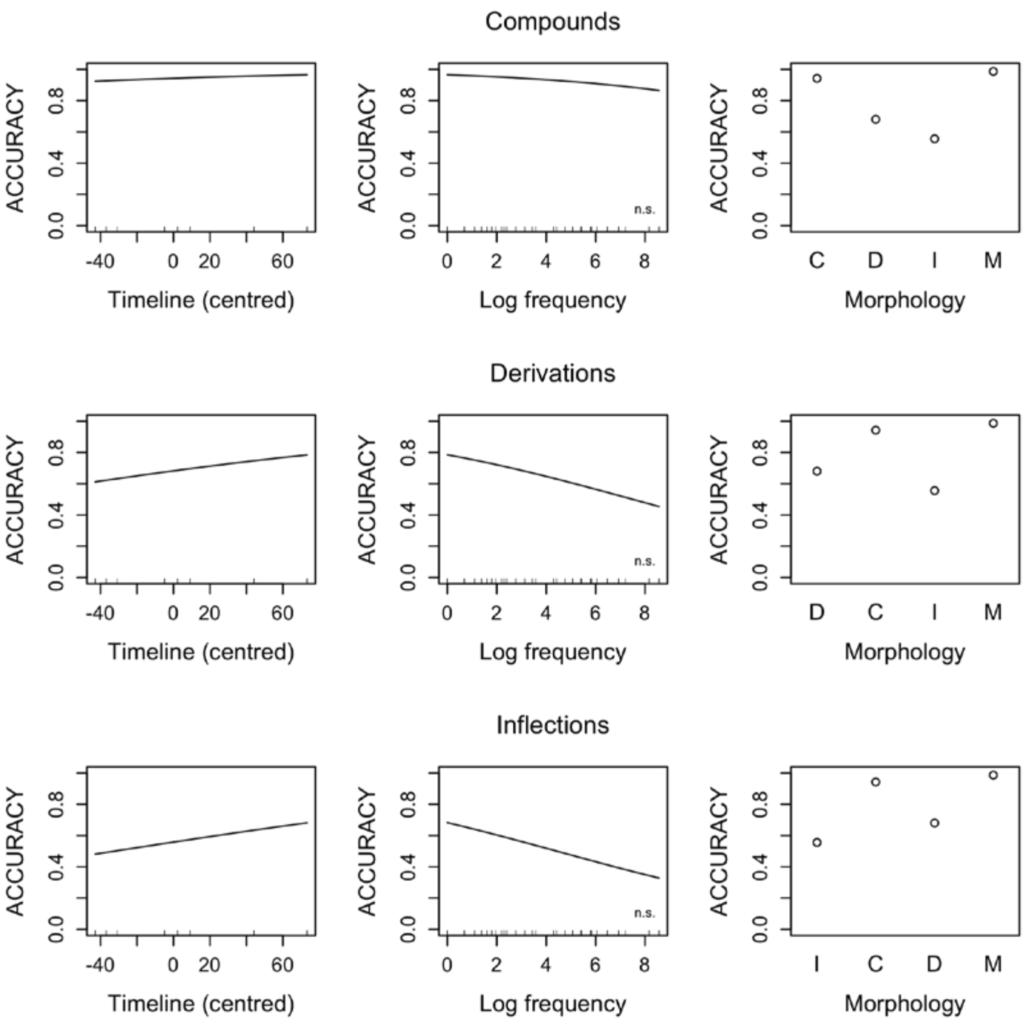
Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	0.776131	0.994103	0.7807	0.43496	
IC	2.575666	0.972852	2.6475	0.00811	**
ID	0.530809	0.824717	0.6436	0.51982	
IM	4.125127	1.364754	3.0226	0.00251	**
log(SurfaceFreq)	-0.173040	0.196970	-0.8785	0.37967	
cDay	0.007201	0.004525	1.5913	0.11155	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix BH

Individual partial effects for new words – Long-term analysis patient JN



Partial effects of TIME (left column), log-transformed FREQUENCY (centre column), and morphology (right column) for compound words (panels in upper row), derived words (panels in centre row), and inflected words (panels in lower row) for new items – Patient JN. Morphology: M = monomorphemes, C = compounds, D = derived words, I = inflected words.

Appendix BI

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for all word types – Long-term joint analysis (compound words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ C + WordType + log(SurfaceFreq + 1) + rcs(cDay, 5) + (1 + cDay | Patient) + (1 | ITEM)

Data: datB

AIC	BIC	logLik	deviance
5657	5745	-2816	5631

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
ITEM	(Intercept)	7.4118e-01	0.8609159	
Patient	(Intercept)	1.3055e-01	0.3613229	
	cDay	4.5232e-05	0.0067255	0.085

Number of obs: 6571, groups: ITEM, 105; Patient, 4

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.30805	0.43524	-0.708	0.47909	
CD	-1.22484	0.25821	-4.744	2.10e-06	***
CI	-2.34083	0.28742	-8.144	3.82e-16	***
CM	-0.42041	0.44331	-0.948	0.34296	
WordTypeN	-0.13727	0.17562	-0.782	0.43444	
WordTypeT	-0.21189	0.08176	-2.592	0.00955	**
log(SurfaceFreq)	0.23062	0.05227	4.412	1.02e-05	***
rcs(cDay, 5)cDay	-0.03330	0.01302	-2.557	0.01056	*
rcs(cDay, 5)cDay'	2.19589	0.23703	9.264	< 2e-16	***
rcs(cDay, 5)cDay''	-14.69372	1.45384	-10.107	< 2e-16	***
rcs(cDay, 5)cDay'''	20.22631	2.00531	10.086	< 2e-16	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix BJ

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for all word types – Long-term joint analysis (derived words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ D + WordType + log(SurfaceFreq + 1) + rcs(cDay, 5) + (1 + cDay | Patient) + (1 | ITEM)

Data: datB

AIC	BIC	logLik	deviance
5654	5756	-2812	5624

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
ITEM	(Intercept)	7.4118e-01	0.8609161	
Patient	(Intercept)	1.3055e-01	0.3613239	
	cDay	4.5231e-05	0.0067254	0.085

Number of obs: 6571, groups: ITEM, 105; Patient, 4

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.53290	0.45990	-3.333	0.000859	***
DC	1.22483	0.25821	4.743	2.10e-06	***
DI	-1.11599	0.24978	-4.468	7.90e-06	***
DM	0.80443	0.38934	2.066	0.038815	*
WordTypeN	-0.13726	0.17562	-0.782	0.434468	
WordTypeT	-0.21190	0.08176	-2.592	0.009552	**
log(SurfaceFreq)	0.23062	0.05227	4.412	1.02e-05	***
rcs(cDay, 5)cDay	-0.03330	0.01302	-2.557	0.010555	*
rcs(cDay, 5)cDay'	2.19590	0.23703	9.264	< 2e-16	***
rcs(cDay, 5)cDay''	-14.69375	1.45384	-10.107	< 2e-16	***
rcs(cDay, 5)cDay'''	20.22636	2.00531	10.086	< 2e-16	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix BK

Fixed-effect coefficients in a mixed-effects model fitted to naming accuracy for all word types – Long-term joint analysis (inflected words)

Generalized linear mixed model fit by the Laplace approximation
Formula: ACCURACY ~ I + WordType + log(SurfaceFreq + 1) + rcs(cDay, 5) + (1 + cDay | Patient) + (1 | ITEM)

Data: datB

AIC	BIC	logLik	deviance
5654	5756	-2812	5624

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
ITEM	(Intercept)	0.74117694	0.8609163	
Patient	(Intercept)	0.13055185	0.3613196	
	cDay	0.00004523	0.0067254	0.085

Number of obs: 6571, groups: ITEM, 105; Patient, 4

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.64887	0.49163	-5.388	7.13e-08	***
DC	2.34082	0.28742	8.144	3.82e-16	***
DI	1.11598	0.24978	4.468	7.90e-06	***
DM	1.92043	0.35287	5.442	5.26e-08	***
WordTypeN	-0.13727	0.17562	-0.782	0.43445	
WordTypeT	-0.21189	0.08176	-2.592	0.00955	**
log(SurfaceFreq)	0.23062	0.05227	4.412	1.02e-05	***
rcs(cDay, 5)cDay	-0.03330	0.01302	-2.557	0.01055	*
rcs(cDay, 5)cDay'	2.19590	0.23703	9.264	< 2e-16	***
rcs(cDay, 5)cDay''	-14.69373	1.45384	-10.107	< 2e-16	***
rcs(cDay, 5)cDay'''	20.22631	2.00531	10.086	< 2e-16	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix BL

The Alberta Language Function Assessment Battery: Post-therapy results

Patient DR

A.) Low level input & production

Repetition of monomorphemic words.

Word frequency			
High:	**91.7%**	**-0.7z**	**8.3**
Low:	**50%**	**-9z**	
Word Length			
Nonword Length			
Word phonological neighbourhood			
Nonword phonological neighbourhood			

B.) Orthographic and phonological processing

Visual Lexical Decision

Wordness			
Word Frequency			
High frequency:	**100%**	**1z**	**3.5**
Low frequency:	**82.5%**	**-2.5z**	
Length			
Long:	**81.3%**	**-2.7z**	**-1.9**
Short:	**91.1%**	**-0.8z**	
Word Phonological Neighbourhood			
Nonword Phonological Neighbourhood			
Concreteness			
Abstract:	**81.3%**	**-2.7z**	**-3**
Concrete:	**96.6%**	**0.3z**	
Word Regularity			
Regular:	**96.9%**	**0.4z**	**3.5**
Irregular:	**79.3%**	**-3.1z**	

Auditory Lexical Decision

Wordness			
Word Frequency			
High frequency:	**95.2%**	**0z**	**2.5**
Low frequency:	**82.5%**	**-2.5z**	
Length			
Long:	87.5%	-1.5z	0.2
Short:	86.7%	-1.7z	
Phonological Neighbourhood			
High PN:	89.7%	-1.1z	-0.4

Low PN:	91.4%	-0.7z	
Concreteness			
Abstract:	**81.3%**	**-2.7z**	**-2.3**
Concrete:	**93.1%**	**-0.4z**	
Word Regularity			
Regular:	87.5%	-1.5z	0.3
Irregular:	86.2%	-1.8z	

Spelling words and nonwords

Word frequency			
High:	**50%**	**-9z**	**6.2**
Low:	**18.8%**	**-15.2z**	
Concreteness			
Concrete:	**43.8%**	**-10.2z**	**3.8**
Abstract:	**25%**	**-14z**	
Orthographic transparency			
Transparent:	**31.3%**	**-12.7z**	**-1.2**
Opaque:	**37.5%**	**-11.5z**	
Phonological complexity			
Complex:	**31.3%**	**-12.7z**	**-1.2**
Simple:	**37.5%**	**-11.5z**	

C.) Word fluency
Morphological word fluency

Summary	N	z
'-er' Words:	**0**	**-19**
'-ing' Words:	**1**	**-18.8**
'-ness' Words:	**0**	**-19**
'-s' Words:	**3**	**-18.4**
Total Words:	**4**	**-18.2**

D.) Semantic access
Synonym judgment: Visual

Concreteness			
Concrete:	**85%**	**-2z**	**3**
Abstract:	**70%**	**-5z**	
Foil type			
Phonological:	**85%**	**-2z**	**3**
Semantic:	**70%**	**-5z**	
Foil type for Concrete words			
Phonological:	**100%**	**1z**	**6**
Semantic:	**70%**	**-5z**	
Foil type for Abstract words			
Phonological:	70%	-5z	0

Semantic:	70%	-5z

Picture naming: Oral

Semantic Category

Animals:	**37.5%**	**-11.5z**
Fruits:	**37.5%**	**-11.5z**
Tools:	**62.5%**	**-6.5z**
Music:	**0%**	**-19z**
Miscellaneous:	**50%**	**-9z**

Picture naming: Written

Semantic Category

Animals:	**37.5%**	**-11.5z**
Fruits:	**12.5%**	**-16.5z**
Tools:	**12.5%**	**-16.5z**
Music:	**12.5%**	**-16.5z**
Miscellaneous:	**50%**	**-9z**

E.) Sentence processing

Sentence Processing: Auditory Comprehension

Syntactic structure

Active:	100%	1z	(E.g., 'The cat chases the dog.')
Passive:	**62.5%**	**-6.5z**	**(E.g., 'The dog is bitten by the cat.')**
Verb:	87.5%	-1.5z	(E.g., 'The man kicks.')
Preposition:	87.5%	-1.5z	(E.g., 'The man walks down the stairs.')
Particle:	100%	1z	(E.g., 'The man turned on the TV.')
Dative passive:	100%	1z	(E.g., 'The flower was given to the woman by the boy.')
S-O relative:	**50%**	**-9z**	**(E.g., 'The boy the girl kicked hugged the man.')**

Sentence Processing: Production

Syntactic structure

Active:	**40%**	**-11z**	**(E.g., 'The boy kicks the woman.')**
Passive:	**0%**	**-19z**	**(E.g., 'The woman is carried by the man.')**
Dative:	**0%**	**-19z**	**(E.g., 'The girl puts the cushion on the bed.')**
Dative passive:	**0%**	**-19z**	**(E.g., 'The ball is given to the baby by the man.')**
S-O relative:	**0%**	**-19z**	**(E.g., 'The man with the phone points at the girl.')**

Appendix BM

The Alberta Language Function Assessment Battery
Patient DP

B.) Orthographic and phonological processing
Visual Lexical Decision

Wordness				
Word Frequency				
High frequency:	100%	1z	0	
Low frequency:	100%	1z		
Length				
Long:	100%	1z	0	
Short:	100%	1z		
Word Phonological Neighbourhood				
Nonword Phonological Neighbourhood				
Concreteness				
Abstract:	100%	1z	0	
Concrete:	100%	1z		
Word Regularity				
Regular:	100%	1z	0	
Irregular:	100%	1z		

Auditory Lexical Decision

Wordness				
Word Frequency				
High frequency:	95.2%	0z		-0.5
Low frequency:	97.5%	0.5z		
Length				
Long:	93.8%	-0.2z		-0.8
Short:	97.8%	0.6z		
Phonological Neighbourhood				
High PN:	**71.8%**	**-4.6z**		**-2.5**
Low PN:	**84.5%**	**-2.1z**		
Concreteness				
Abstract:	**93.8%**	**-0.2z**		**-1.2**
Concrete:	**100%**	**1z**		
Word Regularity				
Regular:	**100%**	**1z**		**1.4**
Irregular:	**93.1%**	**-0.4z**		

C.) Word fluency
Morphological word fluency

Summary N	z	Words per second
'-er' Words: 1	**-18.8**	**60**

'-ing' Words: 3	**-18.4**	**20**	
'-ness' Words: 2	**-18.6**	**30**	
'-s' Words: 3	**-18.4**	**20**	
Total Words: 9	**-17.2**	**26.7**	

D.) Semantic access

Synonym judgment: Visual

Concreteness			
Concrete:	**70%**	**-5z**	**2**
Abstract:	**60%**	**-7z**	
Foil type			
Phonological:	**60%**	**-7z**	**-2**
Semantic:	**70%**	**-5z**	
Foil type for Concrete words			
Phonological:	**50%**	**-9z**	**-8**
Semantic:	**90%**	**-1z**	
Foil type for Abstract words			
Phonological:	**70%**	**-5z**	**4**
Semantic:	**50%**	**-9z**	

Synonym judgment: Auditory

Concreteness			
Concrete:	**30%**	**-13z**	**-4**
Abstract:	**50%**	**-9z**	
Foil type			
Phonological:	40%	-11z	0
Semantic:	40%	-11z	
Foil type for Concrete words			
Phonological:	30%	-13z	0
Semantic:	30%	-13z	
Foil type for Abstract words			
Phonological:	50%	-9z	0
Semantic:	50%	-9z	

Picture naming: Oral

Semantic Category		
Animals:	**12.5%**	**-16.5z**
Fruits:	**37.5%**	**-11.5z**
Tools:	**62.5%**	**-6.5z**
Music:	**0%**	**-19z**
Miscellaneous:	**50%**	**-9z**

E.) Sentence processing

Sentence Processing: Visual Comprehension

Syntactic structure

Active: 87.5% -1.5z (E.g., 'The cat chases the dog.')

Passive:	**62.5%**	**-6.5z**	**(E.g., 'The dog is bitten by the cat.')**
Verb:	87.5%	-1.5z	(E.g., 'The man kicks.')
Preposition:	**75%**	**-4z**	**(E.g., 'The man walks down the stairs.')**
Particle:	87.5%	-1.5z	(E.g., 'The man turned on the TV.')
Dative passive:	87.5%	-1.5z	(E.g., 'The flower was given to the woman by the boy.)
Subject object relative:	**75%**	**-4z**	**(E.g., 'The boy the girl kicked hugged the man.')**

Sentence Processing: Auditory Comprehension
Syntactic structure

Active:	**75%**	**-4z**	**(E.g., 'The cat chases the dog.')**
Passive:	**62.5%**	**-6.5z**	**(E.g., 'The dog is bitten by the cat.')**
Verb:	**62.5%**	**-6.5z**	**(E.g., 'The man kicks.)**
Preposition:	**75%**	**-4z**	**(E.g., 'The man walks down the stairs.')**
Particle:	87.5%	-1.5z	(E.g., 'The man turned on the TV.')
Dative passive:	87.5%	-1.5z	(E.g., 'The flower was given to the woman by the boy.')
Subject object relative:	**75%**	**-4z**	**(E.g., 'The boy the girl kicked hugged the man.')**

Appendix BN

The Alberta Language Function Assessment Battery
Patient PH

A.) Low level input & production

Repetition of monomorphemic words.

Word frequency			
High:	**91.7%**	**-0.7z**	**3.3**
Low:	**75%**	**-4z**	

Visual Lexical Decision

Wordness			
Word Frequency			
High frequency:	**100%**	**1z**	**2.5**
Low frequency:	**87.5%**	**-1.5z**	
Length			
Long:	**81.3%**	**-2.7z**	**-2.8**
Short:	**95.6%**	**0.1z**	
Word Phonological Neighbourhood			
Nonword Phonological Neighbourhood			
Concreteness			
Abstract:	**87.5%**	**-1.5z**	**-1.8**
Concrete:	**96.6%**	**0.3z**	
Word Regularity			
Regular:	**96.9%**	**0.4z**	**2.2**
Irregular:	**86.2%**	**-1.8z**	

Auditory Lexical Decision

Wordness			
Word Frequency			
High frequency:	**95.2%**	**0z**	**2**
Low frequency:	**85%**	**-2z**	
Length			
Long:	**93.8%**	**-0.2z**	**1.5**
Short:	**86.7%**	**-1.7z**	
Phonological Neighbourhood			
High PN:	**61.5%**	**-6.7z**	**-5.6**
Low PN:	**89.7%**	**-1.1z**	
Concreteness			
Abstract:	**78.1%**	**-3.4z**	**-4.4**
Concrete:	**100%**	**1z**	
Word Regularity			
Regular:	90.6%	-0.9z	0.9

Irregular:	86.2%	-1.8z	

Spelling words and nonwords

Word frequency			
High:	**75%**	**-4z**	**6.2**
Low:	**43.8%**	**-10.2z**	
Concreteness			
Concrete:	**87.5%**	**-1.5z**	**11.2**
Abstract:	**31.3%**	**-12.7z**	
Orthographic transparency			
Transparent:	**62.5%**	**-6.5z**	**1.2**
Opaque:	**56.3%**	**-7.7z**	
Phonological complexity			
Complex:	**50%**	**-9z**	**-3.8**
Simple:	**68.8%**	**-5.2z**	

C.) Word fluency

Morphological word fluency

Summary	N	z	Words per second
'-er' Words:	**2**	**-18.6**	**30**
'-ing' Words:	**2**	**-18.6**	**30**
'-ness' Words:	**0**	**-19**	**0**
'-s' Words:	**5**	**-18**	**12**
Total Words:	**9**	**-17.2**	**26.7**

D.) Semantic access

Synonym judgment: Auditory

Concreteness			
Concrete:	**10%**	**-17z**	**-11**
Abstract:	**65%**	**-6z**	
Foil type for Concrete words			
Phonological:	10%	-17z	0
Semantic:	10%	-17z	
Foil type for Abstract words			
Phonological:	**70%**	**-5z**	**2**
Semantic:	**60%**	**-7z**	

Picture naming: Oral

Semantic Category		
Animals:	**75%**	**-4z**
Fruits:	**62.5%**	**-6.5z**

Tools:	**75%**	**-4z**
Music:	**50%**	**-9z**
Miscellaneous:	**50%**	**-9z**

Picture naming: Written

Semantic Category

Animals:	**75%**	**-4z**
Fruits:	**50%**	**-9z**
Tools:	87.5%	-1.5z
Music:	**37.5%**	**-11.5z**
Miscellaneous:	**75%**	**-4z**

E.) Sentence processing

Sentence Processing: Visual Comprehension

Syntactic structure

Active:	87.5%	-1.5z	(E.g., 'The cat chases the dog.')
Passive:	**37.5%**	**-11.5z**	**(E.g., 'The dog is bitten by the cat.')**
Verb:	**50%**	**-9z**	**(E.g., 'The man kicks.')**
Preposition:	**62.5%**	**-6.5z**	**(E.g., 'The man walks down the stairs.'**
Particle:	**62.5%**	**-6.5z**	**(E.g., 'The man turned on the TV.')**
Dative passive:	**50%**	**-9z**	**(E.g., 'The flower was given to the woman by the boy.')**
S-O relative:	**62.5%**	**-6.5z**	**(E.g., 'The boy the girl kicked hugged the man.')**

Sentence Processing: Auditory Comprehension

Syntactic structure

Active:	**50%**	**-9z**	**(E.g., 'The cat chases the dog.')**
Passive:	**62.5%**	**-6.5z**	**(E.g., 'The dog is bitten by the cat.')**
Verb:	**50%**	**-9z**	**(E.g., 'The man kicks.')**
Preposition:	**50%**	**-9z**	**(E.g., 'The man walks down the stairs.')**
Particle:	**62.5%**	**-6.5z**	**(E.g., 'The man turned on the TV.)**
Dative passive:	**50%**	**-9z**	**(E.g., 'The flower was given to the woman by the boy.')**
S-O relative:	**62.5%**	**-6.5z**	**(E.g., 'The boy the girl kicked hugged the man.')**

Sentence Processing: Production

Syntactic structure

Active:	100%	1z	(E.g., 'The boy kicks the woman.')
Passive:	**80%**	**-3z**	**(E.g., 'The woman is carried by the man.')**
Dative:	100%	1z	(E.g., 'The girl puts the cushion on the bed.')
Dative passive:	**80%**	**-3z**	**(E.g., 'The ball is given to the baby by the man.')**
S-O relative:	**60%**	**-7z**	**(E.g., 'The man with the phone points at the girl.')**

Appendix BO

The Alberta Language Function Assessment Battery
Patient JN

A.) Low level input & production

Repetition of monomorphemic words.

Word frequency			
High:	**91.7%**	**-0.7z**	**5.3**
Low:	**65%**	**-6z**	

B.) Orthographic and phonological processing

Visual Lexical Decision

Wordness			
Length			
Long:	93.8%	-0.2z	0.6
Short:	91.1%	-0.8z	
Word Phonological Neighbourhood			
Nonword Phonological Neighbourhood			
Concreteness			
Abstract:	90.6%	-0.9z	-0.5
Concrete:	93.1%	-0.4z	
Word Regularity			
Regular:	93.8%	-0.2z	0.9
Irregular:	89.7%	-1.1z	

Auditory Lexical Decision

Wordness			
Word Frequency			
High frequency:	**100%**	**1z**	**1.5**
Low frequency:	**92.5%**	**-0.5z**	
Length			
Long:	**100%**	**1z**	**1.3**
Short:	**93.3%**	**-0.3z**	
Phonological Neighbourhood			
High PN:	**64.1%**	**-6.2z**	**-4.1**
Low PN:	**84.5%**	**-2.1z**	
Concreteness			
Abstract:	93.8%	-0.2z	-0.5
Concrete:	96.6%	0.3z	
Word Regularity			
Regular:	96.9%	0.4z	0.8
Irregular:	93.1%	-0.4z	

Rhyme Judgment			
Wordness			
Word:	69.6%	-5.1z	-0.1
Nonword:	70%	-5z	
Phonological Neighbourhood			
Target relation			
Response choices			
Nonwords:	**50%**	**-9z**	**-8**
Pseudohomophones:	**90%**	**-1z**	
Spelling words and nonwords			
Word frequency			
High:	**31.3%**	**-12.7z**	**5**
Low:	**6.3%**	**-17.7z**	
Concreteness			
Concrete:	18.8%	-15.2z	0
Abstract:	18.8%	-15.2z	
Orthographic transparency			
Transparent:	18.8%	-15.2z	0
Opaque:	18.8%	-15.2z	
Phonological complexity			
Complex:	**6.3%**	**-17.7z**	**-5**
Simple:	**31.3%**	**-12.7z**	

C.) Word fluency
Morphological word fluency

Summary N z Words per second			
'-er' Words:	**1**	**-18.8**	**60**
'-ing' Words:	**1**	**-18.8**	**60**
'-ness' Words:	**0**	**-19**	**0**
'-s' Words:	**1**	**-18.8**	**60**
Total Words:	**3**	**-18.4**	**80**

D.) Semantic access
Synonym judgment: Visual

Concreteness			
Concrete:	**70%**	**-5z**	**3**
Abstract:	**55%**	**-8z**	
Foil type			
Phonological:	**80%**	**-3z**	**7**
Semantic:	**45%**	**-10z**	
Foil type for Concrete words			
Phonological:	**80%**	**-3z**	**4**
Semantic:	**60%**	**-7z**	
Foil type for Abstract words			

Phonological:	**80%**	**-3z**	**10**
Semantic:	**30%**	**-13z**	

Picture naming: Oral

Semantic Category

Animals:	**0%**	**-19z**
Fruits:	**37.5%**	**-11.5z**
Tools:	**62.5%**	**-6.5z**
Music:	**25%**	**-14z**
Miscellaneous:	**75%**	**-4z**

Picture naming: Written

Semantic Category

Animals:	**12.5%**	**-16.5z**
Fruits:	**12.5%**	**16.5z**
Tools:	**0%**	**-19z**
Music:	**0%**	**-19z**
Miscellaneous:	**0%**	**-19z**

E.) Sentence processing

Sentence Processing: Visual Comprehension

Syntactic structure

Active:	**62.5%**	**-6.5z**	**(E.g., 'The cat chases the dog.')**
Passive:	**37.5%**	**-11.5z**	**(E.g., 'The dog is bitten by the cat.')**
Verb:	**62.5%**	**-6.5z**	**(E.g., 'The man kicks.')**
Preposition:	**62.5%**	**-6.5z**	**(E.g., 'The man walks down the stairs.'**
Particle:	**62.5%**	**-6.5z**	**(E.g., 'The man turned on the TV.')**
Dative passive:	**62.5%**	**-6.5z**	**(E.g., 'The flower was given to the woman by the boy.')**
S-O relative:	**75%**	**-4z**	**(E.g., 'The boy the girl kicked hugged the man.')**

Sentence Processing: Auditory Comprehension

Syntactic structure

Active:	**62.5%**	**-6.5z**	**(E.g., 'The cat chases the dog.')**
Passive:	**37.5%**	**-11.5z**	**(E.g., 'The dog is bitten by the cat.')**
Verb:	**50%**	**-9z**	**(E.g., 'The man kicks.')**
Preposition:	**62.5%**	**-6.5z**	**(E.g., 'The man walks down the stairs.')**
Particle:	**75%**	**-4z**	**(E.g., 'The man turned on the TV.')**
Dative passive:	**50%**	**-9z**	**(E.g., 'The flower was given to the woman by the boy.')**
S-O relative:	87.5%	-1.5z	(E.g., 'The boy the girl kicked hugged the man.')

Sentence Processing: Production

Syntactic structure

Active:	100%	1z	(E.g., 'The boy kicks the woman.')
Passive:	**40%**	**-11z**	**(E.g., 'The woman is carried by the man.')**
Dative:	100%	1z	(E.g., 'The girl puts the cushion on the bed.')

Dative passive:	**40%**	**-11z**	**(E.g., 'The ball is given to the baby by the man.')**
S-O relative:	**40%**	**-11z**	**(E.g., 'The man with the phone points at the girl.')**

Appendix BQ

Consent form

Part 1 (to be completed by the Principal Investigator):

Title of Project: Morphological Therapy Protocol

Principal Investigator(s): Dr. Gary Libben Phone Number(s): (780) 492-5174
Karin Nault (780) 492-7529

Part 2 (to be completed by the research participant):

	Yes	No
Do you understand that you have been asked to be in a research study?	☐	☐
Have you read and received a copy of the attached Information Sheet?	☐	☐
Do you understand the benefits and risks involved in taking part in this research study?	☐	☐
Have you had an opportunity to ask questions and discuss this study?	☐	☐
Do you understand that you are free to withdraw from the study at any time, without having to give a reason and without affecting your future medical care?	☐	☐
Has the issue of confidentiality been explained to you?	☐	☐
Do you understand who will have access to your records, including personally identifiable stroke-related health information?	☐	☐
Do you want the investigator(s) to inform your family doctor that you are participating in this research study? If so, give his/her name _______________	☐	☐

Who explained this study to you?

____

I agree to take part in this study: YES ☐ NO ☐

Signature of Research Participant ______________________________________

(Printed Name) ____

Date: ________________________________

Signature of Investigator or Designee ______________________ Date ______________

THE INFORMATION SHEET MUST BE ATTACHED TO THIS CONSENT FORM AND A COPY GIVEN TO THE RESEARCH SUBJECT

Appendix BR

INFORMATION SHEET

Title of Research Study:	**Words in the Mind, Words in the Brain Morphological Therapy Protocol**
Principal Investigators:	Gary Libben and Karin Nault

Background: Understanding and producing words is at the centre of language ability. The goal of our project is to understand how words are processed and stored in the mind. We do this through a series of language tests in which people are given words of different types and measurements are taken of how they are understood and produced and how long it takes people to do so.

Purpose: The mental lexicon is the storage place for words that we know. Word-building rules seem to be represented in our mental lexicon as well. This study investigates how strengthening unconscious word-building rules affects the processing of words in aphasia. We are therefore asking whether you wish to be a part of this study.

Procedures: In this therapy, you will see words and pictures presented on a computer screen. Your tasks are varied. They involve reading words and indicating as quickly and as accurately as possible whether the words presented are real words of English by pressing either the "yes" or "no" buttons on the computer. You will also be presented with words and pictures and asked to match them. In one task, you break down complex words into their meaningful parts. For example, you may be presented with the word doghouse and a set of pictures. You would in this case choose a picture of a dog and of a house to complete the task. You will also read words aloud.

Time Commitment: Therapy sessions will last approximately 60 minutes and will be administered five days per week. Therapy will be stopped when criterion is reached on the training set or for a maximum of four weeks (20 session).

Possible Benefits: If you choose to participate in the study, you will help us better understand how complex words are represented and processed in the mind and your communicative ability may increase because of this therapy.

Possible Risks: To the best of our knowledge, this therapy poses no risk to you.

Confidentiality: Personal records relating to this study will be kept confidential. Any research data collected about you during this study will not identify you by name, only by your initials and a coded number. Your name will not be disclosed outside the research clinic. Any report published as a result of this study will not identify you by name.

Words in the Mind, Words in the Brain
Morphological Therapy Protocol

For this study, the researcher may need to know a limited set of stroke-related background information (i.e., date of stroke, location of lesion, type of aphasia diagnosed, onset of therapy). This information will be kept confidential and will only be used for the purpose of the research study. By signing the consent form, you give permission to the study staff to ask the speech language pathologist for stroke-related information.

In addition to the investigators, the Health Research Ethics Boards may have access to your records to monitor the research and verify the accuracy of study data.

Voluntary Participation: You are free to withdraw from the research study at any time, and your continuing medical care will not be affected in any way. If the study is not undertaken or if it is discontinued at any time, the quality of your medical care will not be affected. If any knowledge gained from this or any other study becomes available which could influence your decision to continue in the study, you will be promptly informed.

Contact Names and Telephone Numbers:
If you have questions or concerns about your rights as a study participant, you

may contact the Health Research Ethics Board at (780) 492-0302.

You may also contact the researchers, identified below, if you have any questions or concerns:

Dr. Gary Libben, Professor, Department of Linguistics, University of Alberta
Telephone Number (780) 492-5174

Karin Nault, PhD candidate, Department of Linguistics, University of Alberta
Telephone Number (780) 492-7529

Appendix BS

DISCLOSURE OF HEALTH INFORMATION SHEET

Title of Research Study: **Morphological Therapy Protocol**

Principal Investigators: Gary Libben and Karin Nault

Purpose for which the health information may be disclosed: Analyzing therapy outcomes with respect to type of aphasia, lesion site, timeline of stroke onset and therapy start date, previous aphasia assessments and previous speech therapy may help us (1) to better understand the therapy effect overall and also with respect to individual participants and (2) to identify who may benefit most from this type of therapy.

Authorization: I authorize that my name and contact information, previous aphasia assessments, information on previous speech therapy (i.e., type and duration), the lesion site, and date of stroke may be disclosed to Karin Nault.

Possible Benefits of Consenting: Overall, an analysis of the above named factors suggests who potentially benefits most of this type of therapy.

Possible Risks of Refusing to Consent: There are no risks.

Acknowledgement: I have been made aware of the reasons why the health information is needed and the risks and benefits of consenting or refusing to consent.

Contact Names and Telephone Numbers:
If you have questions or concerns, you may contact the researchers, identified below:

Dr. Gary Libben, Professor, Department of Linguistics, University of Alberta, (780) 492-5174
Karin Nault, PhD candidate, Department of Linguistics, University of Alberta, (780) 492-7529

I recognize that I may revoke the consent at any time.

I agree to disclose the health information: YES ☐ NO ☐

Signature of Research Participant ____

(Printed Name) _________________________________ Date __________________

Appendix BT

HEALTH RESEARCH ETHICS BOARD
REQUEST FOR ETHICS REVIEW FORM

*Note – Please complete this form by following the "Instructions for Completing the HREB Request for Ethics Review Form".

SECTION A: GENERAL INFORMATION

A1. Project Title
Title of Project: **Morphological Therapy Protocol**

A2. Applicant Information			
Name: **Gary Libben** Title: **Professor** Department: **Linguistics**			
Mailing Address: **4-55 Assiniboia Hall, University of Alberta**			
City & Province: **Edmonton**	Postal Code: **T6G 2E7**	Phone: **(780) 492-5174**	Fax: **(780) 492-0806**
E-mail Address: **gary.libben@ualberta.ca**			
Signature:			Date:

A3. Co-Applicant Information			
Name: **Karin Nault** Title: Department: **Linguistics**			
Mailing Address: **4-55 Assiniboia Hall, University of Alberta**			
City & Province: **Edmonton**	Postal Code: **T6G 2E7**	Phone: **(780) 492-7529**	Fax: **(780) 492-0806**
E-mail Address: **knault@ualberta.ca**			
Signature:			Date:

A4. Authorizing Signature	
Indication of Department Support for the Implementation of the Project.	
Name of Dept. Chair, Assoc. Dean of Research, or Supervisor: **Dr John Newman**	
Title: **Chair, Department of Linguistics**	
Signature:	Date:

A5. Co-Investigators / Thesis Committee		
Is this project for a graduate thesis? (**x**) Yes ( ) No If yes, please provide the names, departments, and phone numbers of your thesis committee.		
Name:	Department/Program:	Phone:
Dr. Gary Libben	**Linguistics**	**492-3434**
Dr. David Beck	**Linguistics**	**492-3434**
Dr. Tammy Hopper	**Speech Pathology and Audiology**	**492-0836**

A6. Expedited Review	
If the study procedures are **LIMITED** to any of the following, please check (√):	
	Analysis of blood, urine, or any other biological specimen already collected.
√	Examination of patient, medical, or institutional records.
	Modification of a previously approved protocol (specify title and approval date):
	Secondary analysis of data.
	Use of biological specimens normally discarded.

A7. Type of Investigation			
Which one of the following best describes the type of investigation proposed? Check (√) more than one if appropriate.			
	Clinical Trial		Multi-centre Trial
	Drug Study		Pilot Study
	Epidemiological Study	√	Qualitative Study
	First Application in Humans		Technology Assessment / Development
	Sequel to Previously Approved Project (specify title and approval date):		
	Other (specify):		

A8. Site of Research	
Where will the research be conducted? Check (√) more than one if appropriate. Specify the area/department/program.	
Alberta Cancer Board Sites:	
	Cross Cancer Institute:
Capital Health Authority Sites:	
	Community Care and Public Health:
	Glenrose Rehabilitation Hospital:
	North Edmonton Community Health Centre:
	Royal Alexandra Hospital:
	Stollery Children's Health Centre:
	Sturgeon Community Hospital and Health Centre:
	University of Alberta Hospital:
Caritas Health Group Sites:	
	Edmonton General Hospital:
	Grey Nuns Community Hospital and Health Centre:
	Misericordia Community Hospital and Health Centre:
University of Alberta Sites:	
	Specify (e.g. Corbett Clinic):
Other:	
√	Specify (e.g. Edmonton Public Schools, Subjects' homes): **Participant's homes** **Alberta Hospital Ponoka**
Letters of Support:	
( ) Pending ( ) Attached (√) Not Applicable	

A9. Funding / Budget	
How is the project funded? Please check (√) the appropriate box.	
	Funding approved; specify source(s):
	Funding pending; specify source(s):
√	No external funding required.
Budget	
	Please check here (√) that you have attached a budget summary. The summary must include details of investigator payments and recruitment incentives (if present). Please attach the budget as an appendix to the form.

A10. Remuneration	
Are any of the investigators involved receiving any directs personal remuneration or other personal or family financial benefits (either direct or indirect) for taking part in this investigation?	
	Yes. If so, append a letter detailing these activities. Please attach this letter to your budget summary.
√	No.

A11. Safety Approvals					
Please check (√) whether or not this study requires any of the following safety approvals. If a safety approval is needed, please indicate whether the approval documentation is pending or attached as an appendix to this form.					
Biohazardous Materials:					
√	Not Applicable		Pending		Attached
Electromechanical:					
√	Not Applicable		Pending		Attached
Health Protection Branch or Other Canadian Federal Agency:					
√	Not Applicable		Pending		Attached
Radiation:					
√	Not Applicable		Pending		Attached

SECTION B: DETAILS OF PROJECT

Description of the Project

B1. Provide a clear statement of the purpose and objectives of the project.

The purpose of the project is to pilot a therapy protocol that has as its goal the improvement of communicative abilities of individuals with aphasia. The therapy protocol aims to strengthen preserved underlying linguistic structures that play an important factor for the processing of words. Research has shown that individuals with aphasia have the knowledge of the word formation structures of complex words (i.e., doghouse, reading, reader) preserved, but they cannot access the particular items or produce the whole complex word. The therapy thrives to make explicit these underlying structures and the building blocks of these complex words and thereby facilitating access and production of these words. The therapy protocol includes identifying pictures that correspond to words, naming words, and judging words in various ways. Participants either press keys on a computer to indicate their responses and/or provide them orally. The goal of the research is to assess the protocol's ability to improve the processing ability of aphasic speakers.

B2. State the hypotheses and/or research questions.

The piloting of the Morphological Therapy Protocol does not address a specific hypothesis; rather, it is designed to make explicit the underlying morphological structures of complex words and thereby facilitating accessing and retrieving the lexical items.

B3. Briefly summarize past human and/or animal research that has lead to this project.

This research builds upon a program of psycholinguistic and neurolinguistic experimentation that the Mental Lexicon Research Group, headed by my primary advisor Dr. Gary Libben, has carried out over the past decade. This research has investigated through various experimental techniques numerous languages in several populations (i.e., monolinguals, bilinguals, impaired population).

Description of Sample/Population

B4. Describe the numbers and type(s) of subjects to be included. If appropriate, specify the number of subjects in each study group. Provide a rationale for the sample size and include sample size calculations where appropriate.

5 – 15 individuals with aphasia depending on how many individuals will contact us for inclusion in the study.

40 – 50 individuals without language impairment as a control group (Ethics approval already received)

B5. List any subject inclusion/exclusion criteria.
Participants will be adults who have suffered language impairment as a result of damage to the brain. Participants will be sufficiently high functioning so that they can understand experiment instructions and to some extend can read and process complex words.

B6. Please check (√) if any of the subjects who will be recruited fall into one or more of the following categories:	
	Under 18 years of age
	Cognitively Impaired
√	Residing in institutions (e.g. prison, extended care facility)
√	Students
	Employees of researchers' organization
√	Have language barriers (e.g. illiterate, not English-speaking, dysphasic)
	In another country

Description of Research Procedures

B7. Provide a summary of the design and procedures of the research. Provide details on the methods of data collection and data analysis, time commitment for the subjects etc. Please note that any and all study measures need to be appended to the copies of the research / grant proposal (e.g. questionnaire, interview guides, rating scales etc.).

The pre-therapy experiments with individuals without language impairment will include some experiments with response latency timed.

Table 1. Tasks, experimental manipulations, and measured variables to be used.

Tasks	**Manipulations**	**Dependent variables**
Word and picture naming	Stimulus list composition	Response characteristics
Word and picture matching	Stimulus list composition	Response characteristics
Segmentation	Stimulus list composition	Elicited & natural lexical patterns
Category decisions	Stimulus list composition	Elicited & natural lexical patterns
List recall	Stimulus list composition	
Stimulus rating		

Tasks:
The tasks in the first column of Table 1 include standard paradigms for targeting lexical access such as naming and matching. These tasks involve a response by the participant, such as naming or word-picture matching that do not ask for any overt linguistic property analysis. Given that the primary participants have an

acquired language impairment, it is anticipated that the naming task initially may seem to be somewhat challenging. However, the presentation of many examples should help the participants to garner success. Shall the participant require help in performing the various tasks during the therapy sessions, clues on strategies (i.e., how to best break down a complex word or how to best combine two words to make a complex word) will be provided. The main goal of the various tasks is to overtly exemplify underlying psychological processes of complex words with the selected complex-word stimuli.

Manipulation:
Stimulus list composition (i.e., whether the complex stimulus is in the compound word list such as headdress, in the derived word list such as dresser, or in the inflected word list such as dressed) represents the focal means of manipulating the independent variables. The list composition provides a measure of the effect that structural composition of prior stimuli has on lexical access, retrieval, and processing, as measured by response accuracy and response latency.

Dependent variables:
Response latency and accuracy are the primary dependent variables.

Analysis of variations in therapy outcomes:

Therapy outcomes sometimes vary according to factors such as type of aphasia, location of lesion, or timeline of stroke onset and therapy start date. Possible variable therapy outcomes are investigated against a limited set of stroke-related background information (i.e., date of stroke, lesion site, and type of aphasia).

B8. Which treatments or procedures are additional to those required for standard patient care?

As a pilot of a new therapy protocol for lexical deficits in aphasia, this research project as a whole is supplemental to the requirements for standard patient care. The patients will be informed of this during recruitment.

B9. If the procedures include a blind, under what conditions will the code be broken and what provisions have been made for this? Who will have the code?

N/A

Obtaining Consent
B10. Clearly detail who will be recruiting subjects and obtaining consent, and the procedures for doing this. If appropriate specify whether subjects will be randomly assigned to groups before or after consent has been attained. Participants of Neighbourhood CHAT in Edmonton will be told about this pilot study by speech language pathologists. It will be left to the individuals with aphasia whether they want to contact us for inclusion in the study. Karin Nault has volunteered with Neighbourhood CHAT from January 2002 until December 2006, and therefore is known to many of its clients. Individuals with aphasia at the Alberta Hospital Ponoka Brain Injury Rehabilitation Program may also be told about this study by speech language pathologists and if they wish to participate, they are welcome to contact us for inclusion in the study. Consent for a limited set of stroke-related information: For this study, the researcher may need to know a limited set of stroke-related background information (i.e., date of stroke, lesion site, type of aphasia diagnosed, onset of speech therapy). This information will be kept confidential and will only be used for the purpose of the research study. By signing the consent form, the participant gives permission to the study staff to ask the speech language pathologist for stroke-related information.
B11. Specify methods for dealing with groups identified in #B6. If the subjects are not able/competent to give fully informed consent, who will consent on their behalf? Participants will need to be cognitively unimpaired such that they can understand instructions. They must have sufficient language functioning in order to process complex words to some extent. They must have cognitive capacity to ensure that their participation is informed and voluntary.
B12. If the subjects will be offered compensation for participating in the research, provide details. Specify the amount, what the compensation is for, and how payment will be determined for subjects who do not complete the study. N/A
B13. Do any of the procedures include the use of deception or partial disclosure of information to subjects? If yes, provide rationale for the deception or partial disclosure. Describe the procedures for (a) debriefing the subjects and (b) giving them a second opportunity to consent to participate after debriefing. There is no deception or partial disclosure. On the informed consent form and at the outset of the study, participants will be informed that this is a therapy protocol. They will be told that the therapy targets

multimorphemic words and has as its goal an overall improvement of the communicative ability. They will be told that they may view their result of the therapy after the study is complete, and that we will provide them with any resulting publication if they desire. They will be told that their names will not appear on any publications and that they will be identified by pseudonym only. On debriefing, participants will be given another opportunity to withdraw their participation.

Recruitment Aids/Information Letters/Consent Forms					
B14. Are you planning to use any recruitment aids such as posters, newspaper advertisements, radio announcements, or letters of invitation? If so, please indicate the reading level of each aid and check (√) if it has been attached to the form as an appendix.					
Recruitment Aid #1 – Specify (e.g. poster, letter etc.):					
√	Not Applicable		Reading Level		Attached
Recruitment Aid #2 – Specify:					
√	Not Applicable		Reading Level		Attached
Information Letter #1 – Specify: Morphological Therapy Protocol					
	Not Applicable		Reading Level	√	Attached
Information Letter #2 – Specify:					
√	Not Applicable		Reading Level		Attached
Consent Form #1 – Specify: Consent for therapy participation					
	Not Applicable		Reading Level	√	Attached
Consent Form #2 – Specify:					
√	Not Applicable		Reading Level		Attached
B15. What steps have been taken to make the recruitment aids, information letters, and consent forms comprehensible to the person(s) giving consent? We have modified our information sheets to use shorter sentences and simpler syntax.					

Risks and Benefits
B16. What are the benefits of the proposed research for the subject and/or for scientific knowledge in general? <u>For the patient:</u> The goal of the proposed research is to develop and test a protocol that will

provide individuals with aphasia with an additional treatment opportunity. The therapy will provide participants with strategies to increase their communicative ability.

For the understanding of lexical deficits in aphasia:

Information gathered in this study will help us to further understand lexical organization and processing strategies of the brain.

For the understanding of normal language processing:

Evidence from aphasia allows us to understand how individual operations (e.g., the parsing of complex words into their constituents) play a role in the larger process of recognizing and understanding words.

B17. What adverse effects may result from the research? How will adverse effects be dealt with? Please note that adverse effects are not limited to physical risks, but include psychological, emotional, and spiritual risks as well.

We do not foresee the possibility of any adverse effects.

Privacy and Confidentiality

B18. What steps will be taken to respect the privacy of the subjects and protect confidential data?

Individual's names and other personal identifying information will not be used in any publication of this research. Participants will only be identified by pseudonym. Individual records will be stored in a locked cabinet in the Centre of Comparative Psycholinguistics at the University of Alberta.

B19. Identify any agencies or individuals who will have access to confidential data now or in the future.

We will not forward any data that will allow the participant to be identified personally to any other individuals or agencies. Individual testing will be carried out by Karin Nault.

B20. Do you anticipate any secondary analysis of the data? Please note that any secondary analysis requires further research ethics approval.

Therapy results will be used in the dissertation and in either case-study publications or publications that include the performance of groups of aphasic participants and/or groups of control participants. We do not anticipate a secondary analysis of the data beyond these individual and group studies.