Britta Biedermann, Nora Fieder and Lyndsey Nickels

8 Spoken word production: Processes and potential breakdown

1 Introduction

The processes of spoken word production have been a focus of interest for decades and this research has been summarised in several reviews (e.g., Friedmann, Biran, & Dotan, 2013; Nickels, 1997, 2001a,b; Wilshire, 2008). However, many questions remain unanswered and consequently spoken word production remains an area of research interest, informed by data from unimpaired and impaired adult language, as well as language development. Several theories of spoken language production have been proposed over the last half century, each differing slightly in levels of representation, processing steps, and activation flow. In this chapter, we focus on four of the most influential theories of spoken language production.

2 Spoken word production in adult speakers

While, in this section, we only discuss four (prominent) models of speech production, we acknowledge that there are other theoretical frameworks (e.g. Harley, 2013; Stemberger, 1985). These theoretical frameworks differ in the extent to which processing is thresholded (complete at one level before proceeding to the next; e.g. Morton, 1985; Levelt, Roelofs & Meyer, 1999) or cascaded (can flow to subsequent levels prior to selection; e.g. Dell, Martin, Saffran, & Gagnon, 1997), feedforward (flows only in one direction, e.g. Levelt et al., 1999) or interactive (flows both forward and backward through the model; e.g. Dell et al., 1997). We refer the reader to Rapp and Goldrick (2000; Goldrick & Rapp, 2002) for detailed discussion of these issues. In addition, the vast majority of theories of spoken word production assume localist representations (i.e. a single node for a single representation), including all of those described here. However, some computational models implement distributed representations, where no single unit codes for any one item or feature, but instead items are represented by a pattern of activation across a whole array of units. To our knowledge there are no models that focus on spoken word production which incorporate distributed representations (but see, Plaut, 2002). Finally, we only address language production in monolingual speakers, and do not discuss models of bi- or multi-lingual speakers (e.g., Green, 1998; Green & Abutalebi, 2013). However, we

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note that the majority of these theories of bi-/multi-lingual language production are relatively underspecified in terms of production processes, instead they (necessarily) focus on the interaction between languages. Hence, it is likely that the underlying processes for producing a word will be similar across monolinguals and bilinguals, but with additional processing constraints for the multilingual speaker.

2.1 The Logogen model

The Logogen model originated as a model of word recognition (e.g. Morton, 1964; 1969) but was later extended to include spoken and written word production (e.g. Kay, Lesser & Coltheart, 1992; Swinburn, Porter & Howard, 2014; Whitworth, Webster & Howard 2014). It has been incredibly influential, and remains one of the few theories that encompasses all modalities of language input and output. It remains particularly widely used in clinical practice, and forms the basis for assessment tools (e.g. Psycholinguistic Assessments of Language Processing in Aphasia (PALPA), Kay, Lesser and Coltheart, 1992; Comprehensive Aphasia Test (CAT), Swinburn, Porter and Howard, 2010), and textbooks guiding assessment and treatment choices (e.g. Whitworth, Webster and Howard, 2014). Consequently, the Logogen model is commonly used as a tool to help localise the nature of the breakdown of language after stroke and (albeit less widely) in developmental language impairment. Here, we concentrate on the components required to utter a spoken word. Figure 1 depicts the example of saying aloud 'dog' within the Logogen model. According to this model, a speaker needs to first activate a conceptual entry from a pre-lexical component called the 'Cognitive System'. Once a concept has been activated, it activates the corresponding entry in the 'Phonological Output Lexicon' (POL)[1], a store of all word forms that the speaker knows. As soon as a word has reached a threshold of activation in the POL, this word (logogen) can then activate the corresponding representation in the next component, the 'Phonological Output Buffer' (originally known as the Response Buffer). It is at this level that the phonemes of a word are activated. The Phonological Output Buffer also serves as a working memory store, holding the phonemes of the target word active until they are required for articulation.

In terms of information flow from one process to the next, the Logogen model only allows for feed forward processing in word production, and no interactive feedback processes are incorporated. It works in a serial and discrete fashion, in the sense that processing at one level is complete before there is activation of the next level. This model does not distinguish between meaning representations (semantics) that are specific to words (lexical-semantics) and those that are more general and include non-linguistic aspects of meaning (conceptual representations; but see

1 In the original Logogen model the representations at this level would have been termed "phonological output logogens", however, here we use the currently more standard terminology.

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Butterworth, 1983, and Nickels, 2001a for discussion). Neither does it address the storage and access of grammatical information to do with words (lexical-syntax) such as grammatical number (whether a word is singular or plural), or, in languages where it is required, grammatical gender (e.g., in French whether a noun is feminine and requires a feminine determiner "la chaise" (the chair), or masculine "le bureau" (the desk)). In common with many theories of spoken word production it also does not specify processes subsequent to selection of phonemes (phonological and phonetic encoding), for further discussion see Wilshire, 2008).

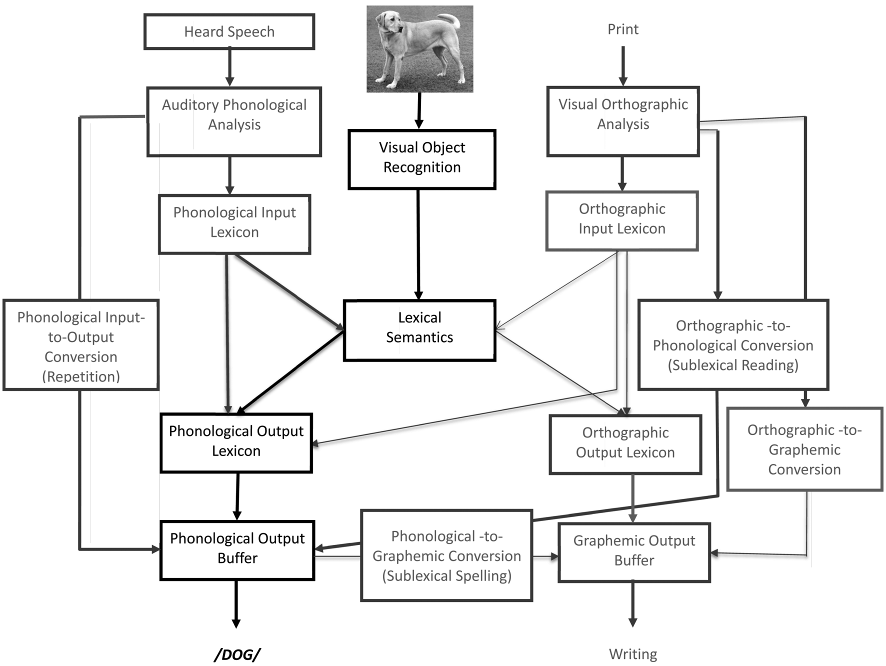

Figure 1: The Logogen model (based on Morton, 1985; Patterson and Shewell, 1987)

2.2 The Two-Step model

The Two-Step model was proposed by Levelt et al. (1999) as an extension of Levelt's (1989) theory of spoken word production and has been implemented computationally in the WEAVER++ model (e.g. Roelofs, 1997; 2014). This model specifically aimed to account for results of experimental (chronometric) studies with unimpaired speakers. Like the Logogen model, this model is strictly serial. Even though it is called the 'Two-Step' model, it differentiates between three significant phases. The first phase involves activation of lexical concepts (at the level we will refer to as lexical semantics). A lexical concept is an information unit that can be mapped directly onto language: it concerns 'meaning that can be packaged into one lexical item, or a lexical phrase'. This 'lexical meaning package' is then mapped onto a lexical-syntactic node (a

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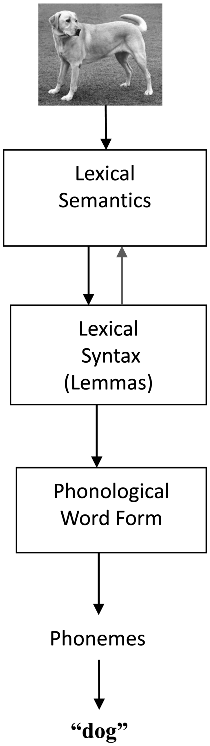

Figure 2: Levelt et al.’s Two-Step model (1999)

lemma). The lemma specifies, for example, whether the lexical item needs to be expressed as a noun, verb or other word class, whether it is being used to refer to a single or multiple object, and therefore needs to be expressed as singular or plural, or to refer to an event in the past, present or future requiring different grammatical tense markers. Other grammatical differences between words are stored at this level as well, for example, many languages, including English, differentiate between ‘count’ and ‘mass’ nouns and other languages, including Italian, French, German and Hebrew differentiate between a number of grammatical genders. This level is also known as the *lemma* level (since Kempen & Huijbers, 1983). However, importantly, the definition of what a lemma constituted shifted between Levelt (1989), where it encompassed both lexical semantics and lexical syntax, and Levelt et al. (1999), where it was purely syntactic. According to Levelt et al. (1999), the lexical-semantic and lexical-syntactic levels interact with each other and are therefore active simultaneously. However, only a single lexical-syntactic entry is mapped onto the next level, the phonological word form level: only one selected lexical-syntactic entry activates its corresponding word form. Levelt (1989; 1999) described this processing step as the ‘major rift’ in lexicalisation, and it also explains the name of his model:

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The Two-Step model – the first step refers to all processes prior to lexical-syntactic selection, and the second step refers to everything following, concerning phonological and phonetic processing. The phonological word form level includes information about the internal structure of the word form including, the phonemes, syllabic structure and word stress. After the phonological word form has been selected, its corresponding phonemes will then be activated and selected at the phoneme level, and inserted into syllable frames, which in turn map onto stored articulatory plans for syllables, which are then unpacked prior to articulation (see Figure 2).

2.3 The Interactive Activation model

In contrast to the two previous models, the Interactive Activation model (see Figure 3) was specifically designed to account for speech error data both from unimpaired

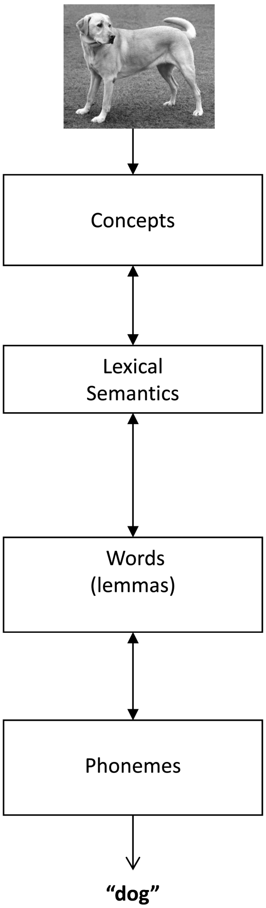

Figure 3: The Interactive Activation Model (based on Dell, Schwartz, Martin, Saffran, & Gagnon, 1997)

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participants and those with aphasia. This model was a development of Dell's (1986) earlier, more comprehensive, account of spoken word production. Like Levelt and colleagues, Dell (1986) also proposed a two-step architecture with the first step involving a lexical-semantic level that maps onto a lexical-syntactic level, which, in turn in a second step, maps lexical-syntax onto a word form level and finally a phoneme level. In contrast, Dell et al. (1997) no longer include a word form level with the lexical-syntactic word node level mapping directly onto single phonemes[2].

The major difference between this model and the Logogen and Levelt et al.'s Two-Step model is that it allows both cascading of activation and interactivity between levels. If one lexical node in the network is activated (regardless of at which level), it activates all nodes that it is connected to (at levels above and below). In one activation cycle, each node receives activation and the activation level also decays back towards zero. After a fixed number of activation cycles, the most active node at the word (lexical-syntactic) level is selected and receives a jolt of extra activation which is sent to its phonemes which are selected in turn. The model can be used to simulate impaired performance by reducing the connection strength between levels (semantic connections or phonological connections; Foygel & Dell, 2000).

2.4 The Interactive Network model

Another prominent word production model is the Interactive Network Model (Caramazza, 1997; Caramazza & Miozzo, 1997; 1998), which essentially maps meaning onto form for word production, but without assuming an intervening level of lexical-syntactic processing. This model incorporates cascading feed forward links between levels. First, a lexical-semantic network is activated that represents semantic features, which in turn activates, in parallel, a phonological word form network and an orthographic word form network (only the former is discussed in this review). The phonological word form network activates the word form's corresponding sounds at the phoneme level. The primary activation of lexical-syntax happens via the phonological word form network (see Figure 4). Pre-activation of lexical-syntax via semantics (see the dotted line in Figure 4) is only possible for syntactic features that have semantic content (for example, word category or number), whereas syntactic features such as 'grammatical gender' are semantically empty and can therefore only be activated after activation of the word form. This order of activation makes a strong claim of phonological mediation before syntax can be accessed, an assumption that differs from Levelt's Two-Step model where phonological information and syntactic information are both activated simultaneously (at different levels)[3].

2 Hence, in this theory the word form representation can best be conceived of as the links between the lexical-syntactic word nodes and the individual phonemes.

3 Although early descriptions of the Two-Step model suggested that phonology was only activated after selection of lexical syntax, Levelt et al. (1999) make it clear that selection of lexical-syntax is not always required prior to activation of phonological form: nodes at the lexical-syntactic level activate both lexical-syntactic diacritics and phonological form simultaneously.

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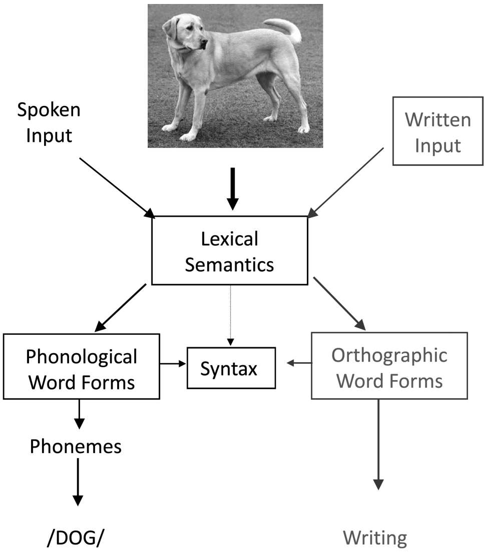

Figure 4: The Independent Network (IN) model (based on Caramazza, 1997; Caramazza & Miozzo, 1998).

2.5 Summary

In sum, Morton's Logogen model is widely used as a clinical tool for interpreting the results of assessments. It is a strictly serial and thresholded model, and does not allow for cascading of activation. It also does not include representation of lexical-syntax. Here, Levelt and colleague's Two-Step model can help out, which is also strictly serial, but incorporates a lexical-syntactic level – some authors have integrated features of both Levelt et al's Two-Step and the Logogen model into a single composite model (e.g.. Biran & Friedmann, 2012; Nickels, 1997). Caramazza's Interactive Network model also includes lexical-syntax but this is activated via the word form, and this model allows cascading of activation from one level to the next. Finally, Dell and colleagues's Interactive Activation model includes both cascading and feedback of activation between all processing levels, and incorporates a lexical-syntactic level.

Overall, each model contributes and highlights different aspects of processing mechanisms, and processing order that are important in spoken word production.

3 Psycholinguistic variables influencing spoken word production

Different stimulus properties have been found to affect picture naming speed and/or accuracy and their effects have been attributed to different levels of processing (for

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review of effects on latency in participants without language impairments see Alario, Ferrand, Laganaro, New, Frauenfelder, & Segui, 2004; and for effects on accuracy in people with aphasia see, for example, Nickels & Howard, 1995; Howard, Best, Bruce, & Gatehouse, 1995). We focus on those variables that are relevant for spoken word production, but note that other variables are relevant specifically to the processing of pictures in picture naming (e.g., visual complexity, image agreement, name agreement).

3.1 Imageability

The variable *imageability* is commonly attributed to the semantic system. *Imageability* is a variable which reflects a rating of how easy it is to visualise an image from memory. For example, *'market'* is rated as harder to visualise than *'apple'*. In general, items high in imageability are easier (faster or more accurate) to produce than items low in imageabilty (see for example, Kremin, Lorenz, De Wilde, Perrier, Arabia, Labonde & Buitoni, 2003).

3.2 Typicality

Typicality relates to how prototypical an item is in relation to other members of its category (e.g., how well represents 'penguin' the category of birds). Rossiter and Best (2013) obtained typicality ratings from people with aphasia and showed that it was a significant predictor of picture naming accuracy, with generally better performance for typical items. To date this variable has been mostly neglected when controlling for psycholinguistic variables on (spoken) word production (see also Sandberg, Sebastian, & Kiran, 2012).

3.3 Semantic neighbourhood

Semantic neighbourhood density refers to how many items there are that are related in meaning to the target word (although there are a number of different ways that this has been calculated in the literature; e.g., Bormann, 2011; Kittredge, Dell, & Schwartz, 2007; Mirman, 2011). Whether there are facilitatory or inhibitory effects may depend on the semantic relationship (e.g., shared feature (cat-dog); associate (cat-basket)). The locus of these effects is likely to be in the interface between semantic and lexical-syntax processing (or semantics and phonological form if there is no intervening syntactic level as, for example, proposed by Caramazza, 1997).

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3.4 Frequency

Frequency is measured from objective counts of how often a word is used in everyday (spoken) language. For example, 'phone' is uttered more frequently than 'abode'. The more frequently a word is used, the faster it is produced and/or the less errors occur. *Frequency* is strongly correlated with *age-of-acquisition and length*. It is generally assumed to have its effects at the level of the lexical system, for spoken word production this would concern the phonological output lexicon. However, the issue is not without debate (see, e.g., Jescheniak & Levelt, 1994) and some authors suggest that frequency affects all levels of processing (see for example, Navarette, Benedetta, Alario, & Costa, 2006; Kittredge, Dell, Verkuilen, & Schwartz, 2008; Knobel, Finkbeiner, & Caramazza, 2008). In theories with interaction between levels, in particular, the effects of frequency may be observed across all levels of processing.

3.5 Age-of-acquisition

Age of Acquisition is strongly correlated with frequency, imageability and word length, and is usually measured as a rating of the age at which a word was first learned. Usually early acquired words are processed faster and are less error prone than words learned late in life. While there has been some debate regarding the locus of age-of-acquisition effects, many researchers suggest it relates to retrieval from the phonological output lexicon (e.g. Alario et al., 2004).

3.6 Phonological neighborhood

Phonological Neighborhood is defined as the number of words which differ from the target by only one phoneme (e.g., mine, pine, mime, mane). The effects of phonological neighbourhood density are complex, with some authors suggesting facilitatory effects (e.g., Baus, Costa & Carreiras, 2008; Mirman, Kittredge, & Dell, 2010) and others (e.g., Sadat, Martin, Costa, & Alario, 2014) suggesting that a dense phonological neighborhood causes inhibition in both unimpaired and impaired spoken word production. Phonological neighbourhood has been hypothesised to have its effects at the phonological word form level, the phoneme level and/or between these levels.

3.7 Word length

Word Length has its effects after the word form has been accessed. Although there is little evidence for an effect of *word length* on picture naming latencies, words with

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more phonemes are more prone to error than words with fewer phonemes in people with aphasia (Nickels & Howard, 1995; 2004). This has been attributed to impairments of the phonological buffer (that serves as a working memory for meaningful sounds) and/or phonological encoding: activation and maintenance of activation of phonemes, and/or selecting phonemes and/or inserting those phonemes into syllable frames.

4 The impairment of spoken word production

The cognitive neuropsychological approach uses as its core methodology the localisation of language breakdown within cognitive models of language processing, such as those discussed above. This approach not only ensures that we understand the breakdown of language in all its different forms, but also helps us to acknowledge the very many possibilities for language breakdown that can potentially be observed within a given theory (Coltheart, Patterson, & Marshall 1980; Marshall, 1984). In turn, the different patterns of language impairment can help us to understand the limitations of our current theories, and hence can be the basis for further expansion of our theoretical understanding.

4.1 Acquired impairments: Word finding difficulties in adult speakers with aphasia

In this section, we will demonstrate how to localise the source of speech errors in the language production system, although as is noted below it is not a one-to-one correspondence between speech errors and level of impairment (see also, Lorenz & Ziegler, 2009).

We will illustrate this localisation using examples from three people with aphasia following a stroke: GSW (Nickels, unpublished), AER and CI (Nickels, 1992; Nickels & Howard, 1995; 2004). On the same set of pictures, AER, GSW, and CI show approximately the same accuracy in picture naming (AER: 54% correct, GSW 52%, CI 58%). However, importantly, even though accuracy is similar, we cannot conclude that they have the same impairment. Critically, their error responses differ which gives us (partial) insight into their level of breakdown (see Figure 5). AER and GSW produce responses that are related to their targets in meaning (semantic errors; e.g 'trumpet' produced for 'saxophone') or descriptions of the target (e.g., 'a dog's residence' for 'kennel'). In contrast, CI's errors consist mostly of responses which share many of the phonological segments of the target (e.g., producing /ɛləvænt/ for 'elefant').

We will now discuss the origins of these errors, within the architecture derived from the Logogen model as depicted in Figure 1.

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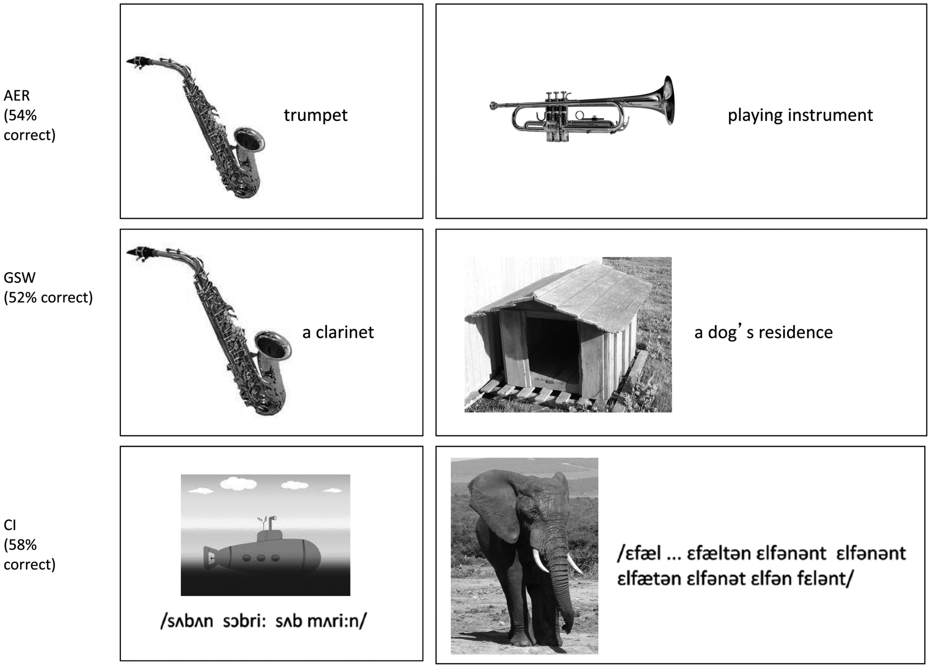

Figure 5: Different picture naming responses of AER, GSW, and CI

4.1.1 Origins of semantic errors

Semantic errors, such as naming a saxophone as a 'trumpet', are common in the spoken word production of many people with aphasia but also occur in the speech errors of unimpaired speakers. Importantly, this type of error can originate from more than one functional location in the process of spoken word production (e.g., Caramazza & Hillis, 1990; Lorenz & Ziegler, 2009): i) an impaired semantic system; ii) the links between the semantic and the phonological levels; iii) the phonological output lexicon (as a framework see Figure 1).

4.1.2 Determining the source of semantic errors?

If the impairment concerns the semantic system directly (e.g., JBR, Warrington & Shallice, 1984; JCU: Howard & Orchard-Lisle, 1984), tasks that use different modalities that use semantic information will all be impaired (e.g., spoken picture naming, written picture naming, spoken and written word-picture matching). However, tasks that do not require semantic processing can be unaffected (in the absence of any additional impairment; e.g., reading aloud of regular words or non-words, auditory

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repetition). Presenting a phonological cue for a semantically related item might cause the 'wrong' target production. For example, when a picture of a tiger is presented, giving the phoneme /l/ may trigger the response 'lion'.

If the impairment is located in the link between the semantic system and the phonological word form level or at the phonological level itself, then (in the absence of additional impairments) comprehension of spoken and written words will be intact, as will written naming.

However, it is important to note, that not only can semantic errors arise as a result of these different impairments, these impairments can result in different types of error, although semantic errors are the most common: Each of the three possible sources of impairment also can result in 'no responses' and, when the impairment is severe, responses unrelated to the target.

For impairments in the link between the semantic system and the phonological word form level, other errors may have some of the characteristics of 'tip-of-the-tongue' responses: for example, producing a detailed semantic description such as 'it's a wild animal', or 'it has stripes'). Sometimes, depending on the target language, grammatical gender might be available in such a word form search (e.g., for German 'der' ... 'der' ... [Tiger]).

4.1.3 Origins of phonological errors

Responses that share sounds with their targets (e.g., producing /ɛləvænt/ for 'elefant', or 'sheet' for 'sheep') can also arise from different sources: i) the phonological output lexicon, ii) the link from the phonological output lexicon to the phoneme level or buffer, iii) the phoneme system/ buffer itself, and iv) phonetic processes.

4.1.4 Determining the source of phonological errors

With all levels of impairment that result in phonological errors, comprehension and written naming should be unimpaired.

Traditionally, phonological output lexicon impairments have been thought to result in phonological errors (e.g., Nickels, 1997). For example, Kay and Ellis (1987) reported the (now) classic case of EST, who suffered from phonological anomia, showing intact comprehension, but poor spoken output. However, more recently it has been debated whether impairments to the phonological lexicon can result in phonological errors (compare e.g., Nickels, 2001, & Friedmann et al., 2013). It is clear that with this level of impairment, all non-lexical production tasks should be unimpaired (reading aloud of regular words and nonwords, repetition). The phonological errors that arise from this level of impairment will tend to be real words (e.g. 'sheet' for 'sheep').

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If the impairment is in the links from word form level to phoneme level or at the phoneme level itself, phoneme deletions, additions, or exchanges are expected and longer words will be particularly impaired. In contrast, metrical structure is generally intact (e.g., syllable number, stress pattern).

If the impairment is at post-phoneme level/ post-buffer, involving phonological and phonetic encoding (e.g. inserting phonemes into syllable plans, retrieving, unpacking and producing syllable patterns), the pattern may be similar to those of a phoneme level/buffer impairment, however, in addition, there may be effects of syllable complexity on performance (e.g., presence vs absence of consonant clusters) and features of apraxia of speech. Theories of spoken word production such as those introduced earlier often not specify these levels of processing. For these types of impairments, we require a model that maps lexical and post-lexical processes onto motor processes (e.g., Hickok, 2012).

4.2 Developmental impairments: Word-finding difficulties in children

While in acquired disorders, problems in spoken word retrieval are described as 'anomia', in the developmental literature they are more commonly called 'word-finding difficulties' (WFD). These impairments are not uncommon in children, and they often co-occur with other language and/or cognitive impairments (Best, 2005, Friedmann et al., 2013): Word finding difficulties are reported to occur in 23% of children with language impairment (Dockrell, Messer, George, & Wilson, 1998) and in 50% of children with learning disabilities (German, 1998). Children produce the similar kinds of errors to those that are observed in acquired anomia.

As is common in developmental fields, often there has been a tendency for WFD to be ascribed to a single underlying impairment. However, it is clear, that like adults different children may have different underlying impairments (e.g., Best, 2005) and adult language production theories may be used for the localisation of underlying impairment(s) of WFD in children, (e.g., Levelt et al. 1989; 1999) as, to date, no detailed developmental theory of lexical access exists (Dockrell & Messer, 2004). In the same way as in adults, WFD can be the result of impairments of both *storage of* or *access to* semantic or phonological representations (Best, 2005; Faust, Dimitrovsky and Davidi, 1997; Kail and Leonard, 1986). In addition to modality-specific accounts, WFD in the context of co-occurring specific language impairments and/or dyslexia have been accounted for by more general underlying deficits, such as impaired auditory processing (e.g., Bishop, 1997; Tallal & Stark, 1981) which are beyond the scope of this review.

Despite the fact that a diagnostic criterion of word finding difficulties has been better comprehension than production, semantic impairments are nevertheless commonly ascribed as an underlying locus of impairment. Children with this level of impairment have difficulties in both language production and comprehension (Best,

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2005). A number of studies have argued for a phonological locus of impairment, as children with WFD were found to produce lower proportions of semantic errors (McGregor, 1997), and higher proportions of phonological errors (Dockrell, Messer & George, 2001) compared to controls. Moreover, as noted above, semantic errors can be caused by phonological access problems (McGregor, 1994; Messer & Dockrell, 2006). Evidence for a phonological origin of children's WFD comes from studies which have found an influence of lexical variables (e.g., frequency, phonological neighbourhood density) on naming accuracy and error types (German & Newman, 2004; Newman & German, 2002), single case studies which have found impaired performance on phonologically based tasks (Chiat & Hunt, 1993; Constable, Stackhouse & Wells, 1997), and intervention studies where phonologically based treatment improved word finding by decreasing semantic and/or phonological errors (e.g., Best, 2005; German, 2002; McGregor, 1994).

In sum, there is no single underlying cause of WFD in children: just as in adults with aphasia, individual children have different levels of impairment as is clearly illustrated in the case studies described by Best (2005).

5 Impairment and theory – A reciprocal relationship

Just as theoretical accounts can help us to understand the nature of language impairment(s), language impairments can help us to evaluate the adequacy of our theoretical models and further specify the nature of processing and representation. Here, we use an example from the empirical investigation of lexical-syntactic impairments to inform our understanding of lexical-syntactic processing.

Countability is a grammatical and semantic characteristic which divides nouns into mass nouns (e.g., milk, rice) and count nouns (e.g., chair, cat). Mass nouns are unusual in that they cannot be grammatically pluralised (e.g., cats vs. *rices), combined with numerals (e.g., three cats vs. *three rices) or quantifiers that denumerate (e.g., many cats vs. *many rice). Semantically, count nouns mostly represent individual entities with clear boundaries, while mass nouns often represent substances and aggregates without clear boundaries. There has been debate in the literature regarding whether the difference between mass and count nouns is coded at the level of lexical-syntax or lexical-semantics.

We have used data from people with aphasia to inform this debate (Fieder, Nickels, Biedermann, & Best, 2014; Fieder, Nickels, Biedermann, & Best, 2015). RAP and DEH were more impaired in describing pictures with noun phrases when those phrases required mass nouns (e.g., some rice) compared to when they required count nouns (e.g., a cat) (RAP 67% mass, 90% count; DEH 17% mass, 77% count). Interestingly, neither DEH nor RAP had more difficulties in naming pictures with a mass noun compared to count nouns when a phrase was not required (e.g., rice vs. cat; RAP 81% mass, 72% count; DEH 69% mass, 69% count). This allowed us to conclude that the problem with mass noun phrases was not due to a problem

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with the representation and processing of the individual mass nouns. We also determined that DEH and RAP did not have a problem with producing the determiners they needed to use to make the phrases – the same determiner could be produced correctly when needed for count noun phrases: For example, producing "*a rice" for "some rice" (mass), but correctly producing "some cats" (count); or producing "*these sugar" for "this sugar" but "this cat" (count) see Figure 6a and 6b). This pattern indicated that the phonological forms of the determiners were accessible.

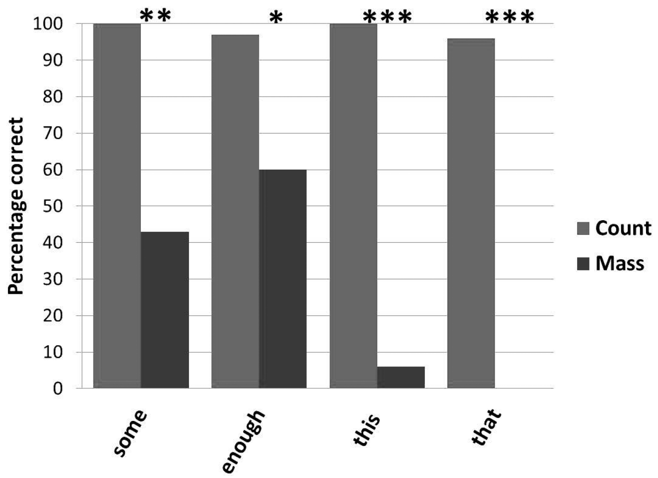

Figure 6a: RAP's determiner accuracy for the determiners which are shared between mass and singular/plural count nouns in the different picture naming tasks with NPs.

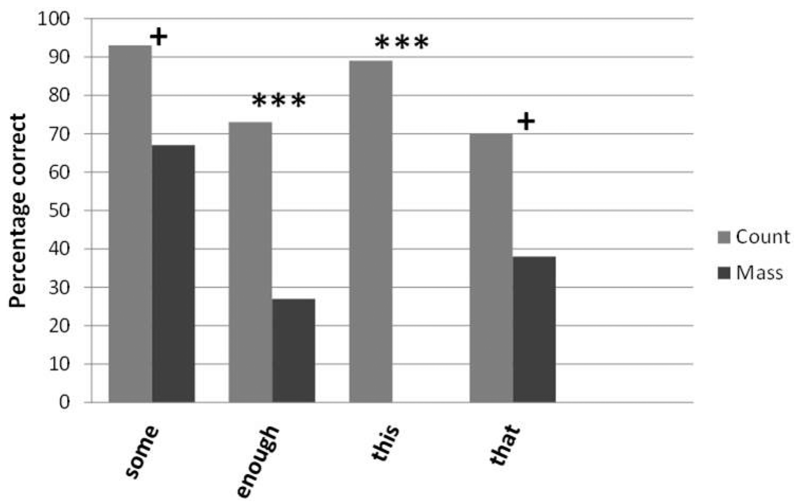

Figure 6b: DEH's determiner accuracy for the determiners which are shared between mass and singular/plural count nouns in the different picture naming tasks with NPs.

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To explain these data, where the same words (determiners) can be produced in one context but not another, requires a model which can distinguish between the contexts. Here, the contexts are different only in that one refers to mass nouns and the other to count nouns – which establishes a difference in lexical syntax. Hence, only models that include lexical syntax can account for the data – which is evidence against the Logogen model. Moreover, as in Caramazza et al.'s Independent Network model (Figure 4), lexical syntax is only activated *after* phonology, it is also hard to see how this model can account for the data. However, Levelt et al.'s Two-Step model (Figure 2) and the Dell et al.'s Interactive Activation model (Figure 3) both comprise a lexical-syntactic level which *precedes* activation of phonology, and are therefore consistent with these data (although Dell et al. is not sufficiently specified to unequivocally determine).

In sum, RAP and DEH's mass specific difficulties could be ascribed to an impairment at the lexical-syntactic level. The results provided evidence that countability (whether a noun is mass or count) is specified at a separate lexical-syntactic level and influences the selection of mass noun determiners.

6 Treatment as a tool for theory development

Once again, while localising impairment within theoretical accounts can help guide treatment, Nickels, Kohnen, & Biedermann (2010) highlighted the potential of treatment as a tool to develop and test cognitive theories. One of the major methods used in treatment to inform theory is generalisation, a concept in treatment that refers to improvement of items beyond the treated sets. Generalisation can occur within modality, across items or across modalities. In this section, we will demonstrate how two opposing psycholinguistic theories concerning the representation(s) of homophones (words that sound the same, but have different meanings, such as 'knight' and 'night') can be disentangled with the help of treatment of anomia. For homophones, the Two-Step model (Levelt et al., 1999) and the Interactive Activation model (e.g., Dell, 1990) propose that the two homophonic words share a phonological representation at word form level (see Figure 7a), whereas Caramazza's Interactive Network model proposes each homophone has an independent phonological representation (e.g., Caramazza, 1997) (see Figure 7b).

Our approach, inspired by Blanken (1989), capitalised on the fact that phonological treatment of anomia in aphasia usually results in item-specific improvement which is attributed to improved retrieval of the phonological form from the lexicon (Nickels, 2002). This provided an ideal test basis for examining the representation of homophones: if there are independent word form representations for homophones, then treatment of one homophone ("night") should not improve naming of the other (untreated) homophone ("knight"). If, however, homophones share a phonological

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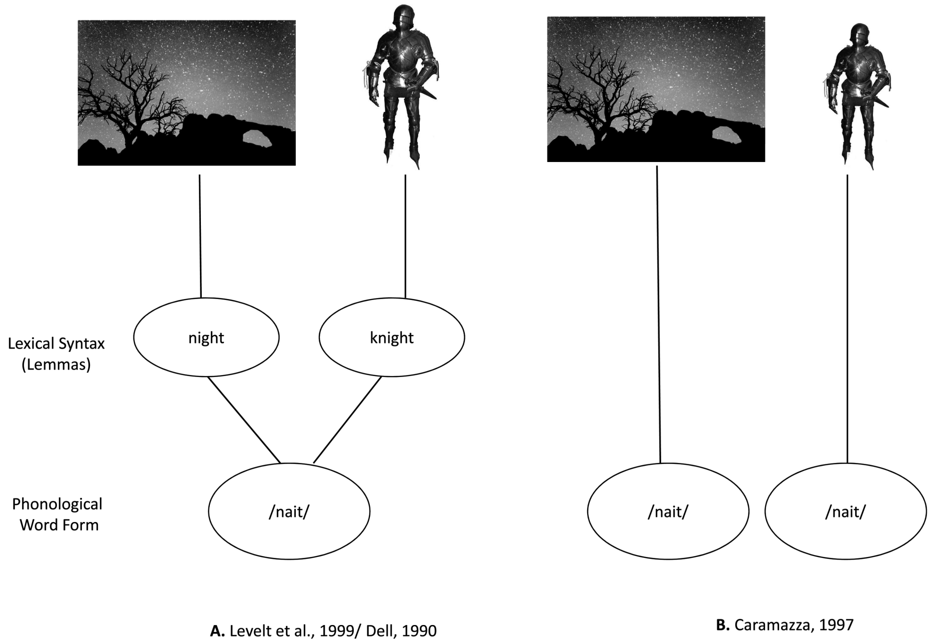

Figure 7: Opposing assumptions about homophone representations

representation, improved naming of one homophone ("night") following treatment should generalise to improved naming of the untreated homophone partner ("knight"). This underlying hypothesis underpinned three experiments with three people with aphasia and breakdown at the phonological word form level. All three experiments used the same paradigm: treatment for spoken picture naming using a phonological cueing hierarchy (one training was carried out in German: Biedermann, Nickels, & Blanken, 2002; and two in Australian English: Biedermann & Nickels, 2008a;b). The picture naming treatment involved the training of only one homophone partner, while the other was never depicted or referred to during treatment. Before and after training, picture naming performance for the treated homophone, the untreated homophone partner, an untreated phonologically related control group, and a semantically related control group was measured. After treatment we found the treated *and* the untreated homophone partner improved in naming performance, while phonologically and semantically related control items did not improve, as was predicted by the shared representation hypothesis. For example, treatment of 'night' improved naming for not only 'night' but also 'knight', but no improvement was observed for 'kite' or 'day' (see Figure 8).

This study illustrates how we can use the effects of treatment of spoken word production impairments to reveal the underlying organisation in our mental lexicon: in this case we found evidence supporting shared phonological representations for

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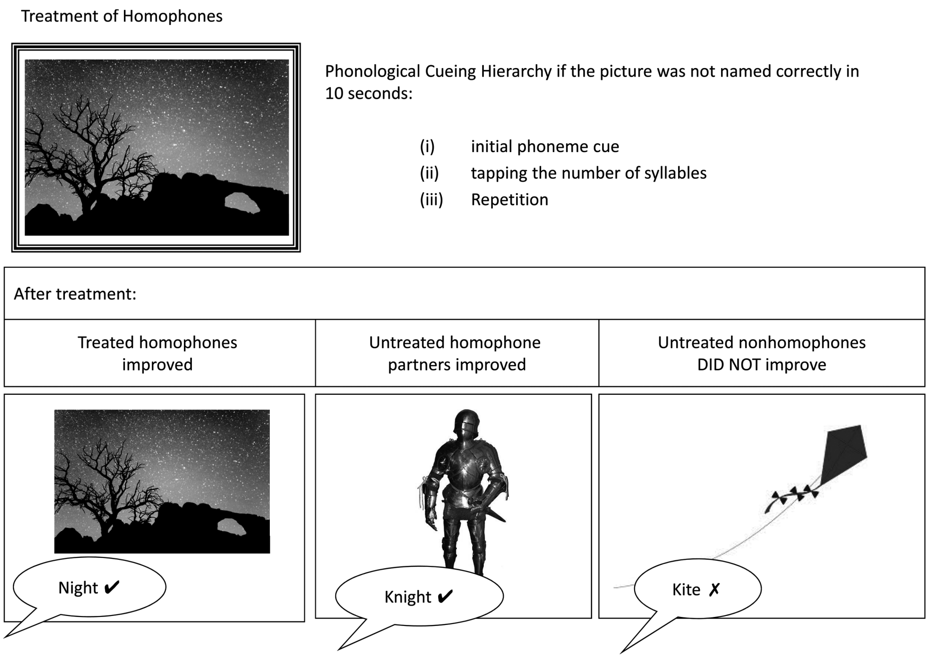

Figure 8: Homophone treatment results (e.g., Biedermann and Nickels, 2008a;b)

homophones, that supports the assumption of Levelt et al.'s Two-Step model (Figure 2) and Dell et al.'s Interactive Activation model (Figure 3), and rejects the independent word form representation view postulated by Caramazza et al.'s Independent Network model (Figure 4). The Logogen model (Figure 1) is agnostic when it comes to shared or independent or shared word form representations in the phonological word form lexicon.

7 Conclusions

This chapter has aimed to highlight the multi-faceted issue of how spoken word production can breakdown. Speech errors that look the same might mask different sources of breakdown, but can be disentangled by careful use of convergent evidence from additional tasks, that enable identification of differences in (the) functional deficit(s). As Marshall (1984) first pointed out, because of the number of different components and connections in the language system, there are many hundreds of different potential combinations of impairment (see also Coltheart, 2001), consequently a syndrome-based approach is inappropriate and we need to work out the precise breakdown for each individual. The underlying theories that are needed to achieve this require an interdisciplinary approach. It requires evidence from psycholinguistic data sets as

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well as cognitive neuropsychological assessment tools and data sets together to inform our theories of the mental lexicon. It is only with well specified theories that we will be able to truly understand the nature of the impairment in language disorders and, hence, ensure that our treatment is accurately targeted.

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