# Why Can't Individuals with Nonfluent Aphasia Produce Sentences? Exploring the Role of Lexical Availability

by

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Abstract

Nonfluent aphasia is a language disorder characterised by sparse, fragmented speech. Individuals with this disorder often produce single words accurately (for example, they can name pictured objects), but have great difficulty producing sentences. An important research goal is to understand why sentences are so difficult for these individuals. To produce a sentence, a speaker must not only retrieve its lexical elements, but also integrate them into a grammatically well-formed sentence. Indeed, most research to date has focused on this grammatical integration process. However, recent studies suggest that the noun and/or verb content of the sentence can also be an important determinant of success (e.g., Raymer & Kohen, 2006; Speer & Wilshire, 2014). In this thesis, I explore the role of noun availability on sentence production accuracy using an identity priming paradigm. Participants are asked to describe a pictured event using a single sentence (e.g., "*The fish is kissing the turtle*"). In the critical condition, an auditory prime word is presented just prior to the picture, which is identical to one of the nouns in the target sentence (e.g., *fish*). The rationale is that the prime will enhance the availability of its counterpart when the person comes to produce the target sentence. Participants were four individuals with mild nonfluent aphasia, two individuals with fluent aphasia, and six older, healthy controls. Consistent with our hypotheses, the nonfluent participants as a group were more accurate at producing sentences when one of its nouns – either the subject or object - was primed in this way. Importantly, in the primed subject noun condition, these results held even when accuracy on the primed element itself was excluded, suggesting it had a broad effect on sentence production accuracy. The primed nouns had no effect on sentence production accuracy for the fluent individuals or the controls. We interpret these findings within models of sentence production that allow for considerable interplay between the processes of lexical content retrieval and sentence structure generation.

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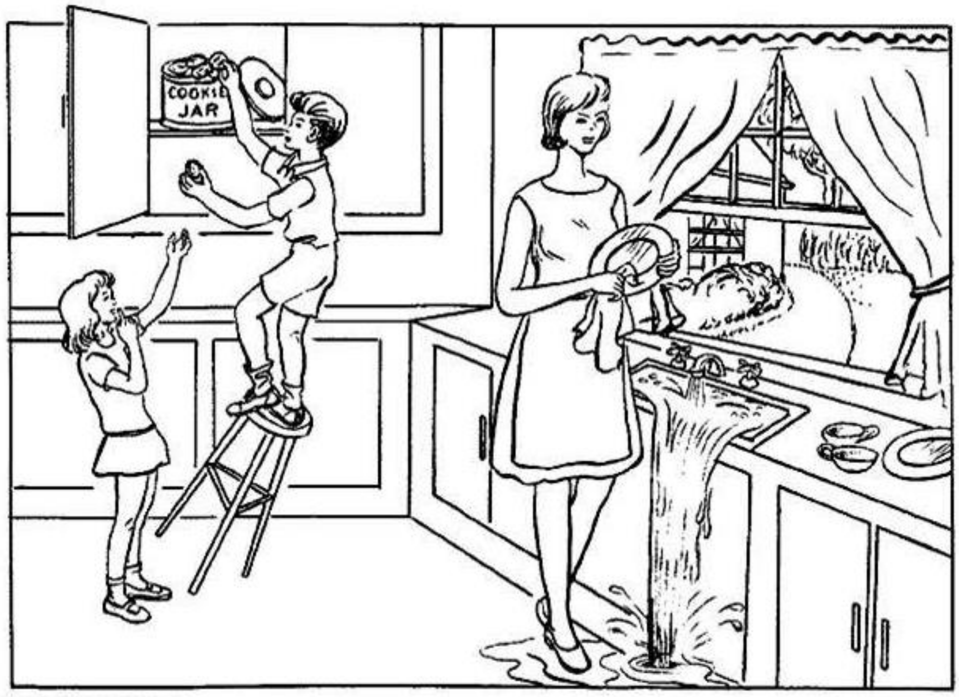
Aphasia is a language disorder that occurs as the result of brain damage which dramatically affects people's ability to produce and/or understand speech. Strokes are the major cause of aphasia but it may also result from a brain tumour or severe brain injury. The disorder can take many forms. Some individuals have great difficulty speaking in full sentences, and may omit many words that are part of normal speech. For example instead of saying "today I went to the movies" they may say "*today…movies*". Others may be able to produce full sentences, but some or all of the words may be incorrect "*well you see um todoy I saw picture moving…oh great*". Some people may also have difficulty understanding speech. Given the importance of communication in daily life, aphasia can be an extremely debilitating condition. Everyday interactions such as answering the phone or buying groceries can be hugely difficult and distressing. Aphasia can severely limit individuals' independence and often places enormous stress on relationships with loved ones. It is estimated that approximately six New Zealanders develop aphasia each day as the result of a stroke ("About Aphasia", 2010). Improving our understanding of the functions that are disrupted in aphasia is a crucial first step in the development of new, effective treatment options. Studying aphasia may also provide insights into the way normal healthy individuals understand and produce language.

Diagnostic assessments make a primary distinction between fluent and nonfluent forms of aphasia (Goodglass, Kaplan, & Barresi, 2001; Kertesz, 2006). According to the Boston Diagnostic Aphasia Examination (BDAE), fluent aphasia describes a pattern of relatively effortless speech, with normal to near-normal articulation and fluency, which contains errors in word selection and/or long word-finding pauses for difficult words

(Goodglass et al., 2001). Individuals with fluent aphasia often use complete grammatical sentence structures, but the key content words may be missing or incorrect. In its extreme form, all of the content words are replaced or dropped and the sentence is completely nonsensical. This can be seen from fluent individual SW's speech sample in Figure 1.1. In fluent aphasia, language comprehension may be significantly impaired. For example, upon hearing a noun (e.g., *mouse*), they may be unable to identify its corresponding picture (Goodglass et al., 2001). Fluent aphasia has been associated with damage to the posterior language regions in the left hemisphere of the brain, including the temporal region (the green area in Figure 1.2) and the temporoparietal area, which is between the temporal and the parietal lobes (the border of the yellow and green areas in Figure 1.2). One common sub-type of fluent aphasia, Wernicke's aphasia, has often been associated with damage to Wernicke's area (see Figure 1.2; Wernicke, 1874). Other key areas identified are the middle temporal gyrus, the superior temporal gyrus and the connecting fibres between the Wernicke's and Broca's areas (Dronkers & Larsen, 2001; Goodglass et al., 2001).




**Fluent Individual SW's response:**

"An /æprɒn… æpərən/… and he's got a little uh… car, jar… I mean cookie… I think she's going to eat something or drink something… he going fly up… you see… I can't see the word! You got it… why is it like that… him going on the… skull... Why is that? …"

**Nonfluent Individual RP's response:**

"Cookie jar… boy… girl… /t/ tip over… washing the dishes… *[long pause]* pill… floors is spill… and gardening… and /tuː/… uh… uh… kitchen… and… cups... plates… cupboards… uh curtains… trees… *[long pause]* curtains again… shrubs… uh lawns."

*Figure 1.1.* A spontaneous speech sample from one individual with fluent aphasia and another individual with nonfluent aphasia, describing the scene in the BDAE cookie theft picture above (Goodglass et al., 2001).

In contrast, nonfluent aphasia presents as effortful and fragmented speech, containing correct content words but sometimes missing out the grammatical elements that characterise normal speech. For example, in Figure 1.1, nonfluent individual RP identifies key elements of the picture, but does not structure his response into phrases or sentences. In some cases, virtually all grammatical features are absent, including function words (e.g., *to, at, of*) and grammatical inflections (e.g., *-ing, -ed*). This form of nonfluent aphasia is known as agrammatism. Despite their difficulty with sentences, individuals with nonfluent aphasia may be quite accurate on tasks that require the production of only one word at a time, such as picture naming (Freedman, Martin & Biegler, 2004; McCarthy & Kartsounis, 2000; Williams & Canter, 1982). Also, their ability to comprehend words and even many sentences is often preserved (Heilman & Scholes, 1976). Nonfluent aphasia is associated with damage to the anterior language regions in the left hemisphere. One common sub-type, Broca's aphasia, has long been associated with damage to the left inferior frontal gyrus, in particular Broca's area (see Figure 1.2; Broca, 1861). Nonfluent aphasia is also associated with damage to the insula which is located in a region of cortex that lies beneath the area where the temporal, parietal and frontal lobes connect (Goodglass et al., 2001).

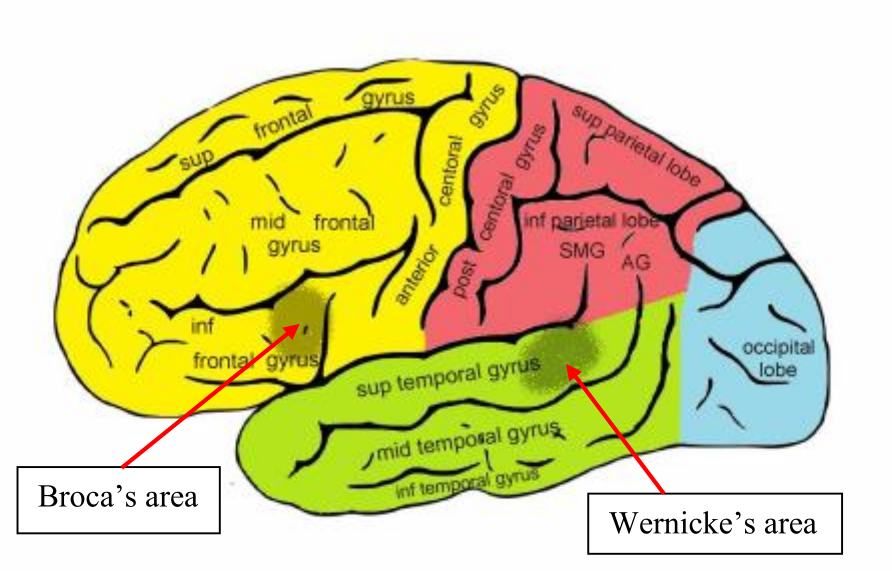



*Figure 1.2.* A lateral view of the surface of the left hemisphere of the brain. Colours represent the four brain lobes: Yellow = the frontal lobe; red = the parietal lobe; green = the temporal lobe; blue = the occipital lobe. Shaded areas show approximate locations of Broca's and Wernicke's regions.

While nonfluent aphasia is more common than fluent aphasia, it has received less attention in cognitive neuropsychological research. As a result, many questions regarding the cognitive underpinnings of the disorder remain unanswered. The current study will focus on sentence production difficulties in nonfluent aphasia. In particular, we will investigate why nonfluent individuals are able to perform reasonably well when producing a single isolated word, but struggle with the production of multiple words in a well-formed sentence. We will examine which conditions can lead to improvements in nonfluents' ability to accurately produce a sentence. In order to understand the language production difficulties of individuals with aphasia, it is necessary to have an understanding of the cognitive processes involved in normal language production. The next section will briefly review this literature.

**Language production models**

Language production at its simplest level is the production of a single word. To translate a conceptual representation of a simple concept – such as an object - into a spoken word, first the appropriate word must be selected and secondly, the word's sound form must be retrieved from memory and the appropriate plan sent to the articulators. There is wide agreement amongst researchers that these two stages of word production are separate and distinct (e.g., Dell, 1986; Garrett, 1975; Levelt, 1989; Schwarz, Dell, Martin, Gahl & Sobel, 2006). The first stage, where the target word is selected, is often referred to as the *lexical selection* phase. For example, the best word to represent the concept of a commonly eaten round, red, crispy fruit is "*apple*". The second stage is where the individual sounds that make up the word are retrieved and/or organised in the right order. This is often referred to as the *phonological encoding* phase. To produce the desired word '*apple*', the phonological units /æpəl/ must be retrieved and appropriately ordered.

Many contemporary theories describe these stages of word production within a spreading activation framework, of the kind shown in Figure 1.3 (e.g., Dell, 1986; Dell & O'Seaghdha, 1991; Stemberger, 1985). In this framework, each semantic concept is represented as a series of features or attributes (e.g., cat: four legs; pet; furry; goes meow; etc.). Each of these attributes is connected with the lexical representations of concepts that possess that feature. A similar network is formed between lexical items and its phonological constituents. During word production, the features of the desired concept become activated, and this activation then flows to all interconnected lexical items. This will activate more than one lexical item - so for example, the concept of a fluffy domestic animal will activate *cat* and *dog*. The item receiving most activation from the semantic layer will be selected, so if the concept is fluffy purring domestic animal, then *cat* will receive more activation than *dog* and therefore be selected. The activated lexical items will in turn pass on activation to their phonological constituents.

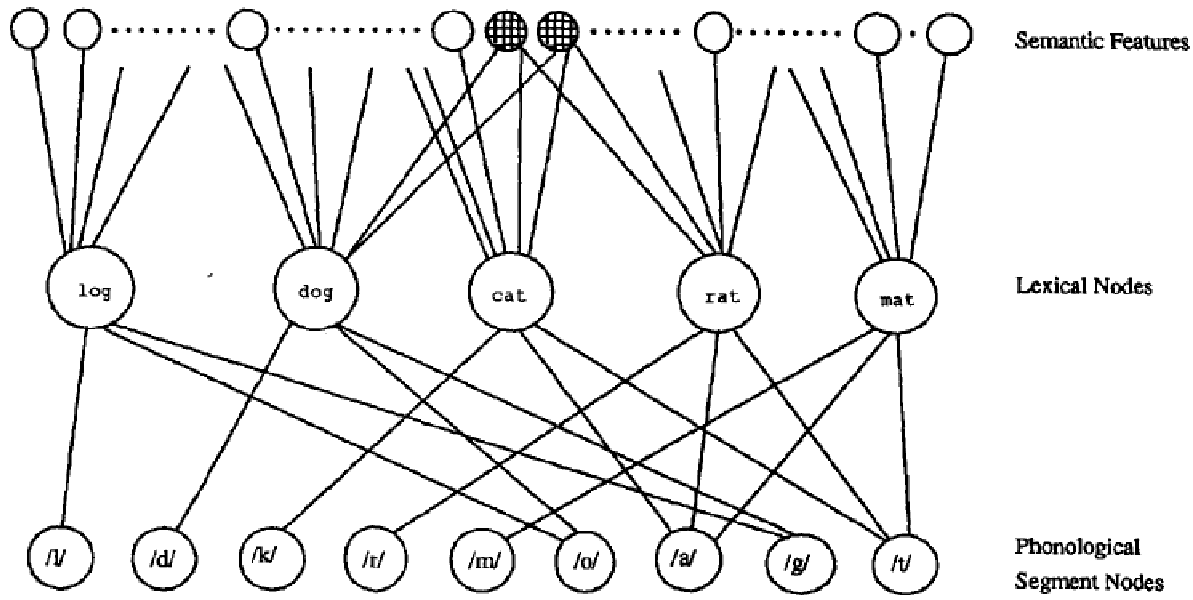



*Figure 1.3.* Dell & O'Seaghdha's (1991) Model of Spreading Activation.

The production of sentences is another order of complexity again. To produce a normal spoken sentence, not only must multiple individual words be selected and articulated, but they must be organised in an appropriate order and contain the appropriate grammatical elements that are required for the language in which it is being spoken. One of the prominent early models of this process is Garrett's two-stage model of sentence production (Garrett, 1975, 1980a, 1980b, 1984, 1989). During the first stage, the *functional level,* lexical selection of the key meaning-carrying words (e.g., nouns, verbs, adjectives) takes place. At this stage, each key word is also assigned a functional role in the sentence (for example, whether it describes an action, an agent performing an action, or a recipient of an action). During the second stage of sentence production, called the *positional level,* an appropriate syntactic frame is built, which provides 'slots' for the open-class words (Garrett, 1980a). This frame also specifies the location of any grammatical closed class elements required, such as inflections *(-ed*, *-ing*) or grammatical function words (*to*, *at*, *for*, *the*). See Figure 1.4 for a depiction of Garrett's model.

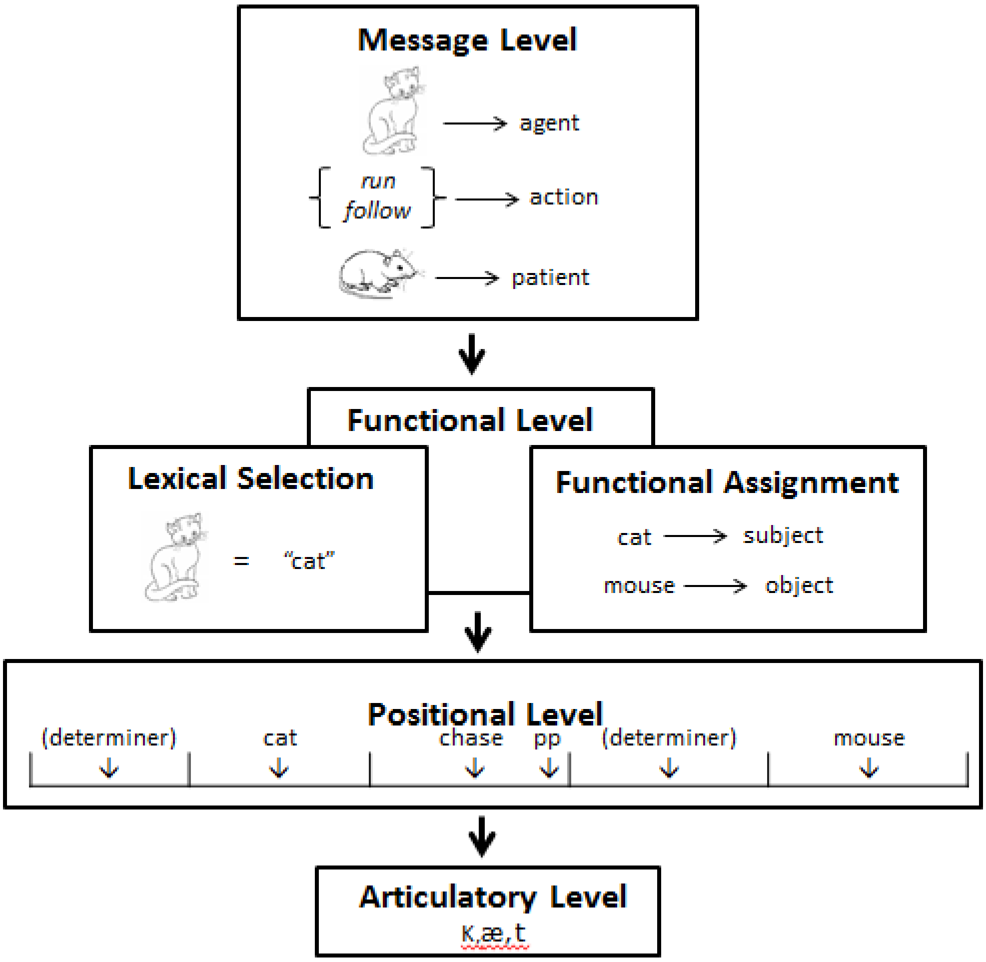



*Figure 1.4.* Garrett's Sentence Production Model (adapted from Garrett 1975, 1980a, 1984).

Other models of sentence production place greater emphasis on the importance of verbs in the construction of the syntactic frame (e.g., Bock & Levelt, 1994; Levelt, 1989). The sentence production model developed by Levelt and colleagues follows Garrett's proposal that there is a functional processing phase in which content lexical items are selected and their functional roles determined, and that this occurs prior to their positional processing and phonological encoding (Levelt, Roelofs, & Meyer, 1999). However, Levelt et al. do not see the syntactic frame as being built independently from the lexical items, but rather being derived from the grammatical properties of the key items, most importantly verbs. Verbs not only specify the nature of the action they describe, but also its argument structure. For example, the verb *kiss* describes one entity acting upon another entity, so requires both a subject and a direct object (Levelt et al., 1999). These syntactic properties of the verb, provide the syntactic frame for the subsequent assembly of the sentence. Furthermore, some information as to the nature of the entities is indicated by the verb. For example, for the verb *eat*, the actor (usually the subject noun) must be animate, while the patient (usually the object) could be either animate or inanimate. This centrality of the verb is supported by evidence that whole-word substitution errors seldom occur with verbs suggesting that they drive the organisation of the other elements (Hotopf, 1980, cited in Bock & Levelt, 1994).

In all of the models just described, there is limited interplay between the processes of lexical selection and sentence construction. That is, with the exception of verb selection, the processes of grammatical frame construction and lexical selection proceed relatively independently of one another. Below, we consider some models that allow for more interplay between these two sets of processes.

## Explanations for the Sentence Production Deficits in Nonfluent Aphasia

The models described above provide a useful theoretical framework for describing the nature of the sentence production deficit in nonfluent aphasia. Much of the research into sentence production in nonfluent aphasia has focussed on a subset of individuals whose speech can be described as "agrammatic" – that is, it is made up entirely of content words (nouns and verbs), without function words and inflections (Goodglass et al., 2001; Rochon, Saffran, Berndt, & Schwartz, 2000; Saffran, Berndt, & Schwartz, 1989). For example, the sentence "*The dog chased after the cat"* might be produced as "*dog…chase…cat"*. This pattern is suggestive of a difficulty with grammatical aspects of sentence production in particular.

Focusing primarily on individuals with this agrammatic speech pattern, various hypotheses have been put forward as to the basis of the sentence production deficit. One hypothesis is that there is a deficit in mapping thematic roles (e.g., Maher, Chatterjee, Gonzalez Rothi, & Heilman, 1995; Schwartz, Saffran, & Marin, 1980). Thematic roles identify the role each noun entity plays in relation to the verb. In the sentence *The cow jumped over the moon*, the *cow* has the thematic role of the *agent*, the role of the action is the verb *jump,* and the *moon* has the thematic role of the *patient* - what the agent acted on. In a study by Saffran, Schwarz, and Marin (1980), subject-verb-object (SVO) pictures were shown to nonfluent individuals, which varied the animacy (living or non-living) of the nouns. They found that individuals had significantly more difficultly when the nouns were either both animate (e.g., *The man washes the baby*) or both inanimate (e.g., *The bike is on the car*), compared to when one was animate and one was inanimate (e.g., *The man washes the car*). This showed, according to Saffran et al. (1980) that the individuals relied on a simple strategy of putting the animate item first in the subject position and the inanimate item in the object position. They did not have the ability to identify the thematic role of the elements and order them accordingly when both elements had the same animacy.

Another hypothesis focuses on the verb argument structure (e.g., Lee & Thompson, 2004; Thompson, Lange, Schneider, & Shapiro, 1997). As noted above, verbs are relational in that they specify information about the type and number of entities involved in the event, and the types of arguments they can take. If an individual is unable to access the argument structure of the verb, they will be unable to build the sentence frame. This explanation is supported by evidence that individuals with Broca's aphasia have more difficulty producing verbs than they do producing nouns (e.g., Breedin, Saffran, & Schwartz, 1998; Chen & Bates, 1998).

A third type of account aims to characterise each person's deficit within a *syntactic tree* framework (Friedmann & Grodzinsky, 1997; Friedmann, 2006). A syntactic tree is a description of a sentence which specifies the hierarchical relationships between the various sentence constituents, with simple constituents, such as nouns or determiners, at the bottom of the tree and more complex ones, such as whole clauses, higher up. At virtually all levels of the hierarchy, rules of agreement apply – that is, there are syntactic requirements for the form of a word to change depending on features of the word it relates to (for example, it is correct to say *I am ready* or *she is ready* but not *she am ready* or *I is ready).* For individuals with a severe impairment, they will be able to produce within-phrase agreement (e.g., *those boys*) and possibly more complex within clause agreement (e.g., *the boys play*), but not higher forms, such as across clause agreement (e.g., *The boys who were playing were getting tired*). For more severe cases, even the simpler structures may be unavailable. Where any individual sits on the continuum will be unique, but it will not be possible for them to produce more complex structures while failing at simpler ones (Friedmann & Grodzinsky, 1997; Friedmann, 2006).

This type of account has extended our knowledge of the different forms that agrammatic nonfluent speech can take and has helped differentiate the complex syntactic requirements of normal speech production. It provides an explanation for some general patterns within agrammatism and some of the ways in which individuals may vary in their syntactic capabilities. However, the framework can be somewhat unwieldy. Friedmann (2006) suggests that each syntactic capacity can be linked to a physical brain location that is subject to dysfunction through brain lesion/injury. Therefore, for each new pattern of grammatical error that is identified, a new conceptual and physical component must be added to the model. Another challenge for the framework is explaining variability *within* a single individual. If a syntactic capability is either intact or 'pruned' from the tree, then the model implies that capability should either be functioning at the same level as healthy individuals or not at all. However, in their results, individuals succeeded some of the time, even at levels that are normally considered beyond their capability (Friedmann, 2006).

**Problems with existing approaches**

The models discussed so far provide an explanation for the most general observation of nonfluent language production: that nonfluent individuals have difficulties in producing speech within correctly formed sentences, while their ability to produce words in isolation remains relatively intact. However, the models leave rather open the question as to the underlying cognitive impairments that give rise to these patterns. More importantly for our purposes, explanations focusing solely on grammatical or relational deficits fail to account for much of the more nuanced variations in performance both between individuals and within individuals with nonfluent aphasia. Between nonfluent individuals, there are significant variations in the types and number of grammatical errors they make. Some consistently fail to produce any function words (e.g., *the, a, at, than*) while others produce some in some circumstances (Saffran, Berndt, & Schwartz, 1989). Variation in the omission of bound morphemes (e.g., *runs, chased fighting*) versus unbound morphemes (which are the same as function words) has also been identified (Caramazza & Hillis, 1989; Rochon, Saffran, Berndt, & Schwartz, 2000).

In addition, there is considerable variability in the nature and extent of grammatical errors made by individual nonfluents in different contexts (Hofstede & Kolk, 1994; Kolk, 1995). In some situations, they may be able to form grammatically complete sentences. For example, individuals have been seen to perform much more poorly in open ended interviews than in closed picture description tasks (Sahraoui & Nespoulous, 2012). Furthermore, nonfluents have also been found to have impaired performance in multiple word production tasks which do not require conventional grammar, such as naming three pictures in one phrase (e.g., "*green fan pig*"' Freedman, Martin & Biegler, 2004; Schwartz & Hodgson, 2002). These individuals may even show characteristic deficits in single word naming tasks, if the pictures are semantically grouped and repeatedly presented (Schnur, Schwartz, Brecher, & Hodgson, 2006; Wilshire & McCarthy, 2002). These studies show that the underlying cognitive impairment can manifest itself even in tasks that do not require construction of a grammatical sentence frame.

**Process Based Models of Nonfluent Aphasia**

The models of nonfluent aphasia discussed so far have focussed on the types of structural representations that are most difficult for these individuals. Alternative models of nonfluent aphasia have emphasised the underlying cognitive processes and the coordination of those processes in the production of a sentence. One prominent example is Kolk's (1995) timing model of sentence production. For Kolk, the key processing deficit in aphasia is a problem of synchronisation between the constructions of the appropriate syntactic frame and the insertion of the correct lexical elements into this frame (Kolk, 1995). Successful sentence production requires both the retrieval of lexical items and the building of the syntactic frame, but it also requires the synchronisation of these two processes. For a word to be successfully produced in a sentence, both the lexical item and the corresponding syntactic slot need to be activated at the same time. For example, to successfully produce *dog* in the sentence *The dog chased the cat,* the speaker needs to have the lexical item *dog* activated at the same time as the *subject noun* slot is activated. If this does not happen, the word may be produced in the wrong position in the sentence or fail to be incorporated in the sentence produced. Failure to synchronise these processes could result from either a slow retrieval or a fast decay of either the lexical items or the syntactic frame (Kolk & Van Grunsven, 1985). A simple noun-phrase like *the dog runs* only requires the construction of the simplest grammatical frame, the retrieval of only three lexical items, and their production in the correct order. A more complex sentence such as *the dog runs out the door to chase the cat* imposes significantly increased timing requirements. Not only does a longer syntactic frame need to be constructed and more lexical items be retrieved, but each item has to be activated at the correct time. For Kolk, timing issues are the underlying cause of sentence production difficulties in both fluent and nonfluent forms of aphasia. What makes the nonfluent speech pattern unique is that these individuals have developed a strategy to skip function words to simplify integration and reduce timing demands, whereas fluents have not (Kolk, 2006).

Kolk's timing-based model provides a much more flexible framework for explaining the large variations in performance between individuals as well as within individuals. The degree of impairment of different individuals will result in significant differences in the extent of retrieval delays or the rate of decay of activated items. Within-individual variation in performance can also be understood in terms of variation in the complexity of the sentence being produced and thus the timing demands for synchronisation. However, one significant problem with Kolk's model is that it does not identify any distinct cognitive deficiencies associated with either fluent or nonfluent aphasia. Rather than having a cognitive basis, the difference is seen as being the result of nonfluents adopting a coping strategy.

Martin and colleagues put forward an alternative process-based model of language production impairments in nonfluent aphasia (Freedman et al., 2004; Martin & Freedman, 2001; Martin & He, 2004; Martin, Lesch, & Bartha, 1999). They argue that the process of combining lexical items and a syntactic frame requires a buffering system which they refer to as semantic short-term memory (Martin & Freedman, 2001). Rather than operating at the level of complete sentences, this buffering system is seen as confined to units no larger than a phrase. Prior to production, a lexical item is linked to its place holder in semantic short-term memory, and activation flows bi-directionally between them, thereby maintaining their period of activation, so that the phrase can be produced at the appropriate point in the utterance being planned. It is this maintenance of activation that is problematic in nonfluent individuals, which impacts on their ability to produce a fully formed phrase (Freedman et al., 2004; Martin & Freedman, 2001). However, this deficit would not be expected to prevent the selection and production of a single word, thus neatly accounting for one feature of nonfluent speech. It is less clear, however, how this model explains other features of nonfluent speech, such as the tendency to produce more nouns and verbs and drop function words and inflections.

**The Importance of Lexical Retrieval in Sentence-Level Planning**

The models of sentence production described so far propose that the processes of sentence structure generation and lexical content retrieval take place largely independently from one another. Indeed, studies of sentence production in nonfluent aphasia have primarily focused on sentence frame construction, while either minimising lexical retrieval demands, or keeping such demands relatively constant across the key comparisons. However, there are reasons to believe that lexical retrieval and sentence structure generation may be much more closely intertwined. A number of studies of normal speakers have demonstrated that manipulating the availability of lexical content items – for example by priming them - can have an effect on the grammatical structure chosen for that sentence (Bock, 1986a; Bock, 1986b; Ferreira & Engelhardt, 2006). For example, in a study by Bock (1986a), participants were required to complete a picture description task. Each picture was preceded by an auditory prime word that was either semantically or phonologically related to one of the target words in the picture. Participants were more likely to turn the sentence into a passive structure when the object noun had been semantically primed. For example, the target sentence "*The lightning struck the church*" was more likely to be produced in passive form "*The church was struck by lightning*" following the semantically related object prime "*worship*". The increased activation of the lexical item appears to result in it being produced earlier, within a syntactic structure that allows for this. There was no similar effect for phonological primes, however (Bock, 1986a, 1986b; Ferreira & Engelhardt, 2006).

These findings from normal speakers suggest that there is much greater interaction between the processes of structure generation and lexical content retrieval than classic models, such as those of Levelt and Garrett, would allow. However, some models do allow for more extensive interaction between these two sets of processes. One early such example is Stemberger's Interactive Activation model of language production (1985). This model is conceived as a structured network of nodes that communicate through the mechanism of spreading activation. In the model, there are two qualitatively distinct networks: one comprising of content representations (for example, semantic, lexical and phonological representations of key meaning carrying words), and the other structural or syntactic representations (for example, representations of the various syntactic classes required for different types of sentences; see Figure 1.5). Importantly, these two networks are not constrained to sequential top down flow, but are highly interactive and operate in parallel. Just as a lexical item is activated by the strength of its connections with the relevant semantic input, the syntactic nodes are activated at the highest level by the thematic roles and grammatical relations of the intended message. These phrase structure units are themselves connected in a structure that drives the organisation of the syntactic frame into a correctly sequenced and syntactically complete sentence. For example, to describe a scene where a dog is running after a cat, the subject noun phrase, verb phrase and object noun phrase will be activated, and in turn, activate their respective constituents. These nodes, called *phrase structure units,* are contentless: they are associated with their corresponding lexical content elements through a process of spreading activation. For example, the subject noun unit will activate all lexical content items that are of the appropriate form class, and the lexical unit with the highest level of activation will be associated with that unit.

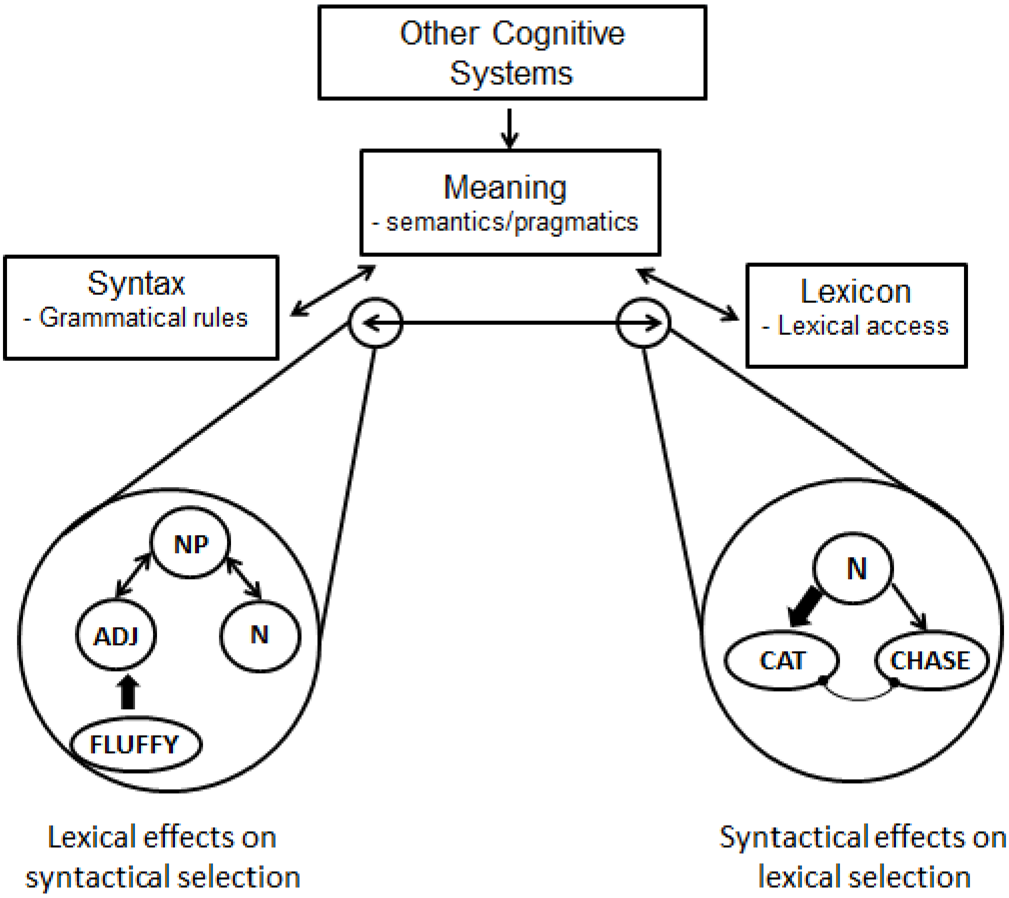



*Figure 1.5.* Key elements of Stemberger's Model of Sentence Production (adapted from Stemberger, 1985). The arrows represent the flow of activation; the bold arrows indicate a larger amount of activation. The filled circles represent inhibition.

All the systems interact with each other bi-directionally, so that as well as the syntactic frame activating the lexical items in sequence, the lexical items can themselves activate the corresponding phrase structure units. For example, the activation of a lexical item such as "fluffy" can activate its corresponding adjectival phrase structure node, ensuring that an adjectival phrase forms part of the sentence structure produced. Under this model which explicitly allows for such bi-directional flow, we can find a cognitive explanation for the findings in the lexical priming studies of Bock and Ferreira (Bock, 1986a; Bock, 1986b; Ferreira & Engelhardt, 2006).

In Stemberger's model, content and structures nodes are capable of interacting directly through bi-directional connections. Gordon and Dell's (2003) Division of Labour model and Chang, Dell and Bock's (2006) Dual-Path (DP) model propose a more constrained structure-content interaction. This model identifies two distinct and specialised systems for the activation of lexical items: the meaning system and the sequencing system (Figure 1.6). The meaning system represents the cognitive processes by which the appropriate semantic concepts are selected and the corresponding lexical items activated.  The sequencing system represents the cognitive processes by which grammatical rules are applied in the planning of the sentence.

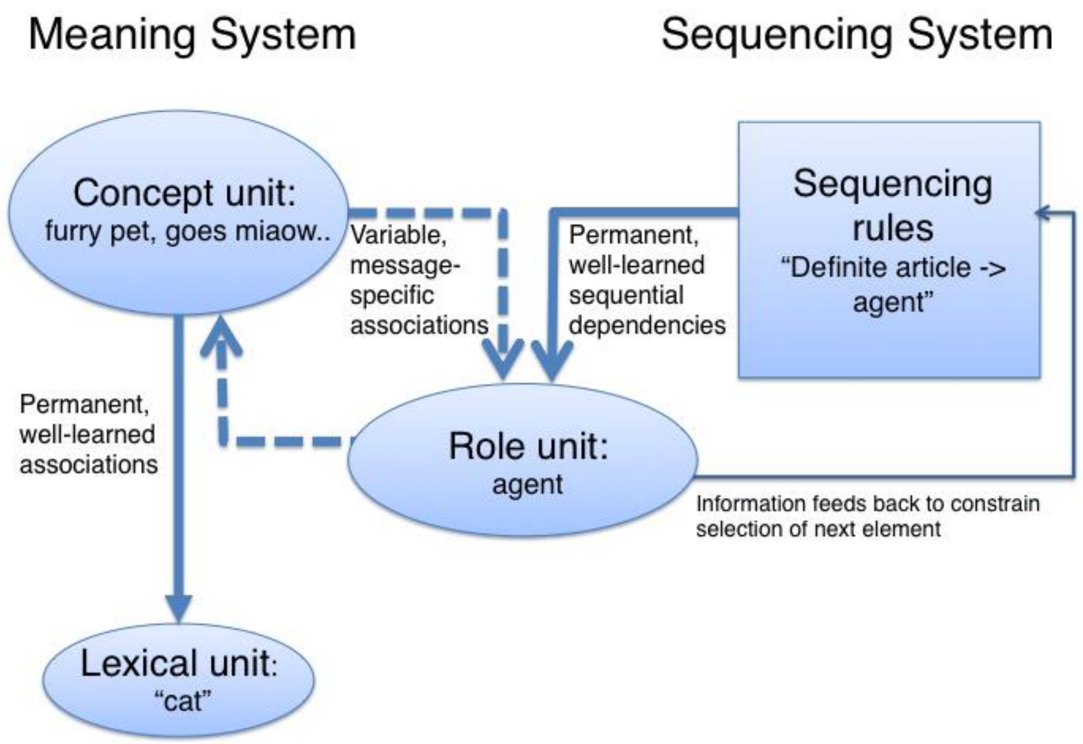



*Figure 1.6.* Adaptation of Chang, Dell and Bock's (2006) Dual Path Model, taken from Speer and Wilshire (2014).

Interaction between these systems takes place via a set of intermediate units that represent thematic roles. As discussed above, thematic roles identify the types of entities involved and their semantic relation to each other. For example, in the sentence *The clown gave the balloon to the girl,* the clown takes the thematic role of *agent*, giving is the *action,* balloon is the *patient,* and girl is the *recipient*. Through repeated practice, an individual learns which entities can occupy which thematic roles, and also which sequencing rules apply to a particular thematic role unit. Sentence production occurs in a sequential manner, so the most activated thematic role unit wins the right to select its appropriate sequencing rules, and so on. Once sentence production is underway, the sequencing rules begin to impose constraints on the selection of subsequent thematic role units. Crucially, since the degree of activation of a given conceptual or lexical representation determines which thematic roles will be most highly activated, this means that the lexical-conceptual system can indirectly influence the selection of the appropriate syntactic structure, particularly at the beginning of the sentence. Once production of the sentence is underway, however, sequencing constraints become more crucial, and the power of the conceptual/lexical system to influence word selection is somewhat reduced.

Another interesting aspect of this model for our purposes, concerns the way in which the meaning and sequencing systems contribute to selection of different types of word classes. Under this model, the activation of lexical items will be driven by both the meaning and the sequencing system. Nouns will be activated primarily by the meaning system because their meaning is relatively constant regardless of the grammatical structure they are used in. Function words will be activated primarily by the sequencing system as they have little isolated meaning. Verbs may be activated by either system depending on their relative semantic weight. Verbs which carry a lot of meaning such as *fly* and *run* will be activated by the meaning system. Verbs that have more contextual meaning and are semantically "light" such as *have*, *is* and *go* will be more activated by the sequencing system (Chang et al., 2006, see also Gordon & Dell, 2003). Under this model, nonfluent aphasia can be seen as a deficit in the sequencing system, so that 'light' verbs and function words are harder to produce and the capacity to order lexical items into a well-formed sentence is restricted.

**Lexical Effects on Structure Building in Nonfluent Aphasia**

As stated above, most research into nonfluent aphasia has focused on structural aspects of sentence production. In an attempt to identify the reasons why these individuals fail to produce grammatically correct sentences, researchers have designed tasks in which the lexical demands are kept constant while manipulating the grammatical demands. A smaller pool of research has looked at this from the reverse perspective. Rather than manipulating grammar, grammatical demands are kept constant while manipulating lexical items in an attempt to identify lexical conditions which support the production of a grammatically correct sentence.

A study by Raymer and Kohen (2006) looked at the effect of lexical training on general word retrieval on the one hand, and success in the full production of grammatically well-formed sentences on the other. They looked at the relative effect of target verb training compared to target noun training. The study was carried out with one individual with nonfluent aphasia and one individual with fluent aphasia. Their findings showed that there were significant generalised improvements in both lexical content and grammatical completeness of sentences, but only for the nonfluent individual and only after the noun training. This was contrary to their expectations which were that verb training would lead to greatest improvement of the grammatical completeness of sentences. This expectation was based on the view that verbs form the basis of sentence construction because of the argument structure which the verb dictates (Raymer & Kohen, 2006). However, it was the noun training which was the key to grammatical improvement for the nonfluent individual, possibly by making the nouns more available. This suggests that for nonfluent aphasia, sentence construction is influenced by the ease with which the lexical content elements can be retrieved, even ones that do not appear crucial to the determination of syntactic structure.

One technological device, specifically developed for individuals with aphasia, is the SentenceShaper® (Linebarger, Schwartz, Romania, Kohn, & Stephens, 2000; Linebarger, McCall, Virata, & Berndt, 2007). This device allows individuals to record initial attempts at sentence production and subsequently play back, add to, and change the order of, the words in the sentence. Using this device, nonfluent individuals with significant sentence production difficulties, were able to significantly improve their sentence accuracy. One of the benefits of the sentence shaper may be that it allows the speaker to record key content words and play them back as required, making those elements much more readily available during sentence planning.

Of direct relevance to the current study is Speer and Wilshire's (2014) investigation of variations in lexical availability on successful sentence production. A group of five nonfluent and four fluent individuals with aphasia were presented with pictured events designed to elicit simple subject-verb-object (SVO) sentences. The lexical availability of the nouns in the SVO sentences was manipulated by drawing nouns from lists of words of high frequency of usage (e.g., *king*) and low frequency of usage (e.g., *fox*). High or low frequency nouns were used in either the subject or object position. The sentence production accuracy and the response time latencies were measured in each condition. Latency times showed all participants were slower to initiate their response when a low frequency noun was in the subject position. The effect of frequency on sentence accuracy, however, differed between nonfluent and fluent participants. For nonfluent participants, sentence accuracy was strongly affected by the frequency of the noun when it was in the subject position. High frequency subject position nouns produced improved overall sentence accuracy including increased object noun accuracy. This variation was not found in the fluent participants or the controls. Here we see a strong support for the hypothesis that highly available lexical content can facilitate structure building for nonfluent individuals. Speer and Wilshire (2014) argue that because nonfluents have a deficit in their structure building system, structure building is heavily reliant on bottom-up activation of structure by content. Faster activation of the subject noun in the high frequency subject condition enables the SVO structure to be activated more quickly. This can facilitate the integration of the lexical items in the correct sequence. In terms of an interactive model of sentence production, structure generation is strongly driven by a bottom-up flow of activation from lexical items to structure. Speer and Wilshire refer to this bottom-up activation of language production as the Content Drives - Structure (COST) hypothesis. For nonfluents, the accessibility of the noun not only affects the retrieval time, it also can activate the structure building process.

In a second experiment, Speer and Wilshire (2014) manipulated the semantic relatedness of the subject and object nouns. Specifically, they were either human characters (e.g., *nurse* and *witch*) or animal characters (e.g., *snake* and *fox*). In the semantically related condition, the nonfluent aphasics' sentence accuracy consistently decreased, while tending to improve for participants with fluent aphasia. In normal speech, a robust syntactic frame may help to ensure that the lexical items are maintained in the correct sequence. Speer and Wilshire suggest that because nonfluent individuals have weaker or incomplete syntactic structures, words of the same class are likely to compete more strongly for selection to a particular position. Under the hypothesis that semantically related nouns activate one another particularly strongly, this abnormality should be particularly evident when two highly related nouns must be included in the sentence. Because fluent individuals and normals are capable of more robust structure building, this semantic relatedness does not interfere with word selection. In fact, for fluent aphasic individuals, semantic relatedness actually aided production, possibly because the mutual boost in activation facilitated lexical selection or retrieval.

The current study follows in the path of Speer and Wilshire in investigating the effect of lexical context on structure in nonfluent aphasia, in particular the effect of increased lexical availability. However rather than manipulating lexical frequency of the constituent nouns, the current study uses an identity priming paradigm to enhance availability.

**Priming Effects on Sentence Production for Individuals with Nonfluent Aphasia**

In language studies, priming involves presenting a related or identical lexical element just prior to a language trial, and examining its effect on the latter. Participants may be asked to perform a task involving the prime, or just passively view or listen to it. The most powerful and long-lived effects are obtained when the prime and target word are identical – called *identity* or *repetition priming* (de Groot, 1985; La Heij, Puerta-Melguizo, van Oostrum, & Starreveld, 1999; Lukatela, Frost, & Turvey, 1999; McQueen, Cutler, & Norris, 2006). The question remains as to whether the primary effect is operating at the level of the semantic/conceptual representation of the word, the lexical representation of the word, or the sound form of the word, or all three levels. Research suggests that the primary locus of the effect is on lexical retrieval. Identity priming does not have as strong an effect when the subsequent task involves categorisation rather than word production (La Heij et al., 1999), suggesting that the prime's activation of the semantic/conceptual level is less significant. In addition, homophones, similar sounding words, have been found to have a similar effect to identity primes (Ferrand, Humphreys, & Segui, 1998). For the current study, identity priming is used to provide a very simple and direct way of manipulating the lexical availability of the primed elements.

Although this type of paradigm has not been commonly used in aphasia, Faroqi-Shah and Thompson (2003) used a variant of this technique. They presented Broca's and Wernicke's patients with pictures depicting agent-action-patient scenes, and required them to produce either an active or a passive SVO sentence. An arrow was added pointing to either the subject or the object to indicate which element should be placed at the beginning of the sentence. In addition, in the critical "cue" condition all the key substantive words (the verb and the nouns) were written on the picture, either in uninflected form (e.g., *hug*) or fully inflected form (e.g., *was hugged*). Sentence accuracy was measured for each of the three conditions. They found that there was only an improved performance in the condition where the inflected forms were given, and this applied similarly to both the Broca's and Wernicke's groups. This result was contrary to their expectation, which was for an incremental improvement in sentence accuracy as more cues were included. Instead their finding suggests that lexical content can only promote sentence production when almost all the lexical information is provided for aphasic individuals, indicating a weak effect of lexical content in retrieving grammatical structure. There are a number of issues with this study which mean that the results must be interpreted with caution. Firstly, the way in which priming is incorporated into the picture naming task may have introduced variables other than increased activation of lexical items. In addition to interpreting the picture, subjects have to interpret the arrow, and in the lexically cued conditions, read words which are not organised in a normal left to right sequence. Therefore, the prime may not have been maximal, particularly if any of the participants had dyslexia. Secondly, in an attempt to elicit passive as well as active sentences, some very unnatural sentence structures were required. For example, *the door was opened by the nurse*. Finally, in scoring the responses, the authors take the best response made by the participant rather than the first response. This does not represent real-life situations when there may not be a chance to change the response. In the current study, we use auditory primes in a task where no special constraints are placed on the speaker as to element order. We score only the first attempt. In addition, we examine the result both at the group and at the individual level, and include healthy controls for further comparison.

**The Scope of Sentence Planning**

Before discussing our study's design in further detail, one final issue that needs to be considered in any study that involves priming sentence production, is the extent to which a sentence is planned in advance of speech initiation. If sentences are planned incrementally, in a word-by-word fashion, then a prime presented before initiation may have little opportunity to influence planning beyond the first few words of the utterance, especially if the key measure of interest is sentence initiation time. If, however, there is more extensive advanced planning, then a prime may be able to exert a more extensive influence across the entire sentence.

There is considerable debate as to the extent to which a sentence is planned in advance of speech initiation. Some early evidence from speech errors suggested that planning at the level of concept selection and role assignment might occur well in advance. For example, word exchanges like *The cheese ate the mouse* suggest a plan that extends across both the key sentence phrases). However, planning at the phonological level may be more incremental, since phoneme exchanges most commonly involve words from within the same noun phrase (e.g., *nife lite*). This effect was found to be even greater when the verb in the preceding sentence and the elicited sentence were the same (Pickering & Branigan, 1998).

Some more recent research suggests a shorter, more incremental scope of sentence planning, even at earlier, pre-phonological planning stages. For example, Griffin (2001) used pictures of three objects in order to elicit sentences in the form *The A and the B are above the C*. The nouns B and C were manipulated to see if they had any effect on the sentence initiation and the production accuracy of A. Variations in the codability of the objects (the number of different names commonly used for the same object, e.g., *cat* and *puss*) and the frequency of the noun in language use were manipulated. They found that participants gazed longer at the object noun pictorials of low codability and low frequency before producing them. However, the codability and frequency of B and C had no effect on the sentence initiation time or the production of A. The increased gaze time suggests that participants' processing time was affected by codability and frequency. However, this manipulation of later sentence items did not affect sentence onset, suggesting that the sentence was being produced incrementally, rather than retrieving all of the lexical items in advance. Similarly, Speer and Wilshire (2014) used a picture description task to elicit a simple SVO sentence and manipulated the frequency of the noun in the subject and object positions. Healthy speakers showed a significant effect of subject noun frequency – but not object noun frequency - on sentence initiation times. Further evidence for incremental sentence planning has come from studies that have used sentences made up of two noun phrases of varying complexity (e.g., Ferreira, 1991; Martin, Miller, & Vu, 2004; Smith & Wheeldon, 1999). In a study by Ferreira (1991), participants had to produce SVO sentences that contained combinations of simple noun phrases (e.g., *the cake...*) and more complex noun phrases (e.g., *the rich and tasty cake...*). Production onset was significantly quicker when the first phrase was simple, but was not affected by the complexity of the second phrase. Again, this finding supports the view that retrieval of the lexical content elements of a sentence occurs incrementally, rather than entirely in advance of production.

**The Current Study**

The current study uses a picture description task. The pictures are designed to elicit simple subject-verb-object (SVO) sentences (e.g., *The lion is licking the monkey*). A single auditory word is presented 800ms before the onset of each picture stimulus. This auditory word is either identical to the target noun (e.g., *lion* -> *The lion is licking the monkey*) or a neutral unrelated word (e.g., *dentist*). Each picture is presented twice during the experiment, once preceded by an identical prime, and once by a neutral unrelated word. Further, each target noun appears in at least two different pictures; once in the subject position of a sentence and once in the object position (e.g., *The mummy is chasing the lion*). This yields four different priming conditions, which are summarised and illustrated in Figure 1.7.

| **Primed subject noun** | **Primed object noun** |
|---|---|
| Hear: *Lion* | Hear: *Lion* |
| Say: *The* ***lion*** *is licking the monkey* | Say: *The mummy is chasing the* ***lion*** |

| **Neutral subject noun** | **Neutral object noun** |
|---|---|
| Hear: *Dentist* | Hear: *Dentist* |
| Say: *The* ***lion*** *is licking the monkey* | Say: *The mummy is chasing the* ***lion*** |

*Figure 1.7.* Depiction of the four different target noun conditions included in the study.

Our reasoning is that priming a key content word will boost the activation of its corresponding lexical representation, thereby facilitating it subsequent activation and selection during production of the target sentence. Based on the COST hypothesis, we predict that if a content element is made more readily available in this way, individuals with nonfluent aphasia will be more successful in producing a grammatically correct sentence. This is because the lexical element will help to drive effective and efficient syntactic frame construction, a process which we believe to be compromised in these individuals. For nonfluent individuals, sentence production difficulties involve both deficits in frame construction and early decay of sentence elements. As a result, it is likely that the subject prime will have a stronger effect by speeding up the construction of the frame so that later elements can be integrated while they are still sufficiently active.

The Current study involved three components. The first was a sentence naming agreement study (Chapter 2). It identified pictures that elicited reliable SVO sentences across a sample of individuals. This was to ensure that we had a set of non-ambiguous pictures suitable for assessing sentence production accuracy. In the second study, we administered the entire sentence production task to six older controls to allow comparisons with the older healthy population (Chapter 3). In the final study we administered the task to six individuals with aphasia; four with a diagnosis of nonfluent aphasia and two with a diagnosis of fluent aphasia (Chapter 4). The fluent individuals provided a point of comparison for the performance of the nonfluent individuals. If individuals with fluent aphasia retain the ability to generate an appropriate grammatical structure for a sentence – although they may struggle to retrieve key lexical content items – we would predict that the effects of the identity priming manipulation in these individuals would be more localised to the primed words themselves, with little effect on their grammatical structure.

Given that nonfluent individuals’ sentence production is characterised by effortful and fragmented speech, methodological decisions over how to score sentence accuracy can have a large influence on the results. For the sentence description task, only the first response was scored for all parts of the SVO sentence. While some studies have accepted a corrected response, these were excluded in the current study. The main reason for this was that we are interested in actual performance in real time, rather than the persons' potential under the most favourable conditions, where strategies such as self-correct and self-cueing might be used to help support correct production. If the initial response produced the wrong word, then the target result was not achieved.

# Chapter 2: Pilot Picture Naming Agreement Study

The sentence naming agreement of the pictures allowed us to develop a reliable set of pictures to use for our picture description task. To be considered for use in the final study, the pictures had to elicit at least an 80% naming agreement between respondents.

## Method

**Participants**. Participants were 156 first year psychology students (86 females; 70 males) attending Victoria University of Wellington who took part in our study for course credit. Participants' ages ranged from 17 to 45 (M = 19.12, SD = 3.41). All were native English speakers with normal or corrected vision. Two additional participants (1 male; 1 female) were excluded due to the fact that they did not follow the task instructions.

**Materials.** A total of 203 drawings depicting subject-verb-object (SVO) sentences were used. An example of a stimulus picture is shown in Figure 2.1. These drawings depicted 60 different target nouns in at least two different pictures: one in which the noun appeared in subject/agent position and another in which it appeared in the object/patient position (e.g., *lion* appeared in the following two pictured scenes: *The lion is licking the monkey*; and *The mummy is chasing the lion).* The aim of each picture was to have the two nouns unambiguous and make the verb easy to interpret so that the picture would elicit a consistent response. In all of the pictures, both nouns were animate so that the sentence was reversible. It was not a requirement that the pictures depicted an event that could occur naturally. For example, *The queen is lifting the bear* was considered to be a valid SVO sentence for the purpose of this study. Many of the pictures were selected from our own picture library or from other open-access sources, but five were drawn especially for this study. A further 112 pictures were created by combining existing pictures of the individual subject and object elements to create a new scene, using picture editing software. These pictures were randomly allocated to one of seven different versions, each with 29 pictures.

*Figure 2.1.* Example of a picture used in the naming agreement study. The target sentence for this picture is *The lion is licking the monkey*.

**Procedure.** Participants were tested in groups, with up to 15 students in a testing room at one time. They were spread out to ensure that they could not see what others were writing, and the different versions were interspersed between participants. They were each given one of the seven booklets containing 29 SVO pictures, and were instructed to write a sentence that they thought accurately described the picture in the space provided below the picture. The first page of the booklet contained some information about the study and instructions for completing the task. Prior to commencing the task, the instructions were reiterated verbally and the participants were directed to write down the first thing that came to mind, and to try not to modify their answers. They were also given an example of a picture with an appropriate response as an additional guide.

**Scoring procedure.** Pictures were required to elicit the correct target sentence for at least 80% of the participants to be considered appropriate for the experiment. For a response to be scored as correct the two nouns had to match their targets exactly; no alternative names were allowed, such as *cop* for *policeman*. However, for the target verb, some variation was allowed: participants could use an alternative verb which was related in meaning to the target and contextually appropriate as long as it did not alter the grammatical properties of the sentence (e.g., *hitting* instead of *punching*). The addition of a verb particle (e.g., *pushing over* instead of *pushing*) or an appropriate preposition (e.g., *chasing after* instead of *chasing*), was also allowed, again as long as it was contextually and grammatically appropriate. Finally, there was no penalty for addition of extra material, such as adjectives and adverbial phrases, as long as it was contextually appropriate and did not alter the grammatical properties of the remaining sentence (e.g., *The lion is licking the monkey on the ear* instead of *The lion is licking the monkey*).

## Results

A total of 116 pictures (57%) met the 80% naming agreement criterion, These were combined with a further 12 pictures of the same form as those piloted, that had already reached naming agreement under identical conditions in a previous pilot study (Speer, 2014; Speer & Wilshire, 2014), giving us a pool of 128 pictures in total from which to select the sentence stimuli for the picture description task.

# Chapter 3: Sentence Production Task in Healthy Older Controls

## Method

**Participants.** Six older control participants (three female, three male) were recruited from a Victoria University of Wellington register of individuals who have participated in previous studies carried out by the School of Psychology. Participants were aged between 66 and 89 (M = 72.5, SD = 9.27) and had no history of any neurological disorders (as indicated on a medical history questionnaire). Participants were given a $20 shopping voucher for each session when they came to the University or a $10 voucher if they were visited in their own home.

**Materials.** The stimulus scenes used in this experiment were selected from the pool of 128 pictures that reached our naming agreement criteria, as described in the pilot naming agreement study. A total of 48 different scenes were selected for the final set, each of which contained a single target noun. Each target noun appeared in two pictures – once as the agent/subject of the sentence and once as the patient/object. All target nouns met the following criteria: they had an age of acquisition of less than nine years (Kuperman, Stadthagen-Gonzalez, & Brysbaert, 2012); they contained either one or two syllables; and they had a frequency of less than 130 tokens per million in the movie subtitles database from the English lexicon project (Brysbaert & New, 2009). Sometimes, a key target noun also appeared as a "filler" (a non-target noun) in one other picture (this was the case for 11 of the target nouns), and occasionally it appeared in two other pictures (this occurred in three instances: *bear, cat and ghost*). In order to minimise any repetition priming effects across separate trials, these repeated instances were spaced widely throughout a session, and wherever possible, the neutral condition always appeared before a primed counterpart and the actual target before the filler. See appendix A for a full list of the pictured sentences used.

In addition to the stimulus scenes, a further set of 40 single pictures was compiled, depicting each of the nouns appearing in the scene, including the 24 target nouns and also the remaining 16 non-target nouns. These pictures were selected from existing picture pools from our laboratory and from other open sources, and all had demonstrated high name agreement (at least 80%) in previous norming studies.

Finally, 48 words were digitally recorded to serve as auditory primes during the experiment. These included the 24 target nouns appearing in the stimulus scenes, plus an additional 24 nouns to serve as neutral words. Each neutral word was paired to a target noun, and was matched as closely as possible to it in frequency (±10 tokens per million in the movie subtitles database) and age of acquisition (±1 years) and had the same number of syllables. The nouns had to be picturable and animate. The only exception were the target nouns *fish* which was matched to *seat,* and *cat* which was matched to *truck* as there were no appropriate animate matches available. This resulted in four conditions for each target noun: Primed Subject; Neutral Subject; Primed Object; and Neutral Object. See Appendix B for a full list of the primes and their matched neutral words. The target and neutral unrelated nouns were recorded by a native speaker of New Zealand English, using the software package Audacity (2013). The experimenter used an external microphone plugged in to the computer to record each noun.

The task was programmed using PsyScope X B46 software (Cohen et al., 1993).

**Procedure.** Four of the participants were tested individually at Victoria University of Wellington, and two were visited in their homes in quiet conditions. Those tested at the university completed the task in a small room with an Apple iMac computer. For the individuals tested at home, sessions were run on an Apple MacBook Pro. In both settings, speakers were attached and set to a volume that was as loud as possible without being aversive. All sessions were recorded on a voice recorder for later analysis.

To test whether participants were able to retrieve all of the noun elements in isolation, participants took part in an initial pre-test session in which they were required to name all of the individual nouns involved in the study. Each participant was tested over five separate sessions separated by at least a week. The initial pre-test session lasted from five to ten minutes. The four sessions of the experiment proper lasted approximately fifteen minutes.

During the pre-test, participants were instructed that they would see pictures of single objects on the screen which they were required to name as quickly and accurately as possible. Each trial began with a fixation cross on the screen which remained for 500ms, followed by the picture, simultaneously accompanied by a tone. The picture remained until the participant began their response. The experimenter then removed the picture and a blank screen remained until the next trial. There were 42 single-item pictures in total, depicting each of the 40 nouns appearing in the stimulus scenes, as well as two practice pictures.

For the main experiment, each picture scene was presented twice to the participant: once preceded by an identical prime (the target noun itself in auditory form) and once by an neutral word (the target noun’s unrelated match). Thus, there were 96 experimental trials in total. These trials were then assigned to four different testing sessions, with the target noun appearing only once in each session (i.e., primed subject, neutral subject, primed object, neutral object). The conditions were balanced across the sessions to ensure that the number of exemplars of each condition was the same for each session. The order of presentation was pseudo-randomised, ensuring that any repetitions of nouns were separated by a minimum of five trials.

During the sentence description task, each session started with written instructions displayed on the screen explaining that participants would see pictured events, which they were asked to describe aloud in one sentence. These instructions were also paraphrased verbally by the experimenter. An example picture and appropriate response was also given, with a verbal commentary from the experimenter. Each trial began with a fixation cross on the screen which remained for 500ms, followed by a blank screen for 500ms, followed by the audio prime. The pictured event was presented 800ms after the start of the prime, accompanied simultaneously by a soft tone (see Figure 3.1 below). As soon as the participant began their response, the experimenter pressed a key to replace the picture with a blank screen. This blank screen remained until the participant had completed their response, and was ready for the next trial. Participants were provided with four practice trials before they began the main task, which consisted of 24 trials. Each participant completed the same four sets of the picture description task, keeping item order constant. However, the order in which these sessions were completed was counterbalanced.

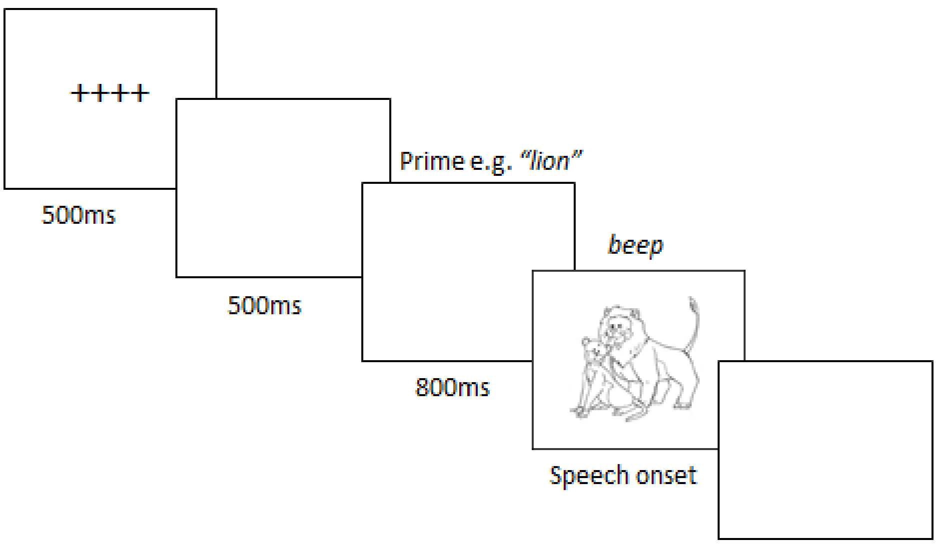



*Figure 3.1.* The procedure for the sentence description task.

**Response scoring.**

***Naming pre-test.*** Participants' responses to the target picture were scored as correct if they provided the target noun. Participants were allowed to say an incorrect response prior to naming the correct noun. However, these responses were not used in latency analyses. Any dysfluencies (e.g., *f-f-fish*) or phonological errors were scored as correct. Naming latencies were calculated manually using the voice recordings. The latency was the interval between the tone which accompanied each picture, and the onset of the participant's response.

***Sentence production task.*** Participants' responses were scored as correct if they correctly produced both nouns and the verb (or an appropriate alternative as in the picture agreement study) in a grammatically correct SVO sentence. Responses were required to include articles for both nouns and an inflection of the verb. If the response excluded the auxiliary verb but was otherwise correct (e.g., *The fish kissing the turtle*), this was scored as correct as this can often occur in normal speech conversation. This was the only truncated response allowed. Additional words that did not alter the grammatical structure of the sentence were allowed (e.g., *The fish is kissing the turtle on the cheek*). Passive sentences (e.g., *The turtle is being kissed by the fish*) were accepted as a correct response but were not included in the latency analysis. Only the first attempt was scored. If the participant self-corrected an item mid-sentence (e.g., *The deer, no goat, kissed the bear*), the correct portion was simply ignored and the remainder of the sentence scored as if it had never been present. Fragments that were aborted before the third phoneme, and corrected, were not penalised (e.g., "*deer no goat"* for *goat* was scored incorrect, whereas "*de..goat"* was scored as correct). The individual elements of the sentence were also scored as correct or incorrect. Misarticulations, which were defined as responses that differed from the target word only by one phoneme and only one distinctive feature, were not counted as phonological errors (e.g., *shooking* was allowed for *shooting*, and *hudding* for *hugging*). Any errors beyond those were considered incorrect.

Three production latencies were obtained for each correct response: the utterance onset latency, the subject noun onset latency and the subject-object noun latency (depicted in Table 3.1). The first two latency measures were calculated by measuring the interval between the tone which accompanied the picture, and the initiation of the particular sentence element being tested. The subject-object noun latency was calculated from the onset of the subject noun to the onset of the object noun.

Table 3.1

*A Description of the Three Response Time Latencies Measured in the Study*

| **Latency measure** | **Description** |
|---|---|
| *Utterance Onset*<br><br>'The lion is licking the monkey' | The time from the tone which accompanied the picture to the initiation of speech<br><br>Any responses that begin with a verbal filler (e.g., "*Um..um..the cow is pushing the clown*"), the filler is ignored. |
| *Subject Noun Onset*<br><br>'The lion is licking the monkey' | The time from the tone which accompanied the picture to the initiation of the subject-noun<br><br>Any responses which contained dysfluencies (e.g., "*the c c cow*"), the onset was taken as the first fragmented attempt. |
| *Subject - Object Noun Latency*<br><br>'The lion is licking the monkey' | The time from the onset of the subject noun to the onset of the object noun |

**Statistical analyses.** Each individual trial performed by each participant was submitted to analysis, rather than collapsing across all trials of the same kind. For the analysis of the participants' accuracy data (correct/incorrect responses), simultaneous logistic regression was used (Liang & Zeger, 1986). We used the Proc Genmod procedure in SAS 9.3 (SAS Institute Inc., 2011, Cary, NC). In this procedure, the regression model is built using Generalised Estimating Equations (GEEs). This enables the researcher to model the effect of a repeated measure – such as the target noun (which appeared in more than one trial in this study). The values reported in the text are the Chi-Square-Score statistics associated with each predictor variable based on empirical standard error estimates.

Latency data were analysed by submitting the data for each item and each individual to a General Linear Mixed Model analysis (or Mixed Effects model, or Linear Mixed-Effects; Diggle, 1988) using the SAS Proc Mixed procedure. The model incorporated two random effects: target noun identity and participant identity (see Baayen, Davidson, & Bates, 2008, for a fuller explanation of the application of this technique to psycholinguistic data).

Before the latency data were analysed, outliers were removed - defined as any latency more than 2.5 standard deviations above the winsorised mean for that particular participant. Also removed were any latency measures that were not available for both conditions for that participant (i.e., the individual had incorrectly responded in one of the priming conditions). This was done to ensure that responses from the primed and neutral conditions contributed equally to the latency comparison. So for example, if the participant had correctly responded to the item *The lion is licking the monkey* when preceded by the prime word *lion*, but not when that same picture was preceded by its unrelated word counterpart *dentist*, then neither trial was included in the latency analysis.

## Results

**Naming pre-test.** Naming accuracy was very high: the mean percentage correct was 98%, ranging from 95% to100% across individuals. All errors involved three items: *seal* (named incorrectly by two of the six individuals), *dolphin* and *goat* (each named incorrectly by one individual). The remaining 37 items were named correctly by all of the individuals. Prior to analysing the latency data, seven outliers were removed using the same criteria as for the main study (above). The mean naming latency for this older control group was 874ms (SD = 182ms; range 829-957ms). Examining across items, the target items *whale, dolphin and turtle* had the longest average latencies (1259ms, 1177ms and 1167ms respectively).

**Sentence production task.**

***Sentence production accuracy.*** As shown in Table 3.2, priming had no effect on sentence production accuracy for any of the individuals or the group as a whole, $\chi^2$ (3) = 0.10, p =.99.

Two of the target nouns yielded an average accuracy of less than 60%. These were *whale* (25%) and *crab* (55%). Therefore in all subsequent analyses, including those for aphasic participants, all items containing these target nouns were excluded from the analysis. However, even with these two items excluded, the overall average accuracy for this group was lower than expected in all the conditions. Excluding the two removed items, the overall accuracy ranged from 74% to 93% across individuals, and from 67% to 100% across target nouns (see Appendix C for the average accuracy results for each target noun). The most common types of errors occurring across all the items were: an incorrect subject noun, accounting for 27% of the errors (e.g., *bull* instead of *cow*, *tortoise* instead of *turtle*); a missing subject noun article, again accounting for 23% of the errors; an incorrect object noun, accounting for 21% of the errors; and an incorrect verb, accounting for 14% of the errors (e.g., *tickling* instead of *pushing*).

Table 3.2

*Percentage of Sentences Correct for each Priming Condition for each Individual and as a Group Average. Bracketed Figures show Standard Deviations*

| Participant | Percent Correct | | | | |
|---|---|---|---|---|---|
| | Subject | | Object | | Overall Average |
| | Primed | Neutral | Primed | Neutral | |
| **AH** | 64 *(49)* | 77 *(43)* | 73 *(46)* | 82 *(39)* | 74 *(44)* |
| **EG** | 82 *(39)* | 64 *(49)* | 77 *(43)* | 86 *(35)* | 77 *(42)* |
| **GA** | 82 *(39)* | 91 *(29)* | 86 *(35)* | 95 *(21)* | 89 *(32)* |
| **JAG** | 95*(21)* | 91 *(29)* | 95 *(21)* | 73 *(46)* | 89 *(32)* |
| **JM** | 86 *(35)* | 100 *(0)* | 91 *(29)* | 95 *(21)* | 93 *(25)* |
| **RS** | 100 *(0)* | 82 *(39)* | 77 *(43)* | 73 *(46)* | 83 *(38)* |
| **Group Average** | 85 *(36)* | 84 *(37)* | 83 *(37)* | 84 *(37)* | 84 *(37)* |

***Latency.*** Latency data were only analysed for responses which were correct and which were in an active sentence structure. A total of 413 trials met this condition (78% of the total possible data points). Outliers were removed according to the procedure set out under Scoring above, resulting in the removal of 14 more data points. Finally, a further 97 trials were removed because their prime/neutral counterpart was failed, leaving us with a final data set of 302 trials (57% of the total possible data points). Even after outlier removal, the latency data were highly positively skewed, with a skewness value greater than two. Therefore, all latency data were log-transformed prior to analysis (see Biegler, Crowther, & Martin, 2008, for a full justification of this procedure).

As shown in Figure 3.2, there was a trend towards shorter overall latencies in the subject prime condition relative to its corresponding neutral condition, but little evidence of a similar pattern for the object primed condition. The data was submitted to a repeated General Linear Mixed Model Statistical analysis. The predictor variable was the priming condition. Analyses revealed that there was a significant effect of priming condition on the utterance onset latencies, $F(3, 292) = 11.02$, $p < .001$. Contrast analyses revealed a significant difference between the subject primed condition and its corresponding neutral condition, $F(1, 286) = 31.73$, $p < .001$, but not between the object primed condition and its neutral condition ($p = .29$). A very similar pattern was observed for the Subject Noun Onset latency measure, where a significant overall effect of condition was again observed, $F(3, 292) = 15.56$, $p < .001$, and contrasts revealed a significant difference between the subject primed condition and the corresponding neutral condition only, $F(1, 285) = 44.73$, $p < .001$.

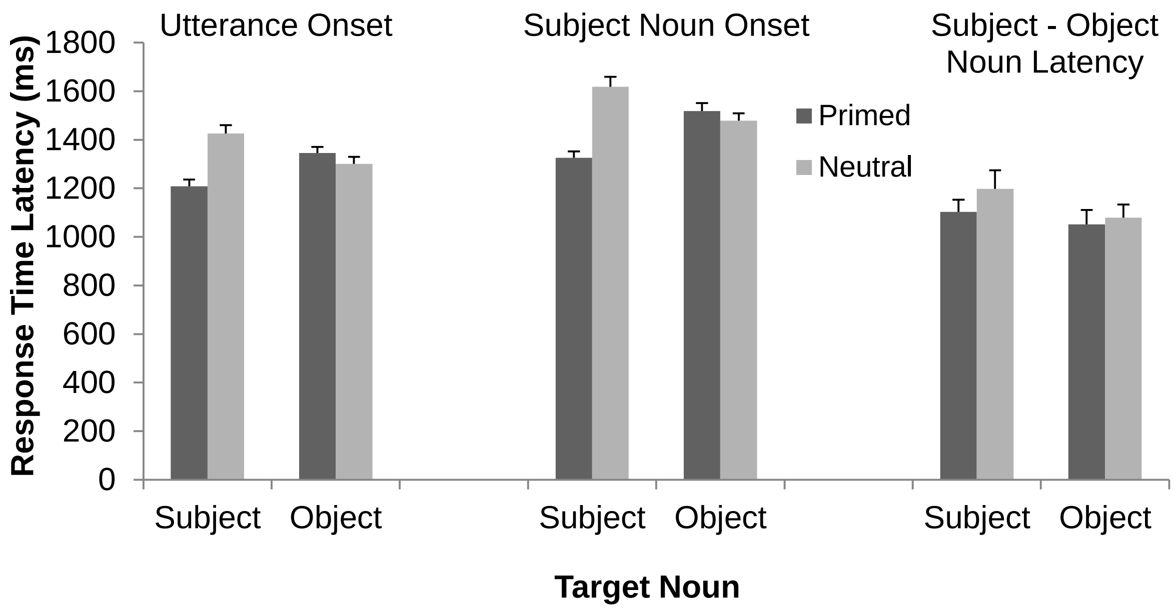



*Figure 3.2.* Geometric means of the response times for each latency measure during both priming conditions. Error bars represent the standard error of the means.

For the Subject - Object Noun latency measure (the delay between the onset of the subject noun and that of the object noun), again a surprisingly similar pattern was observed: a trend towards lower latencies for the subject prime condition, relative to its neutral condition, but no commensurate advantage for the object prime condition. Statistical analyses revealed there was a significant effect of priming condition, F (3, 298) = 4.01, p < .01. Contrasts revealed that only the subject prime condition was significantly different from its neutral condition, F (1, 290) = 5.23, < .05; there was no significant difference between the object prime condition and its neutral condition (p = .50).

**Discussion**

The latency results showed that for controls, the provision of subject primes significantly reduced the time it took for individuals to initiate the sentence relative to a neutral, unrelated prime condition. It had a similar facilitatory effect on the subject noun onset. Object primes had no significant effect on either of these latency measures. The finding that only the subject prime influenced sentence initiation and noun onset is consistent with the findings of Speer and Wilshire (2014), who used lexical frequency to manipulate the availability of the subject and object nouns. It is also consistent with more general evidence of incremental sentence planning as discussed above. Speakers do not need to complete lexical selection for all of the lexical elements prior to commencing the sentence. If they had to wait till all lexical items were selected, then you would expect to see a benefit from having later items made available. That is not to say that all sentence planning is incremental, but rather that it appears to be under the experimental conditions used in the study.

Two other latency results with the older controls were not expected. Firstly, the subject prime also decreased the subject - object noun production latencies. We can conjecture that the facilitatory effect of the subject prime on subject lexical retrieval time may have freed up more time for advance processing of the object noun, enabling it to be produced sooner. Another possible explanation is that the facilitatory effect of the subject prime enhanced the overall rate of speech in the controls; operating, for example, like some sort of 'Go!' signal. No data was collected to examine the overall pace of word production within sentences as the word offset times were not recorded. However, it might be possible in future studies to explore this. Secondly, and perhaps even more surprisingly, we found that the object noun prime not only had no effect on sentence onset, but also it had no effect on the onset of the object noun itself. This is contrary to a study by Speer and Wilshire (2014), who found that subject noun frequency affected sentence and subject noun onset, but had no effect on object noun latency, and object noun frequency affected only the onset of the object noun.

When interpreting the findings from this experiment, it is important to consider the nature of our baseline, the neutral condition. The neutral unrelated prime was intended to represent the absence of a direct prime. However, it is possible that it created a distracting effect, making it more difficult to initiate the sentence. It is possible that in the current study, controls treated the object prime in a similar way to the neutral prime, as a distracter that needed to be ignored in the production of the subject noun phrase/initiating the sentence. As a result of being consciously set aside, the object prime did not increase the availability of the object noun when it came to be produced in the sentence. Because the subject prime supported rather than conflicted with the generation of the subject noun phrase, the full effect of its increased availability was apparent in onset times.

It is also possible that the object prime acted as a distractor during the process of selection of the subject noun. If the neutral prime and the object prime were both distractors, we might expect an even slower response time for the object noun because it would receive a further boost to its activation from the picture item itself and generate syntagmatic competition – making it more difficult to produce the subject noun phrase first. However, no difference in response time was found between the neutral and object primes. An alternative explanation is that the object noun prime may have led to earlier and/or more effortless processing of the object noun, but that this did not result in the earlier onset. This would occur if the processing of the noun phrase was occurring while the earlier part of the sentence was being uttered. In this situation, the noun phrase building could complete before it was possible to produce it.

The accuracy scores, with an average of 85% accuracy, were lower than expected. Close to 100% agreement would have enabled us to characterise any level of performance below 100% as “impaired”. Failure to achieve this was the result of applying very strict accuracy criteria which meant that a plausible but non identical noun was not accepted. Future studies would do well to avoid nouns that have a number of possible names in common use (e.g., *cow*/*bull*, *turtle*/*tortoise*) as these accounted for a significant proportion of the accuracy errors. Nevertheless it is hard to achieve near ceiling levels of agreement using criteria as stringent as ours. In addition, there was no effect of primes on accuracy, so any marked effects of the priming manipulation on accuracy can be reasonably interpreted as abnormal.

# Chapter 4: Investigation of Sentence Production in Individuals with Aphasia

The aim of this study was to explore how identity priming of the subject or object noun affects sentence production accuracy in individuals with nonfluent aphasia. A case description of each of the individuals with aphasia is presented first, followed by the general method for the picture description task.

## Participants

Six individuals with chronic aphasia as the result of a stroke, were recruited from a Victoria University register of past research participants. Four of the participants had been classified as having nonfluent aphasia, all of whom had been diagnosed with Broca's aphasia; two participants had been classified as having fluent aphasia, one with a diagnosis of Wernicke's aphasia, the other with Conduction aphasia. All participants were examined at least 12 months post-onset, and all had mild to moderate aphasia as defined by the Boston Diagnostic Aphasia Examination (BDAE) severity scale (Goodglass, Kaplan, & Barresi, 2001). A requirement for participation was that the participant was able to score at least 50% on the Boston Naming Test from the BDAE (since relatively accurate single noun production was a requirement for the study). Participants were also required to be native English speakers and have normal to corrected vision. We reimbursed participant JHM's travel costs to and from the University. The other five individuals were seen in their homes so they did not receive reimbursement.

Background, medical, diagnostic and lesion information for each participant is presented in Table 4.1. This data comes from prior research carried out at Victoria University involving these individuals; the data presented all come from assessments conducted within the last three years. Each participant had undergone a MRI scan of their lesioned area of the brain within the past 12 months (see also Speer, 2014 for a detailed lesion analysis of these individuals). A spontaneous speech sample of each of the six individuals with aphasia during the Cookie Theft Task (Goodglass et al., 2001) is presented in Table 4.2. Finally, Table 4.3 presents participants' results from a series of language assessment tests conducted prior to this study (again, see Speer, 2014 for more detail). Table 4.4 provides a brief description of each of the test measures. Below we summarise each participant's language profile in further detail.

Table 4.1

*Background, Medical and Diagnostic Information for each Participant with Aphasia*

| Participant | Age | Gender | Years post CVA | Lesion Site/aetiology | BDAE Measures | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Diagnosis | Articulatory agility | Fluency percentile | Fluency classification |
| BY | 59 | male | 37/8 | Subarachnoid haemorrhage, subsequently operated upon, large lesion extending from anterior horn of L lateral ventricle to L parietal lobe | Broca's | 50 | 60 | nonfluent |
| DA | 71 | male | 11 | Medical notes not available | Broca's | 40 | 12 | nonfluent |
| JG | 73 | female | 6 | Isch. CVA, L MCA region | Broca's | 40 | 23 | nonfluent |
| JHM | 52 | female | 10 | Isch. CVA, extensive L MCA | Broca's | 10 | 15 | nonfluent |
| SW | 82 | female | 4 | Haem. CVA, L posterior temporal lobe | Wernicke's | 50 | 88 | fluent |
| WL | 64 | Male | 2 | Isch. CVA, L parietal and L posterior temporal lobe | Conduction | 70 | 100 | fluent |

*Note.* Isch. = ischaemic; Haem. = haemorrhagic; CVA = cerebrovascular accident; MCA = middle cerebral artery; L = left; R = right.

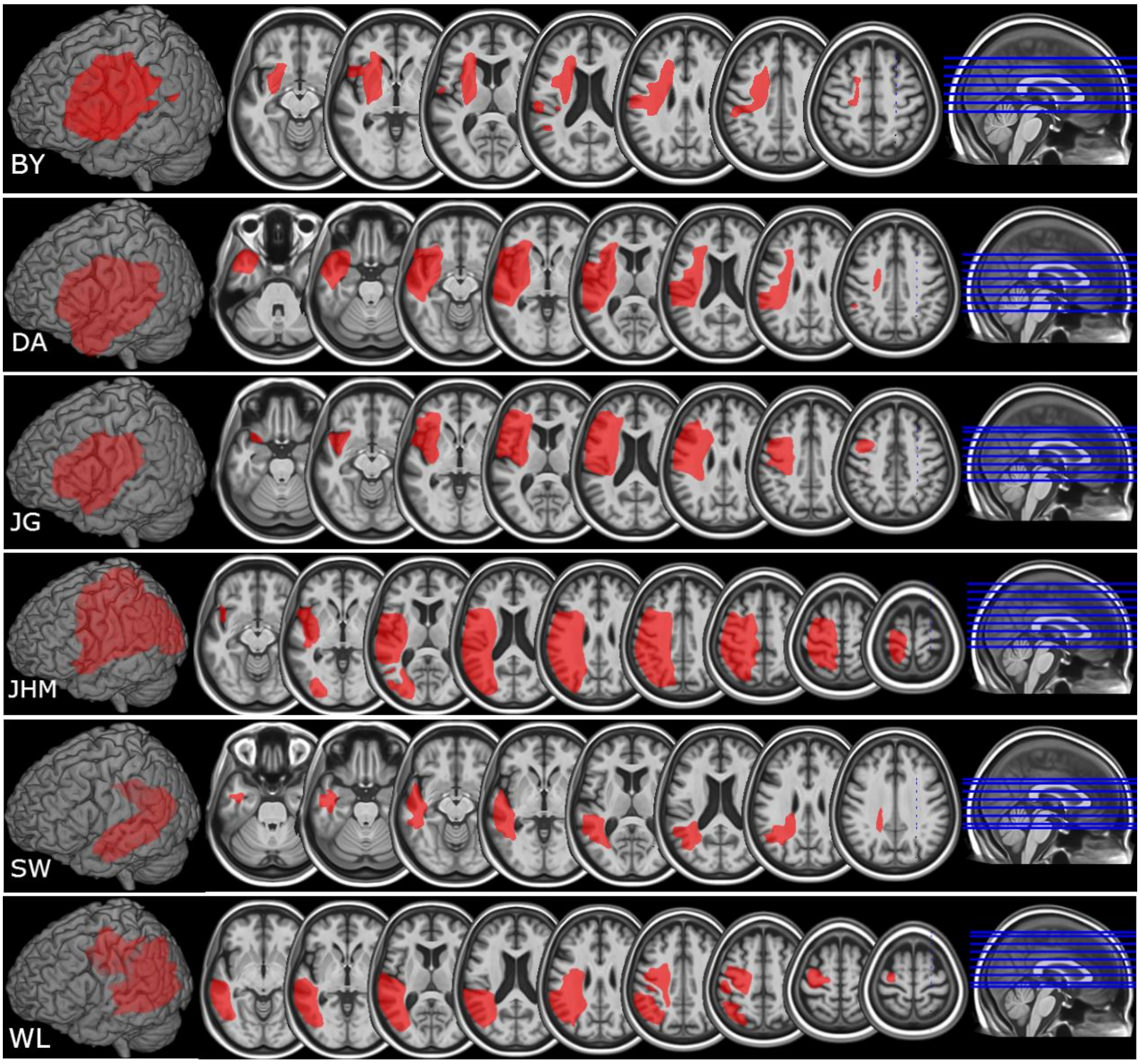



*Figure 4.1.* Lesion maps for four participants with nonfluent aphasia and two with fluent aphasia showing their lesion on a standard template (Colin27; Holmes et al., 1998) and axial slices of the brain on a standard template (Rorden, Bonilha, Fridriksson, Bender, & Karnath, 2012). Slices were selected according to representative display of individual lesions. Lesion maps are courtesy of Paula Speer's Doctoral thesis (Speer, 2014).

Table 4.2

*Spontaneous Speech Sample of the Participants with Aphasia Describing the Cookie Theft Scene in the BDAE (Goodglass et al., 2001). (Dots = pauses over one second; commas = pauses less than one second).*

| | |
|---|---|
| **Nonfluent** | |
| BY | Um… oh god, I dunno… it's it's waiting for it to come… uh… and that … (sigh)… god, I can't say it it's overflowing… *[long pause]* and she's washing dishes and... with her back to the… child getting the.. cookies… [truncated] |
| DA | Um…\| the the the the /tʌd/ the tub was on yeah… um yeah… oh… behind /bihænd/ behind… her children… um… um… *[long pause]* were reaching… *[long pause]* reach reaching… into a cookie jar… in the… in the…um… the cubboard [truncated] |
| JG | Um, a child… and, cookie- jars… um… washing /wɪt/ um the tap… /wɒʃssss/… I dunno yeah (laughs)… /n-/ spilling /ɪ- ʌnn/… /lɪ/ floor… um… garden [truncated] |
| JHM | OK… the the woman ah ah ah dreaming ah dreaming uh uh ah um… she uh dry a plate um…um... the water… overflow uh…. to the floor um…*[long pause]* um the- the boy… stealing a cookie… and um… uh the boy is… giving a…girl /g-/ giving a cookie a /g-, gɔ: / [truncated] |
| **Fluent** | |
| SW | An /æprɒn… æpərən/… and he's got a little uh… car, jar… I mean cookie… I think she's going to eat something or drink something… he going fly up… you see… I can't see the word! You got it… why is it like that… him going on the… skull... Why is that? … [truncated] |
| WL | Ah, the man /ɒ/ or the the boy the boy is um… trying to get, uh the cookie jar, uh to give uh the girl a cookie and the the the the boy /f/-fell down the the uh the uh um The uh… the stool and uh the wife the mother the mother- was washing the dishes and uh /tu:/ /w/ ah overflowed the sink [truncated] |

Table 4.3

*Performance of Participants with Aphasia on Language and Related Cognitive Tests*

| **Language Tests** | **Nonfluent Aphasia** | | | | **Fluent Aphasia** | | **Control** |
|---|---|---|---|---|---|---|---|
| | BY | DA | JG | JHM | SW | WL | 2 SD cut-off |
| **Connected Speech: QPA measures** | | | | | | | |
| Words per minute | 67 | 19 | 69 | 48 | 96 | 126 | *86.82a* |
| Proportion closed-class items | 0.64 | 0.40 | 0.47 | 0.37 | 0.54 | 0.66 | *0.46a* |
| **Word production** | | | | | | | |
| Boston Naming Test (N=60) | 41 | 53 | 46 | 46 | 37 | 40 | *48.1b* |
| Druks and Masterston | | | | | | | |
| Object and Action naming | | | | | | | |
| Nouns (N=50) | 45 | 50 | 43 | 48 | 42 | 46 | *45.16c* |
| Verbs (N=50) | 43 | 45 | 38 | 46 | 30 | 43 | *43.20c* |
| **Comprehension** | | | | | | | |
| PCB Sentence Comprehension subtest | | | | | | | |
| Lexical distracters (N=30) | 30 | 29 | 30 | 29 | 27 | 30 | *29.1d* |
| Reverse role distracters (N=30) | 29 | 21 | 25 | 26 | 12 | 18 | *25.8d* |
| Peabody Picture Vocabulary Test (Form IIIB) Standard | 90 | 99 | 90 | 91 | <40 | 102 | *70* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Score | | | | | | | |
| **Auditory Language Processing** | | | | | | | |
| PALPA same-different discrimination using word pairs (N=72) | 70 | **54** | 71 | 71 | **49** | *70* | *61.97e* |
| PALPA auditory lexical decision task | | | | | | | |
| Words (N=80) | 77 | **64** | 78 | 78 | **69** | 40/40 | 75.9 |
| Nonwords (N=80) | 76 | **45** | 73 | 69 | **42** | 39/40 | 65.3 |
| PALPA auditory word repetition task | | | | | | | |
| High Imageability (N=40) | 39 | **32** | 38 | 40 | **14** | 39 | 33.5 |
| Low Imageability (N=40) | 38 | **26** | 29 | 35 | **5** | 38 | 36.5 |
| PALPA auditory nonword repetition task (N=30) | 24 | 8 | 23 | 25 | 0 | 16 | na |
| **Short-term memory** | | | | | | | |
| PALPA Auditory digit span | 4 | 4 | 6 | 3 | 2 | 3 | na |

*Note.* na=not available
Scores in bold font indicate performance below the normal range.
PCB: Philadelphia Comprehension Battery (Saffran, Schwartz, Linebarger, Martin, & Bochetto, 1988)
QPA: Quantitative Production Analysis (Saffran et al.,1989)
PALPA: Psycholinguistic Assessment of Language Processing in Aphasia (Kay, Lesser, & Coltheart, 1992)
a Control data from Rochon et al., 2000
b Control data for New Zealanders from Barker-Collo (2001)
c Control data are based on Druks and Masterston (2000), who report normative data for a more extensive version (N=100)
d Control data from Breedin and Saffran (1999)
e Control data from Kay et al., (1992)

Table 4.4

*A brief description of the Language and Related Cognitive Tests*

| Test | Procedure | Purpose |
|---|---|---|
| **Single word production:** | | |
| The Boston Naming Test (BNT; Goodglass et al., 2001) | Participants name pictured objects | Assesses participants' ability to name a target noun in isolation. Picture naming ability is clearly a pre-requisite for our study. |
| Druks and Masterston (2000) Object and Action Naming Battery | Participants name pictured actions and objects | Assesses the ability to generate action words in isolation, and also directly compares action and object naming ability. |
| **Connected speech production:** | | |
| Quantitative Production Analysis (QPA; Saffran et al., 1989). | Participants re-tell a well-known story, such as the story of Cinderella | Used to provide an indication of their natural speech rate in words per minute; and the ratio of closed-class words (e.g., *the, at, of*) to open-class words (e.g., *girl, ball, ran*), as a measure of agrammatism |
| **Single word comprehension:** | | |
| The Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1997) | Participants must select the most appropriate picture for an auditory word, from an array of four semantically related pictures. | This provides an assessment of participants' ability to access detailed semantic information about an auditory word. |

| | | |
|---|---|---|
| **Auditory—phonological analysis and auditory word recognition:** | | |
| PALPA Test 2: Same-different discrimination of words (Kay, Lesser, & Coltheart, 1992) | Participants are presented with auditory word pairs, that are either identical (e.g., tip - tip), or minimally different by either voice (e.g., bed - bet), manner (e.g., tack - sack), or place (e.g., might - night). Participants must identify which are which | Assesses auditory-phonological analysis skills |
| PALPA Test 5: Auditory lexical decision | Distinguish between real and nonsense words | Assesses auditory-phonological analysis and auditory word recognition skills. Auditory comprehension ability is necessary for the verbally presented prime in the current study to be an effective manipulation. |
| PALPA Tests 8 and 9: Word and nonword repetition | Participants repeat a series of single auditory words and nonwords | Assesses auditory-phonological analysis and maintenance. |
| **Sentence comprehension:** | | |
| Philadelphia Comprehension Battery (PCB; Saffran et al., 1988) | Participants hear a sentence and must select which of two scenes best depicts that sentence (e.g., *The dog chases the boy*). On some trials, the distractor scene contains an inappropriate lexical element (e.g., *The dog chases the rabbit* instead of *The dog chases* | A comparison between performance on these the two sentence types can provide an indication of participants' grammatical comprehension. |

| | | |
|---|---|---|
| | *the boy*), and on others, it depicts the correct lexical items in reversed roles (e.g., *The boy chases the dog* instead of *The dog chases the boy*). | |
| **Auditory-verbal short-term memory** | | |
| PALPA 13 auditory digit span | Participants are required to repeat back a sequence of digits. | Assesses verbal short-term memory |

### Case Descriptions: Individuals with nonfluent aphasia.

***BY.*** BY is a 59 year-old male who suffered a subarachnoid haemorrhage following a motorbike accident 37 years ago. He suffered a further cerebrovascular accident (CVA) eight years prior to the current study. As shown in Figure 4.1, BY has a large lesion which extends from the anterior horn of the left lateral ventricle to left parietal lobe. BY was classified as having mild Broca's aphasia according to the BDAE. A sample of his spontaneous speech is shown in Table 4.3. Generally, BY's speech was informative and grammatical, but there were some delays both within and between utterances. On the QPA, BY's speech rate was at the higher end of the distribution of scores for individuals with Broca's aphasia according to Rochon et al (2000). The proportion of closed class words in his speech was actually above the range for Rochon and colleagues' Broca's cases.

On the Boston Naming Test, BY was found to be mildly impaired and on the Action Naming Test Battery (Druks & Masterton, 2000), he showed little evidence for a disproportionate impairment in verb production. BY's auditory recognition was also well preserved; as was his auditory sentence comprehension. Finally, his working memory digit span was slightly impaired with a score of four.

***DA.*** DA is a 71 year-old man who suffered a CVA 11 years prior to this study. According to the BDAE, he was classified as having moderate Broca's aphasia. DA's lesion incorporates a large portion of the left inferior frontal gyrus, and a significant portion of the left superior temporal and inferior parietal lobes (see Figure 4.1). As shown in Table 4.3, DA's speech was effortful and fragmented separated by long pauses and with difficulties in articulation. His speech contained mostly content words, but some function words were also present. DA's rate of speech is at the lower end of scores for individuals with Broca's aphasia as reported by Rochon et al. (2000). DA's ability to name single items was very accurate for both nouns and verbs.

DA's performance on tests of auditory phonological processing (e.g., minimal pair discrimination) was impaired. His performance in auditory word repetition (e.g., PALPA Test 9), was also markedly impaired; he produced a number of phonemic (e.g., saying *cak* instead of *cat*) and formal paraphasias (e.g., saying *cap* instead of *cat*). His lexical comprehension was slightly below normal in the sentence picture matching task when the distractor item depicted the correct items in a semantically reversed relationship. His auditory working memory was slightly impaired with a digit span of four.

***JG.*** JG is a 73 year-old woman who suffered a CVA six years prior to this study. Her lesion mainly incorporates anterior language regions, including a large portion of the left inferior frontal gyrus (see Figure 4.1). According to the BDAE, JG was diagnosed as having moderate Broca's aphasia. Her speech was effortful and fragmented with difficulties in articulation. JG's utterances are composed of only one or two words with limited function words (see Table 4.3 for an example). JG's speech rate is at the high end of scores for individuals with Broca's aphasia, and her proportion of closed-class items was close to the average.

JG's naming of nouns and verbs in isolation was impaired in the BNT and the Action Naming Test Battery. JG's auditory recognition was well preserved. However, her auditory word repetition was impaired, particularly for nonwords. JG's auditory sentence comprehension showed a slight deficit in syntactic processing, but her semantic processing was unimpaired. Her auditory working memory was relatively unimpaired with a digit span of six.

***JHM.*** JHM is a 52 year-old female who suffered an extensive CVA 10 years ago. Her lesion is extensive anteriorly, it encompasses the posterior portion of the left inferior frontal gyrus, and posteriorly, most of the lateral surface of the left parietal lobe (see Figure 4.1). She was classed as having moderate Broca's aphasia according to the BDAE. JHM's speech was extremely effortful and fragmented, with slight difficulties in articulation. As depicted in Table 4.3, her utterances most often included only one or two words, consisting of mostly content words with only a few function words and correct inflections. Her speech rate and use of function words were around the average for individuals with Broca's aphasia.

JHM's production of single item nouns and verbs was only mildly impaired. Her auditory recognition was well preserved and auditory repetition of words was very accurate. However, her repetition of nonwords was slightly impaired. JHM's auditory sentence comprehension showed a slight deficit in syntactic processing. Her auditory short-term memory showed a marked impairment with a digit span of three.

**Individuals with fluent aphasia.**

***SW.*** SW is an 82 year-old woman who suffered a haemorrhagic CVA four years prior to this study. See Figure 4.1 for a depiction of her lesion. Her lesion is extensive in the left posterior temporal lobe, through the superior gyrus and middle temporal gyrus, and extends into the left inferior parietal lobe.  She was diagnosed as having moderate to severe Wernicke's aphasia according to the BDAE. As visible in Table 4.3, SW's speech is fluent although sometimes includes a lack of content. She produces syntactical errors as well as formal and phonemic paraphasias. SW's speech rate and function word use was within the range of speech for normal individuals. SW's naming was greatly impaired for both nouns and verbs.

SW's auditory recognition was found to be significantly impaired. She was impaired on an auditory lexical decision task, especially for nonwords (PALPA 5; Kay et al, 1992). SW was also impaired on the auditory minimal pair discrimination task (PALPA 2). Her auditory repetition was greatly impaired, correctly repeating zero of the nonwords (PALPA 8) and only 24% of the words (PALPA 9).

SW's auditory sentence comprehension showed a severe deficit in syntactic processing, correctly matching the corresponding picture 40% of the time with a role reversal distractor. Her semantic processing was closer to normal. SW's auditory short-term memory was greatly impaired with a digit-span of two.

***WL.*** WL is a 64 year-old man who suffered a CVA two years prior to this study. His lesion is extensive in the left inferior parietal lobe and covers the primary motor cortex, the premotor cortex, the primary somatosensory cortex and posterior parts of the superior gyrus and middle temporal gyrus (see Figure 4.1). According to the BDAE, he was classified as having conduction aphasia. As shown in Table 4.3, WL's speech was fluent and grammatically correct, with occasional word finding difficulties or phonemic paraphasias. WL's ability to name single items was moderately impaired, with a greater difficulty with verbs. WL exhibited unimpaired auditory language processing (PALPA 2, 5, 8 & 9). His verbal short-term memory was impaired with a digit-span of three.

## Method

**Materials.** The materials used were the same 42 single-item noun pictures for the pre-test and the same 48 SVO pictures as were used in the sentence production task for controls.

**Procedure.** The procedure was identical to the sentence production task for controls with the following two exceptions. First, for fluent participant SW, whose auditory word comprehension and hearing was impaired, the computer audio speakers were turned up to near full volume to enhance her processing of the auditory primes. Also, since she was unable to complete her response after the picture stimulus had been removed from view, the stimulus remained on the screen until her response was completed. Second, nonfluent participant JHM required two or three breaks throughout the session as she tired easily. The procedure lasted approximately twenty minutes for the individuals with aphasia.

**Response scoring.** Response scoring was the same as for the controls.

**Statistical analysis.** The same grouped analyses that were performed on the controls were performed on the nonfluent group as a whole. In addition, analyses were performed at the individual level for each participant with aphasia. These individual analyses only included one random effect: target noun.

## Results

All significance values are reported to an alpha level of .05.

**Naming pre-test.** Table 4.4 presents accuracy and naming latency scores for each individual with aphasia on our single picture naming pre-test. In general, accuracy for these participants was high - a finding which is perhaps not surprising given that good picture naming skills were a requirement for selection into the study. Nonfluent individual JG and fluent individual SW had a lower accuracy than the others. Errors were semantically related to their target (e.g., *badger* instead of *skunk*) or were an alternative, appropriate name for the target item (e.g., *kitty* instead of *cat*). Individuals appeared to have the greatest difficulty with the sea animals, as shown by the items failed the most often: *seal*, *whale*, *shark* and *turtle*. These items had an accuracy rate of 60% with two individuals failing each of them.

Table 4.5

*Mean accuracy and latencies on the pre-test naming task for each individual with aphasia. Bracketed figures indicate the standard deviations. NFA = the nonfluent group average.*

| **Participant** | **Percent Correct** | **Average RT in ms** |
|---|---|---|
| **Nonfluent Aphasia** | | |
| BY | 98 *(16)* | 1476 *(492)* |
| DA | 98 *(16)* | 2120 *(920)* |
| JG | 88 *(33)* | 2429 *(1975)* |
| JHM | 98 *(16)* | 1228 *(287)* |
| NFA | 95 *(22)* | 1799 *(1191)* |
| **Fluent Aphasia** | | |
| SW | 88 *(33)* | 2211 *(684)* |
| WL | 100 | 2604 *(2056)* |
| **Controls** | 98 *(13)* | 874 *(182)* |

As can be seen in Table 4.5, participants' response times were long; on average, twice as long as the average for the age-matched controls. The latency data were winsorised and outliers removed using the same procedure adopted for controls, leading to the removal of seven items in total. Individual response latencies for the group ranged from 297ms (SW naming *nurse*) to 8410ms (WL naming *witch*). Fluent individual WL had the slowest average response time. He used a lot of verbal fillers and had some tip-of-the tongue blocks (e.g., "*a..a..it's a f..a sheep*"). DA started all responses with a series of verbal fillers (e.g. *um* and *ah*) before attempting to produce the word, which he did correctly in all but one case where he had a tip-of-the tongue block on the word *skunk*. JG was less accurate generally and made more errors in word selection (e.g. *fish* instead of *shark*) or displayed a tip-of-the tongue state before arriving at the correct response (e.g., "*um…ah..sh sh sheep*"). SW also had a slow average response time but also had some very fast responses.

**Sentence production task.**

***Sentence production accuracy.*** The sentence production accuracy for each individual with aphasia as well as a nonfluent and control group average is presented in Figure 4.2.

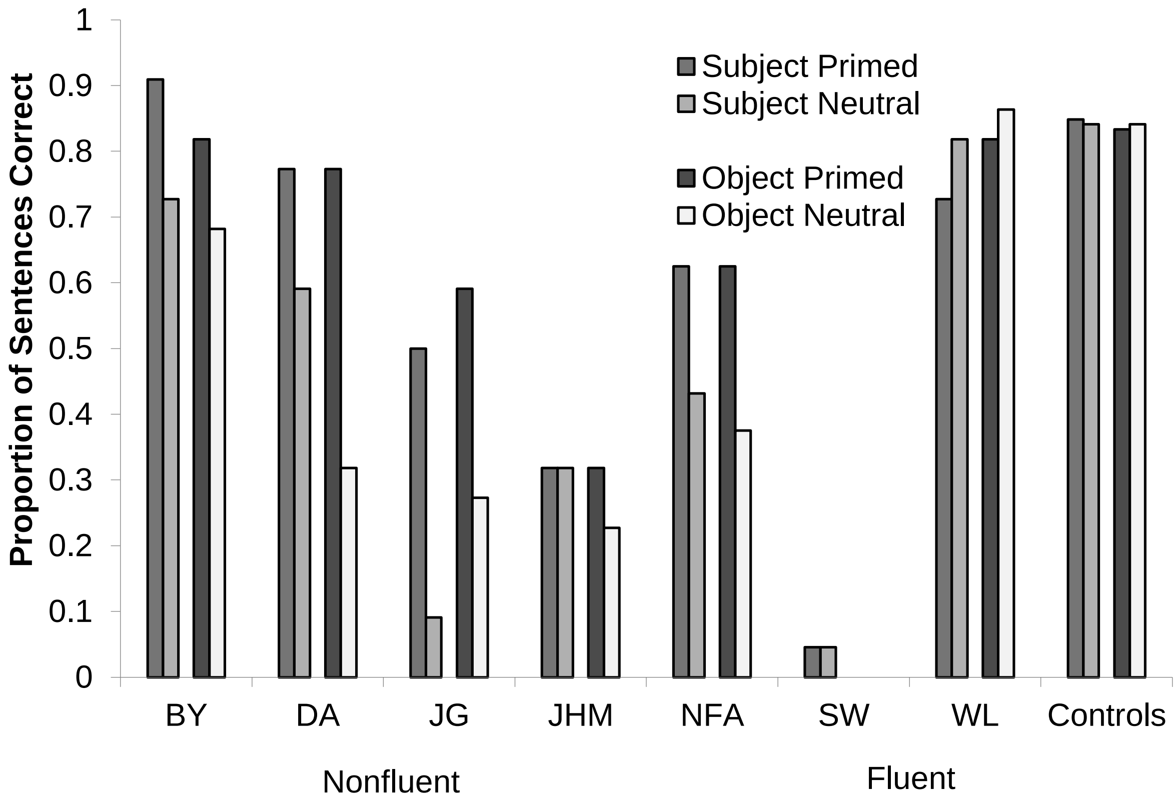



*Figure 4.2.* Proportion of sentences correct for each individual with aphasia. NFA displays the nonfluent group average. The control means are depicted for comparison.

Logistic regression was used to analyse the data for each individual as well as the nonfluent group as a whole. As a group, the individuals with nonfluent aphasia showed a significant effect of the priming manipulations on overall sentence accuracy, $\chi^2$ (3) = 9.65, p < .05. Contrast analyses revealed that this was significant for the subject primed condition compared to its neutral condition, $\chi^2$ (1) = 5.67, p < .05; as well as for the object primed condition compared to its neutral condition, $\chi^2$ (1) = 9.31, p < .01.

These differences amongst the conditions were also statistically reliable at the individual participant level for nonfluent individual JG. She showed a significant effect of the priming manipulations on overall sentence accuracy, JG $\chi^2$ (3) = 11.93, p < .01. Contrast analyses revealed that this was significant for the subject primed condition compared to its neutral condition, $\chi^2$ (1) = 7.36, p < .01; as well as for the object primed condition compared to its neutral condition, $\chi^2$ (1) = 4.45, p < .05.

Turning now to the participants with fluent aphasia, for participant WL, there were no significant effects of the priming manipulations (p = .72). For the other fluent participant, SW, there were only two successfully produced sentences making it impossible to draw any conclusions from her performance in the different conditions.

One of our key hypotheses in this study was that, for the nonfluent participants, the provision of a prime would not just improve accuracy on the primed word itself, but also on the rest of the sentence as well. In order to examine whether this was the case, we rescored sentence production accuracy excluding the primed noun itself.  A sentence was scored correct if all of the rest of the sentence elements were correctly produced: the other non-target noun; both articles; the verb; and the verb inflection (see Figure 4.3). We then repeated the same analysis as for the overall sentence accuracy data; except that we kept the subject and object conditions separate, as we were only interested in whether the primed target increased the accuracy of the rest of the sentence. For the nonfluent group as a whole, provision of a subject prime significantly increased the accuracy of the rest of the sentence compared to its neutral condition, $\chi^2$ (1) = 4.00, $p < .05$. Whereas priming the object noun, did not significantly increase the accuracy of the whole sentence compared to its neutral condition, $\chi^2$ (1) = 3.60, $p = 0.06$. At the individual level, the subject priming effect was again significant for JG, $\chi^2$ (1) = 11.00, $p < .001$, but no other differences were significant.

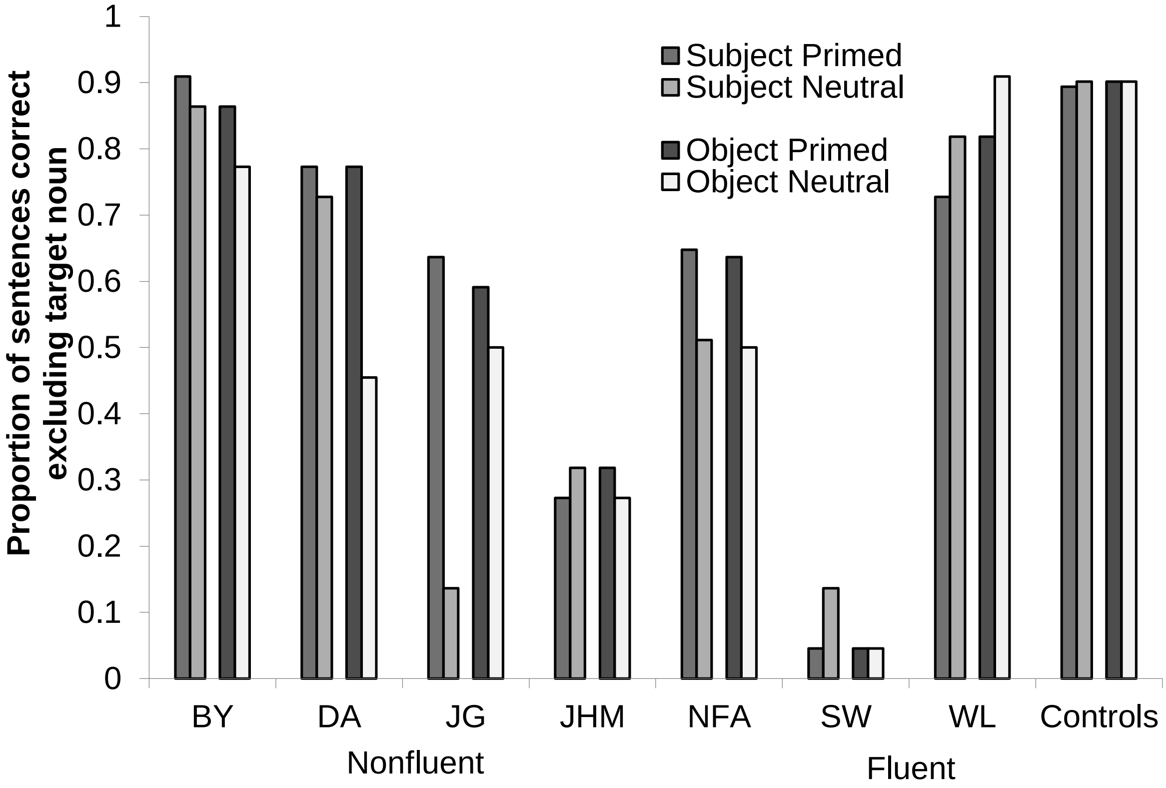



*Figure 4.3.* Proportion of sentences correct excluding the target noun. NFA displays the nonfluent group average.

Another question of interest is whether the primed noun increased the success of any of the individual elements in the sentence, regardless of overall accuracy. A table including the results of all of the sentence elements is presented in Appendix D. Here, we will look at the effect of priming on the primed noun itself, as well as its effect on the other unprimed noun in the sentence. Logistic regression was used to analyse the data for each individual as well as the nonfluent group as a whole. Not surprisingly, for almost all individuals, the provision of an identical prime increased the success of naming the primed noun itself (see Appendix E for the detail of these results). The only exceptions were JHM and WL[1]. Nonfluent group analyses indicated that subject priming significantly increased the accuracy of the subject noun relative to its neutral counterpart, $\chi^2$ (1) = 4.00, $p < .05$; and so too did object priming increase accuracy of object noun production, $\chi^2$ (1) = 8.17, $p < .01$. At the individual level, the only significant difference was for nonfluent individual JG, who showed a significant increase in the accuracy of the object noun production when the object noun was primed, $\chi^2$ (1) = 14.82, $p < .0001$.

More importantly, the primed noun also increased the success in producing the other (non-target) noun in the sentence for all individuals with nonfluent aphasia (see Figure 4.4). This was the case for the object noun when the subject noun was primed. It was also the case for the subject noun when the object noun was primed in all nonfluent individuals except JHM. At the nonfluent group level, the effect of subject noun priming on object noun accuracy was statistically reliable, $\chi^2$ (1) = 9.78, $p < .01$. For the object noun prime however, the effect on accuracy of producing the subject noun was not significant ($p = .28$). At the individual level, the only significant difference was again for nonfluent individual JG, who showed a significant increase in the accuracy of the object noun production when the subject noun was primed, $\chi^2$ (1) = 6.18, $p < .05$. Interestingly, neither of the fluent participants showed any hint of a tendency for noun primes to influence the accuracy of the other unprimed noun in the sentence. The effect of priming on the verb accuracy was also investigated, and found to be non-significant (see Appendix F).

[1] In these analyses for WL, the target was not included as a repeated measure (as it was in previous analyses) because the model failed to converge.

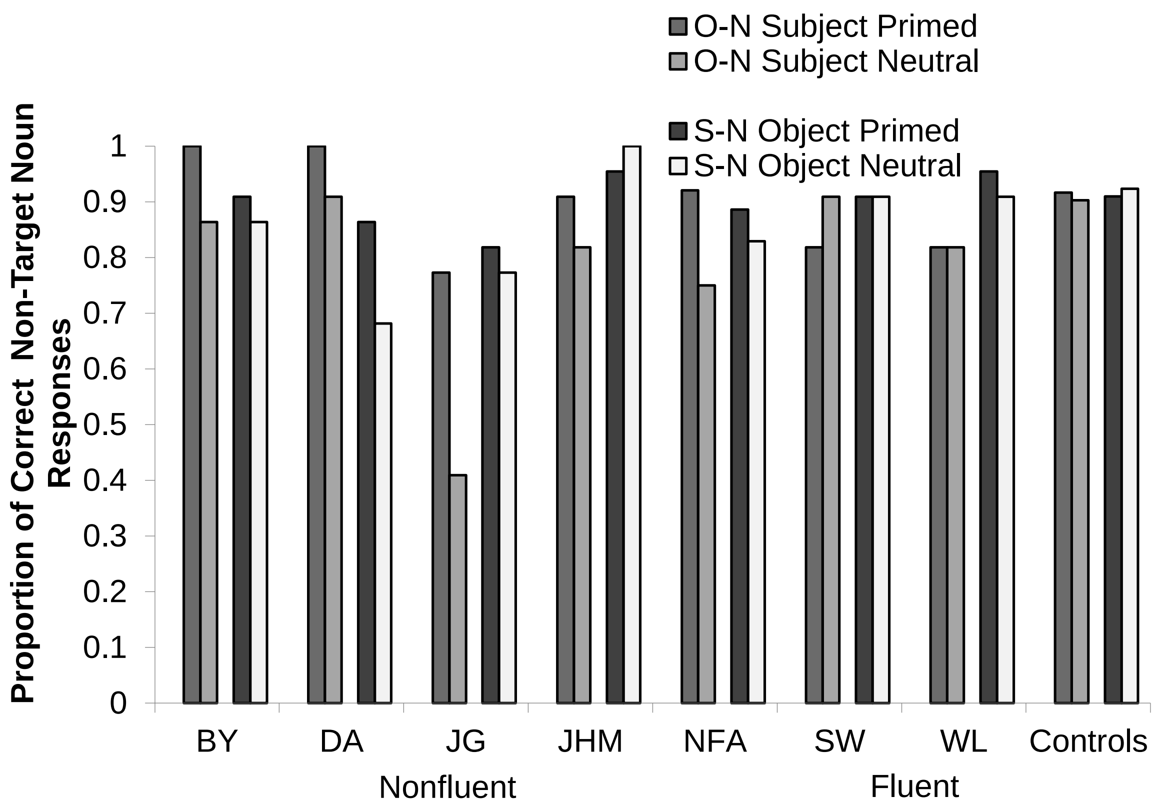



*Figure 4.4.* Proportion of correct non-target noun naming for both subject and object conditions, displayed for each individual with aphasia. S-N = subject noun; O-N = object noun. NFA displays the nonfluent group average.

**Response latency.** Only correct responses which were produced in an active structure were submitted to the analysis of latency data. There were a total of 237 trials that met this condition (45% of the total possible data points), ranging from 2% for SW to 78% for WL. Outliers were removed for each individual with aphasia, following the same procedure used with the controls. Any items which did not have both the primed and neutral counterparts for any individual were also removed. This resulted in a total of 138 trials remaining, ranging from 10 for JG to 52 for WL. For JG and JHM, this left less than 10 pairs of primed and their neutral counterpart items for analysis. This was deemed to be too few to provide a reliable measure and they are therefore excluded from the latency analysis. Fluent participant SW was also excluded as she did not have any data points remaining. The data were log-transformed to reduce positive skewness. Each individual's average latencies for the utterance onset latency and the subject - object noun latency are depicted in Figures 4.5 and 4.6 (see Appendix G for the figure of the subject noun onset latencies, which displays the same trend as the utterance onset latencies).

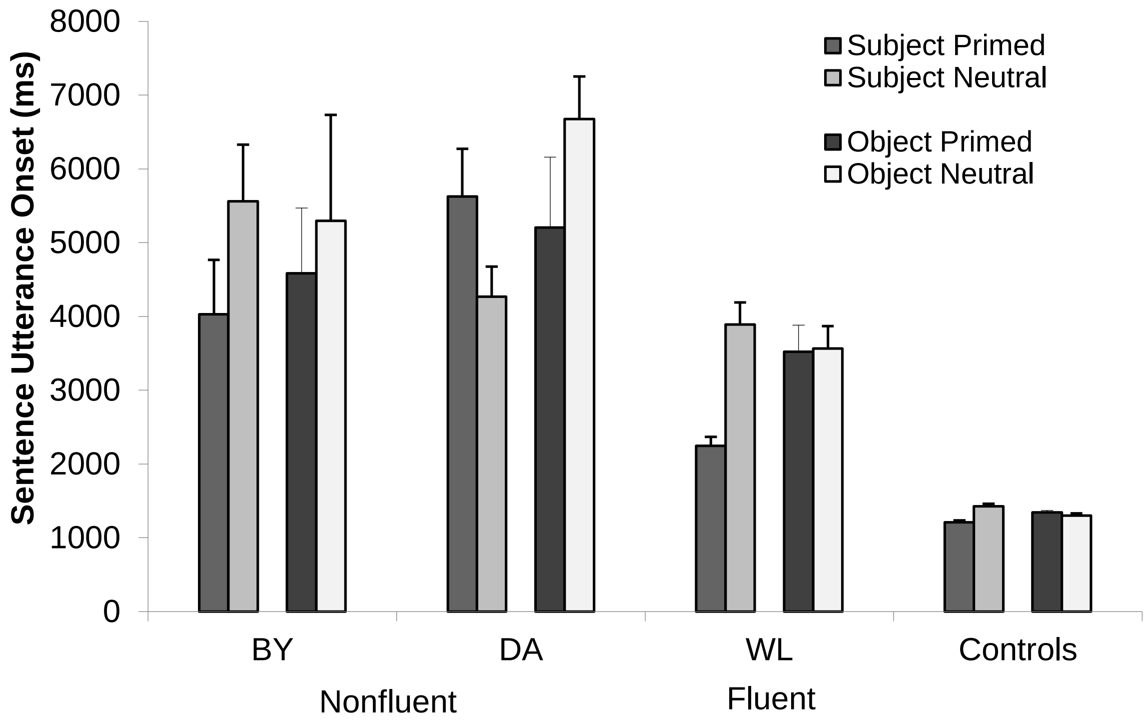



*Figure 4.5.* Geometric means of the sentence utterance onset for both subject and object priming conditions. Error bars represent the standard error of the means.

Latency data were analysed at the individual level for nonfluent participants BY and DA, and fluent participant WL. The data were submitted separately for each individual, for each item, to a General Linear Mixed Model, incorporating one random effect: target noun identity. First, looking at the sentence utterance onset and subject noun onset latencies, the effect of subject primes appears to be quite idiosyncratic in that it does not fit a pattern with fluency diagnosis in any consistent way. Nonfluent participant BY and fluent participant WL showed facilitatory effects on onset when the subject noun was primed. BY was significantly faster at producing the subject noun onset when the subject noun was primed compared to its neutral condition, $F(1, 24.3) = 5.10$, $p < .05$. WL was significantly faster at initiating the sentence when the subject noun was primed, $F(1, 48) = 13.25$, $p < .001$ as well as significantly faster at initiating the onset of the subject noun, $F(1, 29.8) = 20.26$, $p < .001$. Nonfluent participant DA on the other hand showed a reliable trend in the reverse direction. When the subject noun was primed, DA was significantly slower to initiate his sentences, $F(1, 8) = 11.91$, $p < .01$, as well his subject noun onset times, $F(1, 8) = 11.19$, $p < .05$ compared to their neutral conditions. Conversely, when the object noun was primed, DA was significantly faster at producing the subject noun onset compared to its neutral condition, $F(1, 8) = 6.00$, $p < .05$.

Finally, for the subject-object noun latency measure, there was only one individual for whom there was a significant difference. WL had a significantly reduced subject - object noun latency when the object noun was primed compared to its neutral counterpart, $F(1, 31.7) = 8.77$, $p < .01$.

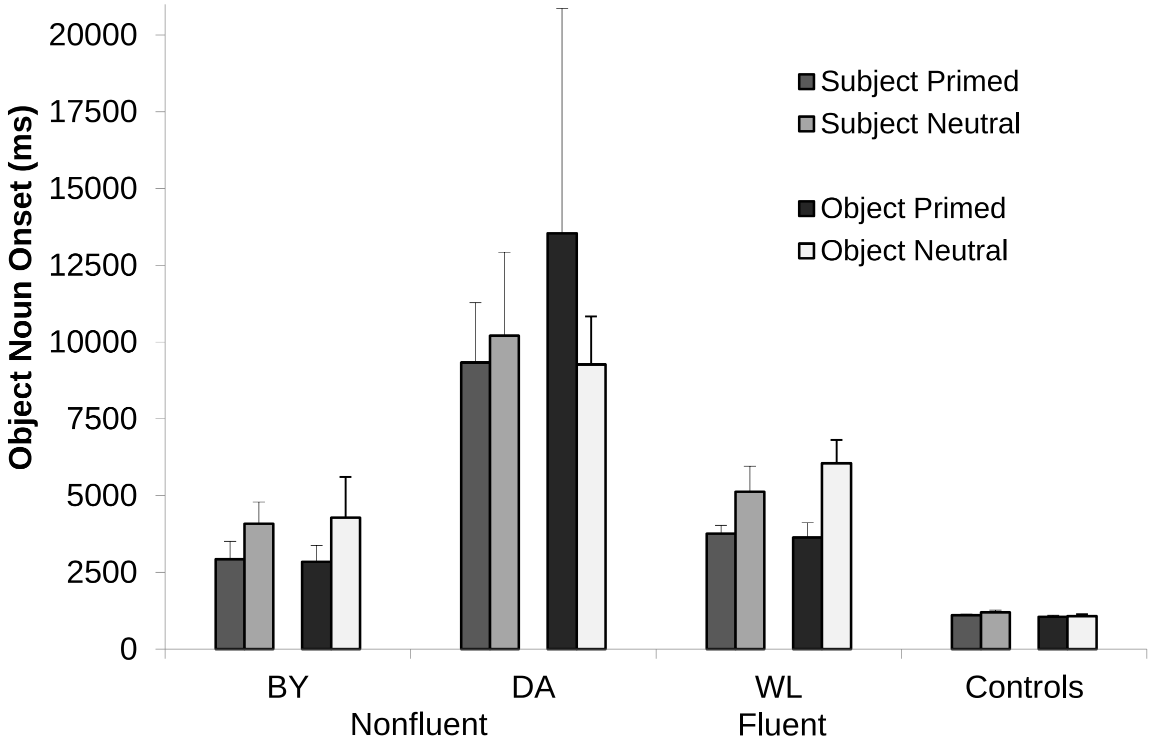



*Figure 4.6.* Geometric means of the subject – object noun latency for both subject and object priming conditions. Error bars represent the standard error of the means.

**Discussion**

**Accuracy results.** As a group, the nonfluents showed significant improvements in overall sentence accuracy in the primed conditions. This applied to both the subject and the object primes. When the target noun itself was excluded, this improved accuracy was only significant for the subject prime condition. At the individual level the only exception was JHM, who had no or small effects for either the subject or object primes on overall accuracy. One possible explanation for JHM's relative insensitivity to the priming manipulation is that she was not able to retain the critical information for long enough to be able to utilise it effectively during the relevant stage of sentence planning. JHM had the lowest digit span amongst the nonfluent group, suggesting that her ability to maintain auditorily presented verbal information may be particularly limited. Another curious aspect of JHM's performance was that her accuracy actually decreased on some sentence elements when the object noun was primed, relative to the neutral baseline. It is possible that she made a conscious effort to retain the primed object noun for later production, which impacted on her production of the other sentence elements. Another possibility is that these object primes acted like distractors to JHM. The auditory input of the prime may have competed with the picture description task. This could have been assessed if a no-prime condition was added to the task. Some ways of testing that hypothesis in future studies will be discussed below.

In contrast to the nonfluent group, fluent individual WL showed no benefit of the auditory primes on his overall sentence accuracy, as was predicted. Increased lexical availability did not influence his ability to generate a successful syntactic structure. Contrary to expectation, there was no significant improvement on the primed nouns themselves. However, WL was at ceiling for subject noun accuracy and near ceiling for object noun accuracy. Fluent individual SW scored very poorly in whole sentence accuracy measures, with only two correct sentences out of the set of 88, so it is very difficult to draw any firm conclusions regarding the effect of the primes. She had relatively good results with noun naming in both subject and object position, but her ability to name the verb in the correct position was poor and her ability to generate a full SVO structure was severely impaired. For example, in response to a picture of a cow chasing a skunk, SW produced *"oh the skunk...the cow...running I think...smell horrible"*. It should be remembered that because of her inability to complete the task under standard conditions, the task was adapted for her and the picture scene remained on the screen throughout her response. This may have had the unintended consequence of producing more descriptive, labelling responses. SW was also often distracted from the task in response to a particular noun. For example in response to a picture of a frog catching a fly, she produced: *"big frog...the tongue...yea something up there a fly or something...it's a big one the frog...my cousin loves loves frogs…we get them some in*

*England"*. Another factor that may have contributed to the lack of a priming effect in particular is her poor auditory processing, as indicated by her PALPA scores (see Table 4.2). Given that auditory priming effects depend on intact auditory word recognition, the primed noun may not have increased activation for SW. As a result of these issues, we were unable to draw any reliable conclusions from the data we collected from her.

**Latency results.** Latency measures were included in the study in order to identify the extent to which increased availability of the primed noun decreased the time taken for it to be produced within a sentence. Latency effects of later sentence elements can also provide insights into participants' sentence planning styles. Within the current study, it is difficult to draw any firm conclusions on the latency effects of identity priming. This is because, firstly, not all participants produced sufficient numbers of accurate sentences for us to examine this measure in any meaningful way. Secondly, the patterns were not consistent even among individuals within the same broad diagnostic group.

When the subject noun was primed, BY showed a facilitatory effect for the subject noun onset latency, and a non-significant trend for the sentence utterance onset. For DA, the reverse was the case - the subject prime significantly increased sentence utterance onset and subject noun onset latencies. In addition, DA showed a significant decrease in the subject noun latency when the object noun was primed. This was unexpected and is difficult to interpret. Of relevance is DA's very slow overall production times. As was the case with the pre-test, utterance onset would often begin with a series of verbal fillers. In the picture description task, his rate of speech also slowed as the sentence progressed. The subject-object noun latency was almost twice that of the nonfluent group average in the neutral prime conditions. This slow and deliberate pacing of speech may in part be a strategy adopted by DA in dealing with his language difficulties. It may also be that he found it more difficult to process the auditory prime alongside the picture stimuli as a result of a significant impairment in auditory processing, as was noted in his case description (also shown in Table 4.2).

It should be noted that this lack of a consistent latency effect differs from the results of Speer and Wilshire (2014). They found that for both fluent and nonfluent participants, sentence onset and subject noun onset times were shorter when the sentence commenced with a high frequency subject than with a low frequency one (making the subject noun more readily available). They also found that the frequency of the object noun had no consistent effect on sentence onset or subject noun onset. Some possible explanations for this discrepancy will be discussed below.

# Chapter 5: General Discussion

This study examined the effect of auditory lexical primes on sentence production accuracy in nonfluent aphasia. Participants with aphasia and healthy older controls described pictured events using SVO sentences. These sentences were preceded by auditory primes that were either identical to one of the nouns in the sentence, or unrelated to either of these nouns. Priming had no effect on overall sentence accuracy for either the controls or the individuals with fluent aphasia. In contrast, the individuals with nonfluent aphasia showed a significant increase in overall sentence accuracy when the subject noun was primed, which extended to other sentence elements beyond the primed noun itself.

Our key finding in relation to our hypothesis was that for nonfluent participants, the direct priming of the subject had significant flow-on effects on sentence accuracy. These effects were independent of any improved performance in producing the primed subject noun itself: for example, both the verb and the object noun phrase production accuracy were improved. No accuracy effect was found in the healthy controls or in the individuals with fluent aphasia. These results are broadly consistent with that of Speer and Wilshire (2014), who manipulated lexical availability by varying the frequency of the noun elements in the sentence.

The finding that lexical availability affects sentence accuracy cannot be explained within a purely grammatical account of nonfluent aphasia. In the current study, the grammatical structure was kept constant, while manipulating lexical availability. Instead we must look to the interaction of lexical items and structure to understand how this study's lexical manipulation affected sentence production accuracy.

In Kolk's (1995) timing and integration model, successful sentence production requires both the retrieval of lexical items and the building of the syntactic frame, but crucially, it also requires the synchronisation of these two processes. For a word to be successfully produced in a sentence, both the lexical item and the corresponding syntactic slot need to be activated at the same time. According to Kolk, this synchronisation of lexical items and their syntactic slots breaks down in aphasic individuals due to a slower retrieval or faster decay of the lexical items and/or the syntactic frame (Kolk & Van Grunsven, 1985). Our findings, however, are not easily understood within Kolk's model. In the current study we see a significant accuracy effect without any significant latency effect. Therefore, timing of lexical item retrieval appears to be less of an issue for nonfluent participants than predicted by the Kolk model.

The findings of the current study are more readily accounted for in models that allow for interaction between the processes of lexical element retrieval and syntactic structure building. For Stemberger (e.g., Stemberger, 1985), the meaning system passes activation to the lexical system – which drives the selection of key content items - as well as activating the phrase structure units in the syntactic system that are connected to the thematic roles and relations of the intended message. During sentence production, the phrase structure units send additional activation to the appropriate class of the lexical item (e.g., noun), ensuring the correct sequencing of items. Importantly for Stemberger, this activation also flows in the reverse direction, so activated lexical items in turn pass activation back to the syntactic system to promote structures that are compatible with the class of the lexical item (e.g., for a noun, different noun phrase structures are activated). This reverse flow of activation from the lexical item to the syntactic phrase node could be the mechanism by which the primed subject increased sentence accuracy in our study. The activation of the subject noun lexical item leads to the activation of the subject noun phrase structure, in this case the simple structure of *article* followed by subject *noun*. This noun phrase structure is of course not the full scope of the target sentence. However, it goes some way to reducing the overall structural planning load of the sentence. In this way, a nonfluent individual who has difficulty activating the syntactic system from the meaning system, can still generate structure from the bottom-up.

The key findings observed in this study are also compatible with the model of Chang et al. (2006). Under this model, the syntactic structure is realised by the sequencing system, while the lexical elements are realised by the meaning system. For Chang et al., lexical units cannot pass activation directly to the sequencing system. Instead, the meaning system and sequencing system interact via an intermediate set of units that represent thematic roles. For individuals with normal language production capabilities, the individual conceptual entities in the sentence are tightly bound to their respective thematic roles. The most highly activated role unit wins the right to select its corresponding syntactic elements. The order of selection of the remaining role units is then tightly constrained by previously learned sequencing rules. For individuals with nonfluent aphasia, we might postulate that there is a difficulty establishing a strong association between thematic role units and their respective conceptual representations. Consequently, sentence initiation is particularly slow, as it relies heavily on these concept-role associations (Speer & Wilshire, 2014).

In relation to our study, the subject primes could potentially boost the activation of the conceptual unit corresponding to the agent, enabling it to be prioritised for production even when it is only weakly associated with its respective role unit. This thematic role in turn then becomes available to the sequencing system so that production of the subject noun phrase can commence. Having initiated a syntactic structure for the agent, the sequencing system can then encode the remaining conceptual elements into a proper syntactic structure based largely on previously learned syntactic rules. This model is able to account for the beneficial effect of enhanced subject noun availability on sentence production in nonfluent aphasia. Increasing the availability of the object noun would not be expected to have the same effect, as the structure building would have to be initialised independently.

In the current study, there was no consistent latency benefit for nonfluent individuals when provided with subject primes. As discussed above, the variable latency results of the individual participants in the current study may have been influenced by the intrusion of a distracting effect of the auditory prime. The prime imposes its own processing demands, which may have obscured any beneficial effect on sentence initiation times. It is also possible that there are some differences between noun frequency and identity priming in the way they facilitate structure building. Within a model like that of Chang et al (2006) association strengths are based on learning. The more a noun is used in a particular role (whether that be syntactic or thematic), the more it will help prime that role. As a result of use and learning, high frequency nouns could develop stronger connections to syntactic structures. The simple provision of a prime on a single occasion would not be expected to have such an effect. It may be that the high frequency nouns used in the Speer and Wilshire study, provide an additional boost to the structure building for nonfluent individuals and that this additional activation is sufficient to increase the speed of onset in addition to increased accuracy. This is a plausible explanation, but more research into the comparative effects of identity priming and frequency would be required to draw clear conclusions.

## Limitations and Suggestions for Future Research

One of the major limitations of the study is the number and range of participants. Only four nonfluent participants were used which means that group level results need to be taken with caution. We have attempted to compensate for this by examining individual as well as group level results and identifying any areas in which there were inconsistencies between the two. In addition, one of the two fluent participants (SW) was not an ideal case comparison. Because she was only able to produce two correctly formed sentences in the picture description task, we were unable to draw any conclusions from her results. The task was too difficult for her level of impairment despite performing relatively well in the pre-test. Also, the effectiveness of the “preactivation” that the prime elicits will depend on the participant’s auditory word recognition skills, and their ability to retain lexical and/or phonological information over the interval required for the prime to exert it effects. Careful screening is required in order to determine subject suitability.

As discussed above, one extra condition that could be incorporated into the design is one where there is no auditory prime at all. Because we lacked such a condition, it is difficult to determine definitively whether the effect in the identical prime condition is the result of the presence of facilitation or simply an absence of interference from an unrelated prime (see La Heij et al., 1999 and McQueen et al., 2006 for some evidence of small interference effect from unrelated primes during word production). If we assume that in this task, the nonfluents are incremental in their sentence planning, then the initial requirement is to produce the subject noun phrase. In that case, the subject prime would be the least distracting condition because it relates to the initial noun phrase. We could also expect that the interference from the object noun prime would be the greatest in the identical object noun prime condition because the prime receives an additional boost to its activation levels directly from the picture. However, there was no evidence for decreased accuracy in the object prime condition.

The research could also be extended by including word frequency as a variable. We found some distinct effects of identity priming as compared with the frequency paradigm used in Speer and Wilshire (2014). Coding the nouns into high and low frequency and balancing them across the priming conditions within a single study design would enable some useful comparisons to be made. In particular we would be interested to determine whether high frequency was the key variable in latency effects in nonfluents. This would address the hypothesis raised in the discussion that high frequency nouns are not only more readily retrieved, but more directly activate phrase structures in which they are commonly used. While we know that both direct auditory priming and noun frequency affects accuracy, it is only by examining both variables within the one study that we can accurately access their relative efficacy.

Finally, a consistent SVO syntactic structure was used throughout this study. Clearly, only a limited portion of natural speech can be represented in simple SVO structures and it remains to be demonstrated that lexical effects can be reproduced in more complex structures. However, while the inclusion of non SVO grammatical structures might have yielded useful comparisons, these possibilities are likely to be restricted by the ability of the aphasic participants to produce a successful sentence within a more complex structure.

**Conclusion**

In this study, we found that the presentation of an auditory noun prime, prior to the picture description task, had a beneficial effect on overall sentence accuracy for participants with nonfluent aphasia. This benefit extended to other sentence elements, even when the primed noun itself was excluded. This effect was only significant when the subject noun was primed and not when the object noun was primed. No such accuracy effect was found for either priming condition in our older controls, nor in the two individuals with fluent aphasia. For the individuals with nonfluent aphasia, the subject primes not only helped build the subject noun phrase structure, but also the verb and object noun phrases for the full SVO sentence. Such an effect suggests that content can drive successful structure building. This finding can only be understood in a connectionist framework which allows for the reverse flow of activation from lexical items to thematic roles or grammatical units.

In terms of our understanding the language difficulties of individuals with nonfluent aphasia, these results suggest that we need to consider not just the nature of the syntactic structure being produced, but also its content. Rather than focusing purely on structure and trying to eliminate the "contaminating" effects of lexical retrieval, future research needs to look at the totality of the sentence planning process in nonfluent individuals, in a way that considers content as well as structure. Given an impaired structure building capability, it is important to examine other ways in which structure building can be facilitated. As the current study shows, in some circumstances, nonfluent individuals can produce well-formed sentences. The broader our understanding of the factors that influence successful sentence production, the better equipped we are to determine the options for treatment and support of individuals with nonfluent aphasia.

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Appendix A: *List of the audio primes used in the experiment, with the matched unrelated neutral prime.*

| Prime | Unrelated prime |
|---|---|
| Bear | Aunt |
| Camel | Lizard |
| Cat | Truck |
| Clown | Bug |
| Crab | Ant |
| Dolphin | Penguin |
| Duck | Wolf |
| Fish | Seat |
| Fox | Mouse |
| Frog | Worm |
| Ghost | Rat |
| Goat | Bee |
| King | Boss |
| Lion | Dentist |
| Maid | Knight |
| Monkey | Student |
| Nun | Vet |
| Pig | Bird |
| Sheep | Goose |
| Skunk | Elf |
| Turtle | Farmer |
| Whale | Twin |
| Witch | Bride |
| Zebra | Goldfish |

Appendix B: *List of the 24 target nouns used in the experiment with their corresponding sentences in both subject and object positions.*

| **Target noun** | **Subject position** | **Object position** |
|---|---|---|
| bear | the bear is hitting the dog | the queen is lifting the bear |
| camel | the camel is biting the rabbit | the pig is chasing the camel |
| cat | the cat is brushing the bear | the witch is cuddling the cat |
| clown | the clown is holding the snake | the cow is pushing the clown |
| crab | the crab is pinching the octopus | the shark is eating the crab |
| dolphin | the dolphin is eating the crab | the mermaid is riding the dolphin |
| duck | the duck is on the cow | the girl is feeding the duck |
| fish | the fish is kissing the turtle | the girl is carrying the fish |
| fox | the fox is pulling the cat | the cat is pulling the fox |
| frog | the frog is catching the fly | the clown is juggling frogs |
| ghost | the ghost is tickling the nurse | the nurse is tickling the ghost |
| goat | the goat is lifting the bear | the cow is licking the goat |
| king | the king is pushing the horse | the queen is tickling the king |
| lion | the lion is licking the monkey | the mummy is chasing the lion |
| maid | the maid is shooting the mummy | the ghost is shooting the maid |
| monkey | the monkey is punching the lion | the zebra is juggling monkeys |
| nun | the nun is brushing the mermaid | the mummy is pushing the nun |
| pig | the pig is pulling the dog | the tiger is kissing the pig |
| sheep | the sheep is hitting the seal | the horse is brushing the sheep |
| skunk | the skunk is biting the goat | the cow is chasing the skunk |
| turtle | the turtle is chasing the fish | the mermaid is kissing the turtle |
| whale | the whale is kissing the shark | the shark is chasing the whale |
| witch | the witch is shooting the judge | the ghost is hitting the witch |
| zebra | the zebra is lifting the nurse | the nun is chasing the zebra |

Appendix C: *Average Sentence Accuracy for each Target Item*

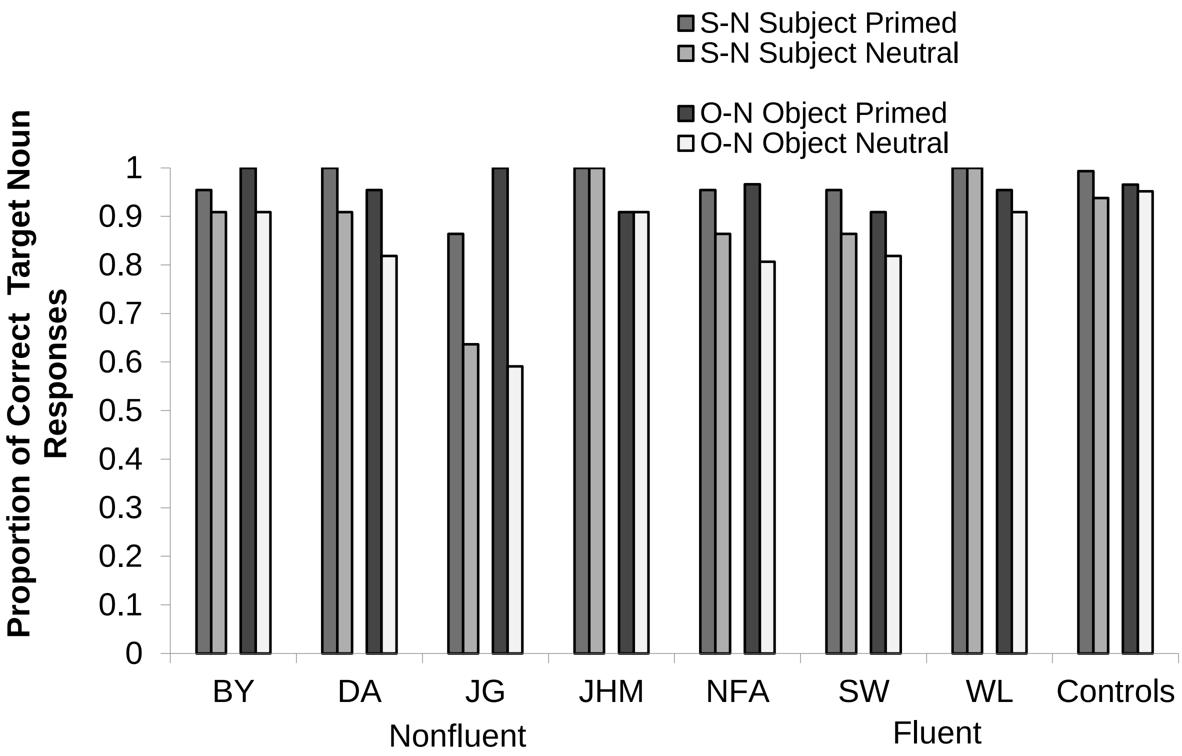
| Target | Percent Correct | | | | |
|---|---|---|---|---|---|
| | **Subject Primed** | **Subject Neutral** | **Object Primed** | **Object Neutral** | **Overall Average** |
| bear | 83 | 100 | 83 | 83 | 88 |
| camel | 67 | 100 | 83 | 100 | 88 |
| cat | 83 | 100 | 100 | 83 | 92 |
| clown | 83 | 67 | 83 | 33 | 67 |
| *crab* | *83* | *83* | *33* | *33* | *58* |
| dolphin | 67 | 83 | 83 | 83 | 79 |
| duck | 83 | 100 | 100 | 100 | 96 |
| fish | 83 | 50 | 83 | 50 | 67 |
| fox | 67 | 83 | 67 | 100 | 79 |
| frog | 100 | 100 | 100 | 100 | 100 |
| ghost | 83 | 83 | 100 | 83 | 88 |
| goat | 100 | 83 | 100 | 100 | 96 |
| king | 100 | 100 | 83 | 83 | 92 |
| lion | 100 | 100 | 50 | 83 | 83 |
| maid | 83 | 50 | 100 | 100 | 83 |
| monkey | 50 | 83 | 100 | 100 | 83 |
| nun | 100 | 100 | 50 | 50 | 75 |
| pig | 83 | 83 | 83 | 83 | 83 |
| sheep | 67 | 67 | 100 | 83 | 79 |
| skunk | 83 | 83 | 50 | 83 | 75 |
| turtle | 100 | 83 | 33 | 67 | 71 |
| *whale* | *17* | *0* | *50* | *33* | *25* |
| witch | 100 | 67 | 100 | 100 | 92 |
| zebra | 100 | 83 | 100 | 100 | 96 |

Appendix D: *Each participant's average accuracy for several individual sentence elements for each of the priming conditions. Bold indicates a significant difference between the primed and neutral conditions.*

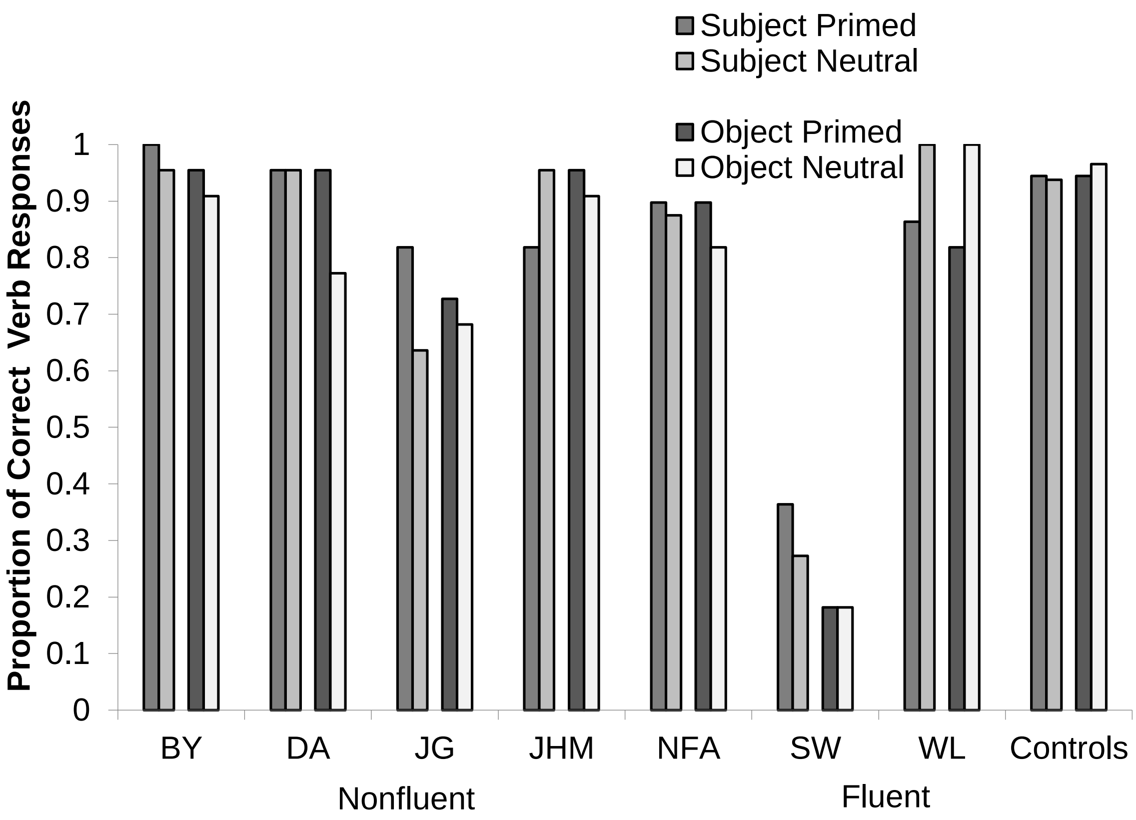
| Participant | Condition | Subject Noun | Subject Article | Object Noun | Object Article | Verb | Verb Inflection |
|---|---|---|---|---|---|---|---|
| Nonfluent | | | | | | | |
| BY | Subject Primed | 0.95 | 0.91 | **1.00** | 1.00 | 1.00 | 1.00 |
| | Subject Neutral | 0.91 | 0.95 | **0.86** | 0.95 | 0.95 | 1.00 |
| | Object Primed | 0.91 | 1.00 | 1.00 | 1.00 | 0.95 | 1.00 |
| | Object Neutral | 0.86 | 0.91 | 0.91 | 0.95 | 0.91 | 0.95 |
| DA | Subject Primed | 1.00 | 1.00 | 1.00 | 0.95 | 0.95 | 0.86 |
| | Subject Neutral | 0.91 | 1.00 | 0.91 | 1.00 | 0.95 | 0.82 |
| | Object Primed | 0.86 | 1.00 | 0.95 | 0.95 | 0.95 | 0.91 |
| | Object Neutral | 0.68 | 1.00 | 0.82 | 0.95 | 0.77 | 0.86 |
| JG | Subject Primed | 0.86 | 1.00 | **0.77** | 0.95 | 0.82 | 1.00 |
| | Subject Neutral | 0.64 | 0.91 | **0.41** | 0.91 | 0.64 | 0.91 |
| | Object Primed | 0.82 | 0.95 | **1.00** | 1.00 | 0.73 | 1.00 |
| | Object Neutral | 0.77 | 0.95 | **0.59** | 0.95 | 0.68 | 1.00 |
| JHM | Subject Primed | 1.00 | 0.86 | 0.91 | 0.77 | 0.82 | 0.41 |
| | Subject Neutral | 1.00 | 0.82 | 0.82 | 0.73 | 0.95 | 0.45 |
| | Object Primed | 0.95 | 0.82 | 0.91 | 0.91 | 0.95 | 0.41 |
| | Object Neutral | 1.00 | 0.82 | 0.91 | 0.73 | 0.91 | 0.50 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fluent | | | | | | | |
| SW | Subject Primed | 0.95 | 0.59 | 0.82 | 0.82 | 0.36 | 0.59 |
| | Subject Neutral | 0.86 | 0.68 | 0.91 | 0.73 | 0.27 | 0.55 |
| | Object Primed | 0.91 | 0.82 | 0.91 | 0.73 | 0.18 | 0.77 |
| | Object Neutral | 0.91 | 0.59 | 0.82 | 0.86 | 0.18 | 0.59 |
| WL | Subject Primed | 1 | 0.95 | 0.82 | 1 | 0.86 | 1 |
| | Subject Neutral | 1 | 1 | 0.82 | 1 | 1 | 1 |
| | Object Primed | 0.95 | 1 | 0.95 | 0.95 | 0.82 | 0.95 |
| | Object Neutral | 0.91 | 1 | 0.91 | 1 | 1 | 1 |

Appendix E: *Proportion of correct naming of the target noun for both subject and object conditions, displayed for each individual with aphasia. S-N = subject noun; O-N = object noun. NFA displays the nonfluent group average.*



Appendix F: *Proportion of correct verb naming for both subject and object conditions, displayed for each individual with aphasia. NFA displays the nonfluent group average.*



Appendix G: *Geometric means of the subject noun onset for both subject and object priming conditions. Error bars represent the standard error of the means.*