SEMANTICS IN SPEECH PRODUCTION

A thesis submitted to the University of Manchester
for the degree of Doctor of Philosophy in the
Faculty of Medical and Human Sciences

2011

MAYA SONI

School of Psychological Sciences

Table of contents

Word count: 64, 137

List of Tables

List of Figures

List of Appendices

ABSTRACT

The semantic system contributes to the process of speech production in two major ways. The basic information is contained within semantic representations, and the semantic control system manipulates that knowledge as required by task and context. This thesis explored the evidence for interactivity between semantic and phonological stages of speech production, and examined the role of semantic control within speech production. The data chapters focussed on patients with semantic aphasia or SA, who all have frontal and/or temporoparietal lesions and are thought to have a specific impairment of semantic control. In a novel development, grammatical class and cueing effects in this patient group were compared with healthy participants under tempo naming conditions, a paradigm which is thought to impair normal semantic control by imposing dual task conditions. A basic picture naming paradigm was used throughout, with the addition of different grammatical classes, correct and misleading phonemic cues, and repetition and semantic priming: all these manipulations could be expected to place differing loads on a semantic control system with either permanent or experimentally induced impairment. It was found that stimuli requiring less controlled processing such as high imageability objects, pictures with simultaneous correct cues or repetition primed pictures were named significantly more accurately than items which needed more controlled processing, such as low imageability actions, pictures with misleading phonemic cues and unprimed pictures. The cueing evidence offered support to interactive models of speech production where phonological activation is able to influence semantic selection. The impairment in tasks such as the inhibition of task-irrelevant material seen in SA patients and tempo participants, and the overlap between cortical areas cited in studies looking at both semantic and wider executive control mechanisms suggest that semantic control may be part of a more generalised executive system.

Declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright Statement

i. The author of this thesis (including any appendices and/or schedules to this thesis) owns any copyright in it (the “Copyright”) and she has given the University of Manchester the right to use such Copyright for any administrative, promotional, educational and/or teaching purposes.

ii. Copies of this thesis, either in full or in extracts may be made **only** in accordance with the regulations of the John Rylands University Library of Manchester. Details of these regulations may be obtained from the Librarian. This page must form part of any such copies made.

iii. The ownership of any patents, designs, trade marks and any and all other intellectual property rights except for the Copyright (the “Intellectual Property Rights”) and any reproductions of copyright works, for example graphs and tables (“Reproductions”), which may be described in this thesis, may not be owned by the author and may be owned by third parties. Such Intellectual Property Rights and Reproductions cannot and must not be made available for use without the prior written permission of the owner(s) of the relevant Intellectual Property Rights and/or Reproductions.

iv. Further information on the conditions under which disclosure, publication and exploitation of this thesis, the Copyright and any Intellectual Property Rights and/or Reproductions described in it may take place is available from the Head of the School of Psychological Sciences or the Vice-President and the Dean of the Faculty of Medical and Human Sciences.

Acknowledgements

I would like to thank my supervisors, firstly Professor Matt Lambon Ralph, who saw me through from occasional undergraduate classes to the end of my doctorate; secondly Dr. Catherine Hodgson, who oversaw my Masters in Research Design and the first year of my PhD; and third (but not least) Dr. Anna Woollams, who took me through to the completion of this thesis. They all provided me with inspiration, ideas, technical expertise, and perhaps most importantly, the belief that I could do it. Drs. Hodgson and Woollams also provided much needed sideline chats on child rearing. Thanks are also due to Ms. Sheeba Ehsan, Dr. Faye Corbett and Dr. Paul Hoffman for their invaluable assistance in the collection of my data. I also feel privileged to have worked in the wider community of NARU, which was a helpful and supportive working environment. Thanks also to the ESRC, whose funding made my studies possible. I must sincerely thank the patients I worked with, BB, EW, HN, JD, ME, NY, PG and SC: none of this work would be possible without their continued effort and friendly co-operation, and I very much enjoyed working with them all. Thanks to my Mum and Dad, who waited a long time for this. Finally, to my immediate family: this grew from just partner Jonny Tysoe at the beginning of the process to include my lovely boys Riley and Louis by the end – thanks for putting up with me and my “homework” for so long.

The Author

I entered higher education late, deciding on a degree in Linguistics at the University of Manchester. I have always also been interested in biology, and my teachers in the Linguistics department encouraged this theme by allowing me to take courses in Biological Science and Psychology, thus developing my fascination with the neural bases for language. In my final semester at undergraduate level, I took a class with Professor Lambon Ralph on the cognitive neuroscience of language and memory. This led to my opportunity to continue at the University of Manchester, undertaking a Masters in Research Design followed by a PhD in Psychology, supervised by Professor Lambon Ralph and Dr. Catherine Hodgson, later replaced by Dr. Anna Woollams. My postgraduate research has focussed on how the semantic system is involved during speech production, both in stroke patients with semantic aphasia (SA) and healthy participants.

CHAPTER 1

INTRODUCTORY CHAPTER

Overview of thesis

This thesis is presented in alternative format: each of the five data chapters is written as a stand alone journal article. The chapters that have already been published or submitted for publication will be cited as such in the text. The experimental chapters are preceded by an Introductory Chapter, designed to give an overview of the main research themes, questions and methods of the thesis. Background literature will be explored to give a theoretical basis for the following experimental work, and a précis of each data chapter will be included. After the data chapters (2 – 6), the final Discussion Chapter will review the themes raised in the Introduction, indicating how the findings that emerged from the research combine to address the key questions of the thesis.

Thesis aims and key research questions

In the broadest terms, this thesis examines how the semantic system engages with the process of speech production. There are two parts to semantic cognition: semantic representations, which may be characterized as the store of semantic information, and semantic control, or how we utilize our stored knowledge to successfully complete the task at hand (2006; Jefferies, Patterson, & Lambon Ralph, 2008). In this set of experiments we study the semantic contribution to speech production as exemplified by single word picture naming, using behavioural measures such as reaction times, accuracy, and error types; semantic errors in particular can reveal the processing stages which have taken place. However, the literature offers several competing theories of speech production encompassing different architecture and relationships between processing stages, leading to my first Research Theme:

1. Interactivity between semantics and phonology during speech production, and what can occur when naming fails.

The second section of the Introductory Chapter looks at the more mobile, online aspect of semantic cognition, semantic control. This can be described as the way that particular elements of semantic knowledge are brought to the fore when relevant to the task in hand. For example, there are many things that can be known about a piano, from the musical structure represented by its keys to its weight and size (Saffran, 2000). In order to play the piano one must access certain elements of that knowledge, but in order to move it an entirely different set of facts must be utilized: the knowledge used to achieve one task will not serve to achieve the other. The semantic control system, when working efficiently, selects the appropriate elements from the pool of potentially relevant knowledge. The semantic aphasic or SA patients who took part in this series of experiments are an apt group in which to explore this aspect of speech production, as they are known to have difficulties with semantic control in the presence of relatively preserved semantic representations (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Noonan, Jefferies, Corbett, & Lambon Ralph, 2010; Soni et al., 2009; Soni, Lambon Ralph, & Woollams, in press). Research Theme 2 can therefore be posed as:

2. Semantic control in speech production: its function and associated anatomical structures, and the effect of semantic control deficits in SA.

Once the behavioural profile of the SA group has been explored with reference to semantic control in speech production, we turn to a methodology which is thought to induce similar control deficits in healthy participants, namely tempo picture naming. Although initially developed for use with word reading (Kello & Plaut, 2000), Hodgson and Lambon Ralph (2008) adapted the tempo task to use with picture naming, where it was shown to produce error patterns in normal participants that mimicked those seen in SA patients. Using audio and visual cues, the tempo procedure sets up a rhythm in which response initiation is strictly controlled. Hodgson and Lambon Ralph (2008) concluded that the tight timing requirements reduce available executive resources that might otherwise be available for accurate response selection. Tempo naming is therefore reasoned to interfere with semantic control in an analogous way to the SA patients' lesions, making it suitable for the series of direct comparisons with this patient group presented in Chapters 2 – 4. With its focus on performing two task elements simultaneously, response selection and timing, tempo naming has been likened to a dual task, similar to those used to investigate more general executive control mechanisms. A major question in this field is whether the more constrained semantic control system could be part of the wider executive control system which operates in other cognitive and behavioural realms. Research Theme 3 can be characterized thus:

3. The effect of tempo naming on semantic control and the relationship of semantic control to a wider executive network.

THEME 1:

Interactivity between semantics and phonology during speech production, and what can occur when naming fails.

Before the detailed discussion of models of speech production, Research Theme 1 briefly examines some models the organisation of semantic memory and the nature of semantic representations, which are after all the raw material with which speech production processes work. The next section begins the examination of speech production by looking at the time course of lexical access, about which there is some consensus amongst different speech production models. This will be followed by an examination of some of the most influential theories of speech production: one type is the two stage[1] model, within which we consider both discrete and interactive subtypes, and in the subsequent section, parallel distributed processing or PDP models will be considered. The overall architecture of each will be examined, in addition to evidence from the literature of how well they account for observed empirical effects. Research Theme 1 concludes with a section on the potential origins of semantic errors in the competing theories of speech production, as semantic errors are one of the chief behavioural effects studied in the following data chapters.

Semantic representations and the organisation of semantic memory

Models of semantic representation have in general been designed to accommodate concrete objects (e.g., Rogers et al., 2004; Rosch, Mervis, Gray, Johnson & Boyes-Braem, 1976; Warrington, 1975), with focus upon the interrelationships between similar items (co-ordinates) and taxonomic-style hierarchies such as categories/superordinates (e.g., furniture) – basic level objects (e.g., chair) – subordinate level objects (e.g., dining chair) – composite features (e.g., seat, legs, back, etc.). Far less attention has been paid to other types of relationship between objects, for example an associative relationship between items from different categories, both between real world items like producer

---

[1] Refers to conceptual/semantic and phonological stages of processing (Garrett, 1980).

and product (e.g., cow, milk) or verbal associations (e.g., cat, mouse), which are nonetheless rooted in real world connections. Similarly, models of semantic representation are not usually built to accommodate action naming, which is far less easy to classify hierarchically (e.g., human bodily movement (category) – jump (basic level) – upright posture, both feet leaving the ground (features)?). The experiments in this thesis examine both action naming (Chapter 2) and associative relationships (Chapter 4).

One model which did attempt to include all the items related to a target, whatever the type of relationship, was proposed by Collins and Loftus (1975). On activation of a target, activation was hypothesised to flow to all items that had a conceptual link to it, including categorically related items, associates and also properties (e.g., colour). An earlier model of semantic concepts by Quillian (1967) cited by Collins and Loftus (1975) also specifically codes verbs as present in the links between two involved entities, in effect forming a concept in themselves. However, inclusion of verbs in models of semantic representation is relatively rare. Bird, Howard and Franklin (2000) compared verbs to inanimate objects, citing their common property of more functional and fewer perceptual features in comparison with the reverse balance for concrete, animate objects. Nouns are generally held to have higher imageability than verbs, giving concrete objects semantic representations which are held to be richer or more detailed in content than actions (Bird, Howard & Franklin, 2003), although certain classes of noun, namely abstract nouns, may group more towards verbs due to their lower imageability and lack of concreteness (Hoffman, Jefferies & Lambon Ralph, 2011). This distinction between concrete and abstract objects has also been explored in a series of papers by Crutch and Warrington (2005, 2006, 2009), where it is asserted that concrete objects are linked to categorically related information whereas abstract objects are represented in associative networks. This distinction is evaluated in Chapter 4, where the effect of associatively related cues on (concrete) object naming is tested.

In an early theory of the organisation of semantic memory, Warrington (1975) asserted that categorization proceeds from the specific example directly to the highest level, then down the hierarchy through each level in turn (for example LIVING-ANIMAL-BIRD-DUCK-MALLARD). Collins and Loftus (1975) argue for activation proceeding successively upwards through the hierarchy (MALLARD-DUCK-BIRD-ANIMAL-LIVING). However, these theories share the idea of hierarchical organisation of semantic memory. A contrasting idea of the organisation of semantic memory is represented well by PDP models where a distributed bank of features allows the ‘online’ computation of any particular concept when it is demanded by the task at hand (e.g. Hodges, Graham & Patterson, 1995; Martin & Chao, 2001; Rogers et al., 2004). A distributed account which allows for the influence of context therefore melds well with our hypothesis on semantic control (see Research Theme 2), which is based on the interaction between context and the semantic representational system.

The time course of lexical access

The process of speech production encompasses everything from conception of the response to be spoken through to articulatory planning and execution, but this review will focus on the part of the process from activation of semantic concepts to phonological planning as applied to single word production. Before looking in more detail at the varying theories of speech production, it is necessary to examine some more general properties of this process. In connected speech, words are selected at a rate of two to three per second from tens of thousands of potential stored candidates, an extremely fast and efficient process in normal speakers. In all the models considered here, the time course of normal lexical access shows an early semantic phase, and a later phonological phase (Dell & O'Seaghdha, 1992; Garrett, 1975, 1980; Levelt, 1992; Levelt, Roelofs, & Meyer, 1999; Nickels, 2002b; Peterson & Savoy, 1998; Rapp & Goldrick, 2000; Roelofs, 1997). In ‘two stage’ models, subtypes of which are considered in more detail below, these processes are clearly instantiated in the architecture, although varying in the degree to which they operate serially or in parallel. Even parallel distributed processing or PDP models which are structured quite differently have both semantic and phonological processing units: although these systems are highly interactive, early activation is largely semantic and the later part mainly phonological (e.g. Lambon Ralph, Moriarty, & Sage, 2002; Levelt et al., 1999; Peterson & Savoy, 1998).

Empirical evidence of these early semantic and later phonological stages comes from several sources. Garrett (1975, 1980) used speech error data from connected speech to distinguish between the two stages. He asserted that whole word errors, which are almost always from the same grammatical class and may often be semantically related (e.g. “toe” for FINGER), derive from the first, semantic stage of processing: this is where concepts are being selected and slotted into appropriate places in a phrase structure.

Sound exchanges (e.g. “heft lemisphere”) occur during the later phonological stage of processing: they do not necessarily respect grammatical class and are often from items occurring close together in a phrase.

Shriefers, Meyer and Levelt (1990) used picture word interference or PWI to highlight the time course of semantic and phonological processing. In this paradigm, pictures to be named are shown with distractors, which may be written words or pictures. These distractors may be shown preceding the target (a negative stimulus onset asynchrony or SOA), simultaneously, or immediately following the target (positive SOA). Furthermore, distractors may be unrelated to the target (e.g., “stone” with a pictured BED), or semantically related (e.g., “sofa” with a pictured BED). Shriefers, Meyer and Levelt (1990) showed that semantically related distractor words (e.g. “goat” with SHEEP) only caused interference (longer latencies) when given at negative SOAs, whereas phonological distractors (e.g. “sheet” with SHEEP) facilitated naming (shorter latencies) when shown simultaneously or with short positive SOAs. From this they concluded that the raised activation of the semantic distractor word was able to disrupt naming because it was activated before the target, affecting the early selection process between close semantic alternatives: the phonological distractor had no effect at this early stage, but later, after a response had been selected, it was able to facilitate selection of its phonological form.

Peterson and Savoy (1998) used a priming paradigm to show that semantic processing occurs at an earlier stage than phonological processing. They presented pictures to be named, which were sometimes followed by a word to be named: SOAs of -50, 100 and 150 ms were used. Words that were semantically related to the immediately preceding picture (e.g. “bed” with COUCH) were named more quickly than unrelated words at the shortest SOA of 50 ms, whereas phonologically related words (e.g. “count” for COUCH) were only named more quickly at the longer SOA of -150 ms. This again showed that semantically related items have an earlier effect on target processing than phonologically related stimuli.

Two stage models of speech production

We now turn to contrasting theories of speech production that attempt to explain the process in fine detail. The most thoroughly specified models are in the form of instantiated computational models which can be used to predict empirical data, and also lesioned to represent aphasic speech patterns. This section will focus on the discrete model (Levelt et al., 1999) and two closely related interactive two stage models (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Foygel & Dell, 2000).

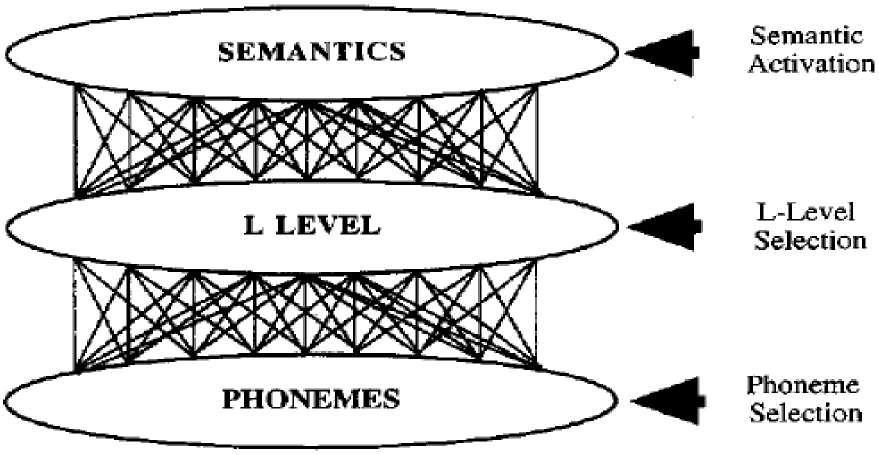


Figure 1.1: Generalized two-stage model of speech production (p. 464, Rapp & Goldrick, 2000)

The diagram above represents a generic ‘two stage’ model of speech production: the transfer from semantics to the intermediate ‘L-Level’ makes up the first stage of processing, and phoneme selection the second stage. ‘L-Level’ stands alternatively for ‘lemmas’ (Dell et al., 1997; Levelt et al., 1999) or ‘lexical nodes’ (Dell & O'Seaghdha, 1991, 1992). The two stage model has its origins in early work by Garrett (1975, 1980), and with various alterations is still subscribed to today by many researchers in the field of speech production. All two stage models share a certain amount of architecture: processing units are grouped into conceptual/semantic, lexical, and phonological layers, and activation spreads through connected units. The first of the two stages is *lexical selection*: a jolt of activation is given to relevant concepts or semantic features, which after *n* time steps results in the selection of the most active item. The second stage, *phonological encoding*, begins with activation spreading from selected word units to relevant phonological units: after *n* time steps a phonologically specified word form is produced.

Even within the conceptual semantic level, there are differences between the discrete and interactive models. The discrete model postulates a single semantic concept which is *nondecompositional* in nature (Levelt et al., 1999; Roelofs, 1993): it is a single whole unit, not broken down into features. Conversely in an interactive two stage model (e.g., Dell et al., 1997; Foygel & Dell 2000), a concept is made up of a number of *semantic features*, some of which may be shared between similar entities. For example, the concepts CAT and DOG would share the feature ‘domestic animal’. Referring again to Figure 1.1, next comes the ‘L-Level’ (Rapp & Goldrick, 2000): both types of model characterize this level as an amodal stage where a semantic concept is linked to the syntactic information necessary to form grammatical utterances, forming a localised unit without phonological information. As lemmas are hypothesised to hold grammatical information, words are potentially marked as nouns or verbs at this stage; issues around the processing of verbs will be more fully discussed in Chapter 2. Both the discrete model (Levelt et al., 1999) and the weight decay model (Dell et al., 1997) term these units ‘lemmas’; the semantic-phonological model prefers the term ‘word node’, but the concepts are similar.

The second stage is where the phonemes of selected lemmas are activated and placed in the correct serial order. A key factor that distinguishes Levelt and colleagues’ discrete WEAVER ++ model (Levelt et al., 1999; Roelofs, 1997) is its assertion there is an absolute separation between lemma selection and phonological encoding. This is a *feedforward* system, with information flowing in one direction only, from concept to articulation: lexical selection produces a single lemma that will be passed on to become phonologically activated. The modules occur in strict serial order: there is assumed to be no *cascading* of information, where output from one level feeds forward to the next level before processing has finished (Humphreys, Riddoch, & Quinlan, 1988; McClelland, 1978). In discrete models there is also no *feedback* of information from later to earlier levels (e.g., Dell, 1986; Martin, Dell, Saffran, & Schwartz, 1994).

In contrast, cascading activation and feedback are both features of interactive models such as the weight decay model (Dell et al., 1997) and the semantic-phonological model (Foygel & Dell, 2000). The models incorporate both seriality and interaction by being globally modular and locally interactive (Dell & O'Seaghdha, 1991): there are still separate stages for lemma selection and phonological encoding, but processing is assumed to proceed partially in parallel. Interactive two stage models are built from bidirectional excitatory connections so that activation spreads back and forth between semantic features and the lemma level, and also between the lemma level and the phonological stage (Dell et al., 1997; Foygel & Dell, 2000; Schwartz, Dell, Martin, Gahl, & Sobel, 2006); there are no inhibitory connections in these models.

What evidence is presented in the literature to support each of these positions? In support of their discrete account, Levelt, Schriefers, Vorburg, Meyer, Pechmann and Havinga (1991) present a picture naming experiment with subsequent auditory probes presented 73ms after the picture: a lexical decision had to be taken on the probe word, which could be a nonword, an unrelated real word, or a real word which was related in various ways to the target. For example, with a picture of SHEEP, the distractor word could be *sheep* (identical), *goat* (semantic distractor), or *sheet* (phonological distractor). In order to test whether a semantic alternative (e.g., *goat*) showed any phonological activation, i.e. whether information on a number of active lemmas had cascaded to the phonological level, a number of trials also incorporated phonological probes related to that semantic alternative (e.g., *goal*). The identical and semantic (*sheep* and *goat*) probes produced increased latency on the lexical decision task, but phonological probes such as *goal* had no effect on latency when presented immediately after a pictured SHEEP. The authors conclude that while multiple lemmas may be active, only the selected lemma (*sheep*) is passed down to phonological processing, i.e., *goat* remains phonologically inactive.

In a similar experiment to Levelt et al. (1991), Peterson and Savoy (1998) used a ‘production priming’ picture naming procedure with healthy participants: intermittently a word appeared straight after the target picture which was also required to be named. It was found that the dominant name of the picture was primed (e.g., COUCH), shown by faster latencies, but also that the names of near synonyms (e.g., SOFA) were also primed. The authors suggest that this is due to several candidates cascading forward from the semantic stage of processing, which then all become phonologically active to some extent. This argues against a strict separation of discrete semantic and phonological processing. In answer to this, Levelt et al. (1999) allow that in the case of near synonyms such as COUCH and SOFA, two lemmas might attain identical levels of activation, thus allowing both to be simultaneously passed down to phonological processing. However, this exception to their original strict assertion of discrete processing levels militates against their strong position, opening the door to some interaction between semantics and phonology.

Convergent evidence from speech error data also points towards interactive accounts, for example the over-representation of mixed errors (producing “rat” for CAT), which occur at greater than chance rate in recorded data. Such an error is both semantically and phonologically related to the target, and would imply that “rat” receives both feedback from the phonological units it shares with “cat”, and lateral spreading activation from CAT at the semantic level. This can be contrasted with a potential error such as “dog”, which is only semantically related to the target. As such, the mixed error effect favours accounts of speech production that incorporate feedback to some extent (Dell & Reich, 1981; Harley, 1984, 1990; Martin, Weisberg, & Saffran, 1989; Schwartz et al., 2006): in a strictly feedforward model there is no locus where phonological activation could influence the selection of an error.

Any explanation of speech production needs to account not just for normal speech, but also for aphasic speech patterns. Evidence about how interactive models may account for aphasic speech patterns comes from the weight decay model (Dell et al., 1997) and the semantic phonological model (Foygel & Dell, 2000). To preface their discussion of aphasic naming errors, Dell et al., (1997) propose the *continuity thesis*, whereby aphasic patterns of speech represent an extension and magnification of errors seen in normal speakers. Their interactive model therefore initially set parameters that would approximate normal speech, which fit well with actual control performance on the Philadelphia Naming Test (Roach, Schwartz, Martin, Grewel, & Brecher, 1996): few errors, mainly semantically related to targets. The model was subsequently ‘lesioned’; the lesions consisted of altering connection weights between units and/or the rate at which activation decayed in individual units. Model lesions purely to connection weights tended to produce more semantic errors, whereas pure ‘decay rate’ lesions tended to produce more nonwords.

The Foygel and Dell (2000) semantic-phonological model built on the strengths and principles of the two stage weight decay model outlined above, but also attempted to make the parameters of the model closer to factors which are of primary importance in theories of speech production, namely semantics and phonology. This model abandoned decay as a manipulable parameter to focus on connection weight strength, divided into semantic-lexical and lexical-phonological connection weights, which were therefore able to be lesioned separately. In each case the authors then attempted to fit the output from differently lesioned models to patterns shown by fluent aphasic stroke patients with various diagnoses including transcortical sensory aphasia (TSA), anomia, conduction and Wernicke's aphasia. In both studies, the authors consider the data supports an interactive two stage model of speech production. In the weight-decay model, the fit between the patients' responses and the model's predictions was within statistical bounds in most cases (with the exception of one patient prone to perseverative errors), although there was also a small but systematic overprediction of semantic errors overall. The semantic-phonological model was equally good at predicting the patterns produced by individual patients, but the focus on semantic and phonological parameters in the architecture more closely represents current psycholinguistic and neuropsychological theory. Schwartz, Dell, Martin, Gahl and Sobel (2006) support the semantic-phonological model's account of aphasic picture naming patterns in a large and varied cohort of aphasic patients.

PDP models

Parallel distributed processing or PDP models have very different architecture from the two stage models described above. There are several general principles that PDP models share, namely that "processing is graded, random, adaptive, interactive, and nonlinear and that representations and knowledge are distributed" (p.99, Plaut, McClelland, Seidenberg, & Patterson, 1996). They incorporate interactivity in a much more complete sense: the activation levels of all units may influence any others in the system due to multiple interconnections between them.

Semantic and phonological processing units are represented independently, but these layers of units act in parallel and interact directly to produce an outcome. Though activation begins largely in semantic units, it cascades to phonological units before a single item is selected, and from there feeds back again to semantic units. Activation reverberates through the system until it converges on a single set of semantic constraints which is most appropriate to the intended message or picture to be named; full activation of the correct phonological units can then proceed (Lambon Ralph, Sage, & Roberts, 2000). Therefore, although the system is nonlinear, the early activation is largely semantic and the later part mainly phonological, corresponding to empirical evidence (e.g. Lambon Ralph et al., 2002; Levelt et al., 1999; Peterson & Savoy, 1998).

PDP models can be instantiated using a learning algorithm such as back-propagation, where the occurrence of errors changes connection weights during a training schedule, allowing regularities in input to settle into patterns over time (Harm & Seidenberg, 2004; Rumelhart, Hinton, & Williams, 1986; Seidenberg & McClelland, 1989). This allows unstructured input to eventually produce internal structure such as semantic categories (Rogers et al., 2004), and stable though distributed 'representations' of individual items (Plaut & Kello, 1999). This sensitivity to statistical regularities allows PDP models to produce output in an extremely fast and 'automatic' manner (Lambon Ralph et al., 2002; Lambon Ralph et al., 2000; Plaut et al., 1996; Plaut & Shallice, 1993).

Some models incorporate hidden units between meaning and form (Harm & Seidenberg, 2004; Plaut & Kello, 1999; Woollams, Joanisse, & Patterson, 2009), which via the learning algorithm come to be responsive to both semantic and phonological input. Hidden units perform a somewhat similar function to the 'L-Level' in two stage models: they represent an intermediate stage between meaning and form. However, representations here are not 'word-like' individuated nodes, but rather distributed patterns of activation amongst the whole layer of units created 'online' to approximate most closely to the intended target: a single unit can contribute to multiple items. The mixed error effect is well accounted for by this feature: units making up the distributed representations of CAT, MAT, DOG and RAT would be shared to a greater or lesser extent; items which are both semantically and phonologically related (e.g., CAT and RAT) would therefore share the greatest number of units, leading to a greater than chance level tendency for this error type.

In Plaut and Kello's (1999) model, speech production is yoked to comprehension, so the same semantic and phonological systems serve for both input and output tasks: this highlights the bidirectional nature of interactions between semantics and phonology, allowing these two systems to guide and constrain each other to produce output. The *primary systems hypothesis* (Lambon Ralph et al., 2002) incorporates interaction between the basic processing systems of semantic memory, phonology and visual processing (orthography) for reading (Patterson & Lambon Ralph, 1999); for picture naming, visual processing would be in the form of object recognition rather than orthography. Aphasic naming patterns such as semantic or phonological errors can readily be accounted for in the 'triangle model' (see Figure 1.2 below) by selective or combined damage to semantic, phonological or visual units (Lambon Ralph et al., 2002).

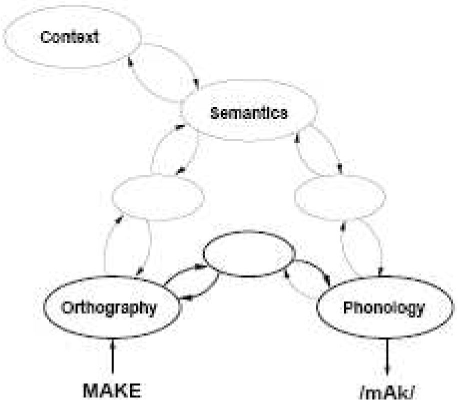


Figure 1.2: Diagram of the triangle model of language processing (p. 526, Seidenberg & McClelland, 1989)

In conclusion, PDP models have the advantage of accounting for the performance of a variety of language tasks such as naming (Lambon Ralph et al., 2002; Lambon Ralph et al., 2000; Rogers et al., 2004), reading (Harm & Seidenberg, 2004; Patterson & Lambon Ralph, 1999; Plaut et al., 1996), past tense generation (Joanisse & Seidenberg, 1999; Woollams et al., 2009) and repetition (Valdois, Carbonnel, David, Rousset, & Pellat, 1995) with resort to the same underlying systems, which have evolutionary plausibility as well as a good fit to current empirical data concerning speech production. It is easy to imagine from earliest human times the development of neural interaction between knowledge of the world (semantic memory), perception of that external world (visual processing), and once even rudimentary language developed, consistent and systematic use of particular sounds (phonology).

The origins of semantic errors

Often the most prevalent error type in both normal and aphasic naming is the semantic error, for example ELBOW → “knee”, and this error type will be focussed on in the coming experimental chapter, so a short discussion of their potential origins is warranted. However, researchers postulate several ways in which these could occur, often linked to the various background frameworks of speech production.

In two stage models, there are two potential origins for a semantic error; deficits at the conceptual level involving semantic features (a central semantic deficit), for example shared semantic features allowing activation to spread to the semantic neighbour of the target as well as the target itself (Schwartz et al., 2006). Separate ‘post-semantic’ impairment is also possible at the level of lexical representations. This dual origin hypothesis is supported in work with acute stroke patients, where damage to Wernicke's area (BA 22) was associated with semantic errors of production combined with semantic errors of comprehension in word-to-picture matching (WPM) tasks (Cloutman et al., 2009). Cloutman et al. argued that these errors were the result of conceptual-semantic level deficits, whereas other patients who made similar semantic errors in production but not in comprehension tasks like WPM (suggesting damage at the level of accessing lexical items) were more likely to show tissue damage in the left occipitotemporal area (BA 37). In a more modular system, Caramazza and Hillis (1990) suggest that patients who show frequent errors in oral naming and reading but who demonstrate unimpaired comprehension of the same items have damage to a phonological output lexicon. This is contrasted with a more central impairment to lexical-semantic processing, where patients show similar errors in both comprehension and output tasks like oral naming and word writing.

PDP models do not postulate semantic errors originating from damage to individuated 'lexical' representations as this level of representation does not exist in such models, which rely on the direct interaction of semantics and phonology to produce distributed semantic representations. However, proponents of distributed models assert that deficits such as anomia, including impairments which elsewhere might be described as 'post-semantic' (production errors with little accompanying comprehension deficit) can be accounted for by damage to semantic and/or phonological units without the need for an abstract lexical level of representation (Lambon Ralph, 1998; Lambon Ralph, McClelland, Patterson, Galton, & Hodges, 2001; Lambon Ralph et al., 2002; Lambon Ralph et al., 2000).

Some semantic errors arise from progressive damage to semantic representations, for example the increasingly typical category members frequently named in semantic dementia or SD such as "horse" or even "animal" for ZEBRA. These errors occur when the fine-grained level of detail is increasingly lost from semantic representations, leaving only gross category features (Bozeat et al., 2003; Rogers et al., 2004; Woollams, Cooper-Pye, Hodges, & Patterson, 2008). The final potential origin of semantic errors covered in this section is the result of a failure of semantic control. These errors might be characterised by the associative semantic error, where the correct semantic representation has clearly been reached, but an incorrect element selected, for example "nuts" for SQUIRREL. These errors arise in conditions such as SA, when the system for manipulating semantic information is damaged, leaving the basic information relatively spared.

THEME 2:

Semantic control in speech production: its function and associated anatomical structures, and the effect of semantic control deficits in semantic aphasia.

The first section of Research Theme 2 will introduce the concept of semantic cognition as the combined input of two separable elements, representations and control, and explore the role of semantic control in the speech production process. The following section will look at the anatomical structures and functional subdivisions which have been related to semantic control within speech production. There will then follow a more detailed exploration of the evidence for the specific deficit to semantic control in SA in the presence of relatively spared semantic representations. Data from SA patients will be used to illustrate the effects of impaired semantic control, and this will be contrasted with a condition which causes damage to representations rather than control, semantic dementia or SD. This comparison will help to show the contributions and potential for independent damage of the two elements of semantic cognition.

What role does semantic control have within speech production?

Semantic cognition appears to consist of two parts, the actual information, contained in semantic representations, and a system for selecting the most appropriate element for the task in hand, semantic control. Semantic representations are obviously crucial to speech production; they are the raw material, what there is to be produced. However, the other part of semantic cognition, semantic control, also has a vital role to play in the fast, accurate assembly of speech online, even at the level of single word naming. This aspect of speech production has been underexplored to date, which provided motivation for the series of experiments presented in this thesis. Although the word ‘control’ might imply some form of strategy consciously employed by patients or participants to enhance test performance, the term ‘semantic control’ in this thesis is used to evoke a deeper level, more automatic process, able to be accessed by experimental manipulation but not necessarily open to conscious direction by participants. Semantic control is rather a property of an internal executive type system which operates on or with stored semantic knowledge, an online process evoked by the interaction between the stimulus and the internal semantic system.

A mechanism for selection amongst multiple candidates, or selection of the appropriate level of response (specific type, basic level object, category), must be incorporated in any instantiated model of speech production. In the WEAVER ++ account (Levelt et al., 1999), target concepts are stored as whole units (the nondecompositional account; Roelofs, 1993). When a concept is selected for production, it must first activate an individuated word node or lemma. Activation spreads from the concept until it meets lemmas which are semantically appropriate: conceptual information may activate several lemmas which are appropriate to varying degrees. A selection mechanism compares the activation of any potential response candidates using the Luce ratio, which weighs the activation of each against all the others. This process produces a single most activated lemma which then goes forward to phonological processing in the serial, discrete WEAVER ++ model. The Luce ratio can be seen as a mechanism in the WEAVER ++ model which accomplishes a similar task as semantic control in the selection of the best candidate during speech production. However, the scope of semantic control is wider than the selection mechanism in WEAVER ++, as in our framework it operates from the conceptual semantic level through a postulated lexical level (not present in PDP models which can also accommodate the concept of semantic control), and can also engage with phonology via the mechanisms of cascading and/or feedback of activation.

The Dell et al. (1997) model allows for both cascading of activation and feedback, such that an original jolt of semantic activation can trickle down to both appropriate lemmas and thence to matching phoneme units, which can then reflect activation back up the system, honing selection at both a semantic and a lemma level. This process leads to a group of active candidates which includes the target and its close semantic and formal neighbours. According to Dell et al. (1997), during single item picture naming the most active noun is then selected from this group. This selection of the most active candidate for production does not preclude the operation of the system we are terming semantic control, which could operate in the framework described above to enhance or facilitate productive pathways (based on the task at hand, for example visual input) and inhibit unproductive ones.

What is not present in either of the speech production models mentioned above is an explicit way to take context into account. This is where the idea of semantic control comes in, as an overt way to accommodate context or task demands. Although in single word naming the context is relatively simple, i.e., the visual stimulus, in most naturalistic speech production situations the demands of context can be complex and subtle. The hypothesised semantic control system is a way to maximise the efficient use of the other part of semantic cognition, the representations, manipulating stored information to meet online task demands (Hodgson & Lambon Ralph, 2008; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009). Although as yet the semantic control system has not been fully instantiated in a computational model, its role in semantic cognition has been depicted in Lambon Ralph and Patterson (2008), rehearsed below in Figure 1.3: semantic control (‘frontoparietal control system’ in the diagram) is shown to have a bidirectional link with amodal semantic representations. We can surmise some of its properties from patients who are deemed to have semantic control deficits. Patients with the multimodal semantic deficit SA are impaired in functions such as the inhibition of prepotent responses, selection amongst multiple competitors, and augmentation of activation for inherently weaker responses, for example targets that are weakly associated with a probe in the presence of a more strongly associated distractor (Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009).

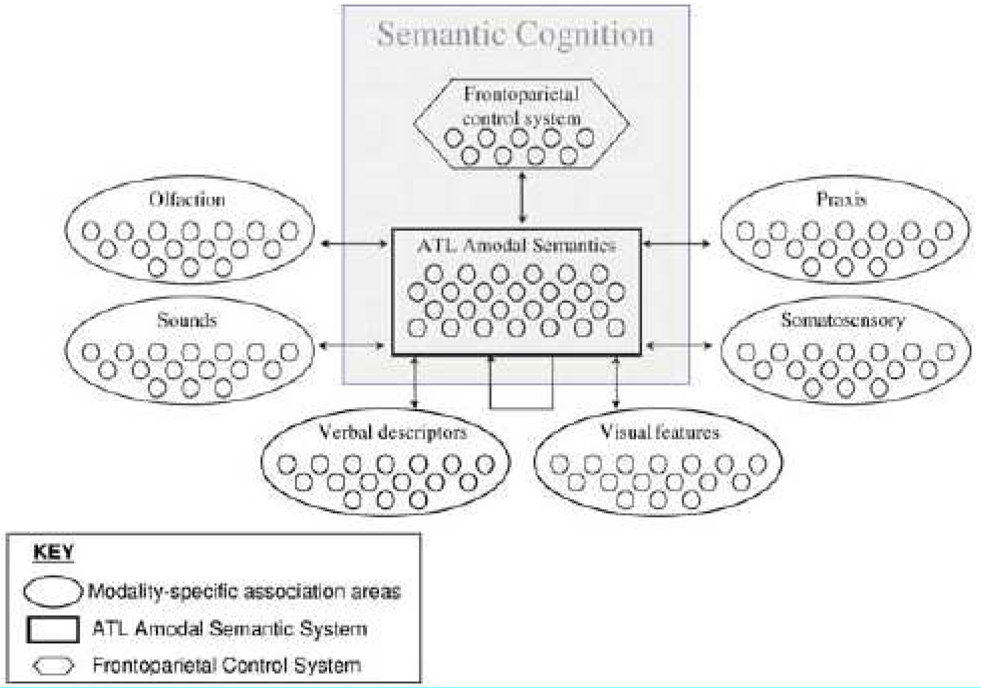


Figure 1.3: Extended theoretical framework for semantic cognition (Figure 4 from p.74, Lambon Ralph & Patterson, 2008)

As well as experimental effects, we may offer further speculation on the exact processes of semantic control during speech production, although these mechanisms have not yet been demonstrated either in human participants or fully instantiated computational models. The basic task accomplished by semantic control during speech production is the facilitation of productive pathways leading to correct naming responses and the hindrance of other pathways which might lead to errors, in other words ‘loading the dice’ towards task appropriate behaviour. It is hypothesised to operate at the semantic level (concepts and/or compositional features) and the lexical level (although in PDP models this step is not modelled). However, if the assumption of interaction between semantic and phonological processing in speech production is followed (as per Dell et al., 1997), semantic control may also engage with phonological processing although based at the semantic and lexical level. We speculate that semantic control may work with ‘automatic’ effects such as the rise in activation of particular semantic features/concepts caused by presentation of a visual stimulus, or any potential lateral inhibition of close semantic neighbours when a target is activated: such rises or falls in activation can be magnified by the semantic control system in order to produce the most appropriate response according to context and task demands. The theory of semantic control proposed here is consistent with both cascading and interaction in speech production, but not with discrete, serial models such as WEAVER ++ (Levelt et al., 1999), although (as noted above) both the Dell et al. (1997) and WEAVER ++ models have mechanisms which might be seen as equivalent to semantic control. PDP models (e.g., Harm & Seidenberg, 2004; Rumelhart et al., 1986; Seidenberg & McClelland, 1989) are also compatible with the idea of semantic control, which would act on semantic units and engage with phonological units while activation reverberates between them (Lambon Ralph et al., 2000), again enhancing useful connections or unit activations and inhibiting unproductive ones.

This facilitation of task appropriate behaviour has two sides, the enhancement of ‘correct’ or useful information and/or links, and the inhibition of ‘incorrect’ or distracting information, which may in some cases be more salient than the target. For example, part of this process could be achieved by enhancing semantic activation which is linked to visual input or strengthening the link between a visual stimulus and a semantic representation (or several), boosting the activation of a small set of semantically related items. In parallel, semantic control could act to synthesise input from other modalities such as auditory information in the cueing paradigm, initiating or strengthening links between levels of processing. When a correct cue is presented (e.g., /t / with TIGER), these two inputs match; hence the control system gathers the two activation boosts, focussing on an item which is highlighted by both modalities and potentially forging (or deepening) a path between them, resulting in faster, more accurate target naming. If a miscue is presented (e.g., /l/ with TIGER), the two inputs do not match: visual and semantic input which is partially appropriate to another candidate (LION) receives a boost of activation either through spreading activation from the target itself, or via overlapping activation of shared semantic features. The semantic control system combines the boost to a competitor’s initial phoneme with its relatively high semantic activation: in effect the system has been ‘tricked’ into facilitating a competitor for production, erroneously linking visual, semantic and phonological information and resulting in a semantic error. In a repetition priming paradigm, the semantic control system would use the previously heightened activation of the prime and (if the prime was named) the links between an item’s visual, semantic and phonological representations as a starting point in a subsequent naming trial, facilitating the naming of the target over items which may be visually similar and have some semantic overlap.

The flipside of this enhancement of productive, useful pathways is the downgrading or inhibition of unproductive activation and links. Although lateral inhibition (by targets on close semantic neighbours) within speech production is still contested in the literature (Levelt et al., 1999; Vitkovitch, Rutter & Read, 2001), inhibition is a core task of more general executive processing (see Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000, and Collette, Van der Linden, Laureys, Delfiore, Degueldre, Luxen & Salmon, 2005). Inhibition could be achieved by our proposed semantic control system by reducing levels of activation of non-target competitors or weakening links when two inputs are poorly matched, for example a pictured big cat with spots and the concept of TIGER. Although still debated, the effects of failure of such inhibitory mechanisms have been noted in SA patients, for example their susceptibility to miscueing and their difficulties with strongly associated distractors (Noonan et al., 2010; Soni et al., 2009, 2011). We hypothesise that this behaviour is associated with poor semantic control. When a semantic interference effect (SIE) is found, for example longer naming times in the presence of a semantic distractor, we argue that the longer latency reflects the time taken by the semantic control system to inhibit the semantic activation of the competitor.

The 'hyperonym problem'

A single semantic representation is a richly detailed pool of information with links to similar items (category co-ordinates) and items from different categories which are linked by verbal or real-world co-occurrence (associates). Different elements of such a representation may be highlighted at different times, so effective semantic control is essential for determining the most appropriate element for the task in hand. Part of producing the correct response in a picture naming task is selecting between levels of representation: is this item to be named an ANIMAL, a CAT, a SIAMESE, or TIDDLES? This has been termed the *hyperonym problem* (Levelt, 1989; Levelt et al., 1999), and can be formally stated thus: if the meaning of item A (e.g., CAT) is encompassed by the meaning of item B (e.g., ANIMAL), then B is a hyperonym or superordinate of A; as all the features of CAT are also contained within the representation of ANIMAL, how is the desired element activated? In nondecompositional models such as WEAVER ++ (Levelt et al., 1999; Roelofs, 1993), this problem is circumvented by the individuated nodes for each item concept, meaning that even though the features of CAT are encompassed by the concept ANIMAL, each of these items has its own conceptual and lexical representation which become activated in particular instances.

The hyperonym problem has been raised as a potential problem for feature based models such as Dell et al.'s weight decay model (1997) which like Levelt et al.'s (1999) model incorporates the notion of localist nodes or lemmas, though instead of being linked to unified semantic concepts these lexical representations are fed by a common pool of semantic features. A similar difficulty could be envisaged for PDP type models (e.g., Lambon Ralph et al., 2002; Lambon Ralph et al., 2000; Plaut et al., 1996; Plaut & Shallice, 1993), which also incorporate a common feature bank to be used by any relevant concept, but which do not include localist lexical nodes: semantic representations are simply distributed patterns of activation which interact directly with phonological units to produce a name. In any system relying on shared semantic features, multiple lexical items could be mapped onto the target semantics, so how does the speech production system know which level to select?

The concept of semantic control goes a long way towards solving the hyperonym problem, in that it is defined as the selection of task appropriate information from amongst the large amount of stored knowledge in a semantic representation (Noonan et al., 2010). The response produced depends on the most relevant facet of a representation at the time, demanded by task or context. In a picture naming test, people are made aware that a basic level name is sought, hence the response “animal” (or indeed “Siamese” or “Tiddles”) to a pictured cat is inappropriate and counted as an error. Any of the above responses may be accurate and appropriate in particular circumstances, but the semantic control system is needed to distinguish between all these potential responses to select the element required by the task.

Anatomical correlates of semantic control

The division between semantic control and representation is highlighted by the different areas they tend to recruit. Broadly, it is suggested that semantic control is subserved by both prefrontal and parietal regions (Badre, Poldrack, Pare-Blagoev, Insler, & Wagner, 2005; Berthier, 2001; Hodgson & Lambon Ralph, 2008; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Thompson-Schill et al., 1998). Other studies suggest that the amodal store of semantic representations may be contained in the temporal poles, which are richly connected with cortical association areas (Bozeat et al., 2003; Bozeat, Lambon Ralph, Patterson, & Hodges, 2000; Gloor, 1997; Gough, Nobre, & Devlin, 2005; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008). Research Theme 2 is about semantic control within speech production, hence this will be explored in more detail.

Many studies focus on the semantic control functions associated with the left frontal cortex, variously defined as the left inferior frontal gyrus (LIFG), the left inferior prefrontal cortex (LIPC) and the left ventrolateral prefrontal cortex (VLPFC): these areas partially overlap, and are also designated by Brodmann's Areas 6, 44, 4 and 47. The terms LIFG, LIPC and VLPFC will all be used here, depending on the terms employed in individual papers. Some studies propose a *competitive account* for the function of this region (Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997; Thompson-Schill et al., 1998), where the LIFG is responsible for selecting between several potential responses, both in healthy participants in fMRI (Thompson-Schill et al., 1997) and patients with focal frontal lesions (Thompson-Schill et al., 1998). An alternative *noncompetitive account* is given by Wagner et al. (2001), who assert that the LIFG is responsible for controlled semantic retrieval, giving higher LIFG activation when the association between cue and target is weak. In this account, the relationship between cue and target is key, not the relative strengths of several potential responses. Wagner et al. (2001) propose that when a single prepotent response exists, processing occurs in a more automatic manner, with less LIFG activation. Later papers offer greater consensus. Thompson-Schill and Botvinick (2006) assert that selection demands and association strength may effectively be processed by the same mechanism, with the LIFG supplying a top-down signal which can resolve conflict or search for a weakly associated response. Badre et al. (2005) propose an anatomical and processing separation between these two types of operation, with selection by the left mid-VLPFC and retrieval supported by more anterior portions of the left VLPFC and mid temporal cortex, where long term representations are stored.

Several papers describe anatomical and functional subdivisions of the LIFG. Snyder et al. (2007) found that both anterior and posterior regions of the LIFG were activated by both semantic and phonological tasks, and attribute a domain-general mechanism for resolving conflict from task-irrelevant material. Devlin et al. (2003) conducted a combined fMRI and TMS study: TMS to the anterior LIPC slowed RTs in a semantic task relative to a perceptual control task, showing that this region was essential for the semantic processing required by their task. However, the fMRI data showed that both semantic and phonological processing activated a common set of areas in the LIPC, but semantic activation was concentrated in the anterior and phonological activation in the posterior portion. Wagner et al. (2001) also postulated a functional distinction between the anterior portion of the LIPC (BA 45/47), responsible for semantic processing, and the posterior portion (BA 44/6) for more phonological type control. Gold and Buckner (2002) allowed that the LIFG could offer a site where ambiguous relationships between stimulus and representations can be resolved, be that semantic or phonological in nature. Gough et al. (2005) also suggest that the LIPC may be the place where different forms of linguistic information (semantic, phonological) become integrated and ambiguities can therefore be resolved. A critical idea to introduce here is that of *graded specialisation* (Plaut, 2002). In a connectionist model, Plaut describes how it is possible for a set of units to be globally responsible for a number of tasks, but locally some units will be more specialised to deal with task A, others with task B and so on. Graded specialisation can account for the somewhat variable findings on anatomical and functional subdivisions of the LIFG.

Despite some continuing disagreement, it is clear that the left inferior frontal cortex is involved in controlled semantic processing. However, this is not the full extent of areas reputed to be involved in semantic control: there are also more posterior components to the system. Several interesting papers show anatomical links between frontal and other cortical regions which could be utilised by tasks involving controlled semantic processing. Gold and Buckner (2002) postulated that the left inferior frontal cortex co-activates with different regions according to task demands, controlled semantic retrieval with the left temporal cortex, and controlled phonological retrieval with left posterior frontal and parietal regions. Gough et al. (2005) describe the connectivity patterns from the anterior and posterior LIPC, with the anterior portions (associated with semantic processing) linked to the temporal pole, associated with semantic memory, and posterior LIPC (linked to phonological processing) to temporoparietal regions related to auditory speech processing. Badre et al. (2005) also highlighted connections between the left VLPFC and the mid temporal cortex, a suggested ‘storage’ site for semantic representations. The involvement of a similar range of regions in semantic processing was also cited in an fMRI study on word reading and picture naming (Mechelli, Josephs, Lambon Ralph, McClelland, & Price, 2007). Semantically related word pairs modulated activity in a left lateralized network including the pars orbitalis (part of the LIFG), the superior frontal gyrus, the middle temporal gyrus and the angular gyrus. Regardless of potential fine-grained subdivisions, this series of papers highlights the idea of connectivity between cortical regions, with a network of frontal, parietal and temporal regions subserving the semantic control system which supports accurate speech production.

Semantic control in SA

Semantic aphasia or SA is a somewhat newly coined term (Corbett, Jefferies, Ehsan, & Lambon Ralph, 2009; Jefferies & Lambon Ralph, 2006; Noonan et al., 2010; Soni et al., 2009) describing a functional grouping of left-hemisphere stroke patients. The inclusion criterion was failure of both word and picture versions of tests of semantic association such as Pyramids and Palm Trees (Howard & Patterson, 1992) and/or Camel and Cactus (Bozeat et al., 2000). Both of these tests give a probe picture, for example a pyramid, and a choice of two (PPT) or four (CCT) pictures beneath, such as a palm tree and a pine tree: the task is to pick the item most associated with the main picture. The semantic distance of the targets and distractors from the probe picture may be manipulated, making the test a sensitive way to examine the access and manipulation of semantic material. When semantic distance between probe and target was greater, SA patients had more trouble picking out the relevant relationship.

Phonology seems to be relatively spared in this group of patients; mean performance in the word repetition element of the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA, Kay, Lesser, & Coltheart, 1992) was over 90% correct. SA patients show impaired performance on nonverbal reasoning tests like Raven’s coloured matrices (Raven, 1962), and also attentional/executive measures such as Brixton (Burgess & Shallice, 1997), Wisconsin card sorting (WCST, Milner, 1963; Stuss et al., 2000) and elevator counting tests (Robertson, Ward, & Ridgeway, 1993). They also show correlations between semantic tests and poor performance on executive tests (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008), indicating that compromised executive control may be affecting semantic cognition. The impairments in SA are characterised by reduced ability to direct attention to the appropriate facet of a concept (Jefferies & Lambon Ralph, 2006), an aspect of semantic cognition which has been termed semantic control.

Despite the functional similarities, SA is not a ‘traditional’ aphasia classification, nor does it have a single neurological origin. Patients with several different aphasia diagnoses have been included (e.g., transcortical sensory aphasia or TSA, mixed transcortical and conduction aphasia) due to their comparable performance on a range of semantic and executive tasks. Neurologically, patients with SA are a subgroup of stroke patients with damaged prefrontal and/or temporoparietal areas in the left hemisphere including the inferior frontal gyrus (Brodmann areas 44, 45 and 47), the superior, middle and inferior temporal gyri (Brodmann areas 22, 21 and 20) and parietal areas such as the angular and supramarginal gyri (Brodmann areas 39 and 40). Of the group of eight SA patients who took part in some or all of the experiments in this thesis, all except one (JD) have damage either to cortical or subcortical tissue in temporo-parietal regions: three also have cortical damage in frontal regions (NY, PG and BB). JD has purely subcortical damage to the putamen and capsule which underlie frontal and parietal cortical regions. Further details of their lesion sites and extent of damage can be found in Table 1 of each data chapter.

This range of prefrontal, parietal and temporal areas showing involvement in controlled semantic tasks such as target selection amongst multiple candidates and inhibition of prepotent responses is strikingly similar to many of the PET, fMRI and TMS studies with normal participants detailed in the previous section (Badre et al., 2005; Devlin et al., 2003; Gold & Buckner, 2002; Gough et al., 2005; Thompson-Schill & Botvinick, 2006; Wagner et al., 2001). A similar network of brain areas was also noted in Berthier’s (2001) study of TSA, an aphasia type characterised by fluent speech with some comprehension impairment but good auditory repetition[2]. Berthier investigated the deficits shown by subgroups of TSA patients who had either purely frontal or temporoparietal damage, along with a third group who were damaged in both areas. Using the Western Aphasia Battery (Kertesz, 1982), he found virtually no significant differences between any of the groups, judging them to be functionally indistinguishable despite differences in lesion site. He concluded that his data indicated a semantic system dependent upon a distributed network of brain regions, and that a lesion in any part of this network could lead to a similar breakdown in processing (Berthier, 2001).

---

[2] Our SA group includes four patients who fit the criteria for TSA (HN, PG, SC and ME)

To return to the behavioural and functional aspects of SA, patients have shown multimodal semantic problems in both verbal and nonverbal domains, with uneven performance across tasks, items being recalled perfectly in some contexts but not in others. These differences in recall are observed when different modes of semantic processing are required, for example between naming and word to picture matching (WPM), rather than when performing the same task in a different modality, such as verbal and pictorial WPM (Jefferies & Lambon Ralph, 2006). From this we can infer that semantic representations are not altogether lost in SA, as they can still be accessed in some contexts. For example, naming accuracy can be significantly improved by the presentation of phonemic cues in conjunction with the pictures (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009; Soni et al., in press). There is also a tendency in SA to produce associative semantic errors during naming such as “nuts” for SQUIRREL (27% of all semantic errors, Jefferies & Lambon Ralph, 2006). An error such as this clearly indicates that the semantic representation of SQUIRREL has been reached: the strong association with nuts is relatively specific to squirrels amongst small mammals. However, despite the remaining knowledge displayed, an inappropriate element of a detailed semantic representation has been selected. A deficit of semantic control provides a parsimonious account for behavioural effects such as associative errors, improvement in naming in the presence of phonemic cues, and correlations with poor scores on executive tests.

In order to demonstrate the specific and distinct nature of the impairments shown in SA, earlier studies (e.g., Jefferies & Lambon Ralph, 2006) compared the condition with semantic dementia or SD, which is also a multimodal semantic impairment. SD also provides a useful stable comparison group due to the uniformity of disease progression, which causes remarkably similar symptoms across cases. SD causes progressive bilateral atrophy of the anterior temporal lobes (temporal pole); cortical matter is lost and lobes become thinner causing a characteristic ‘knife-edge’ appearance. There is a progressive loss of semantic knowledge co-occurring with relatively spared episodic memory, self-care, spatial skills and phonological ability.

Although overall error rates in picture naming in SD and SA (Jefferies & Lambon Ralph, 2006) were the same (41% of items correct), their responses show interesting qualitative differences. Instead of the large number of associative semantic errors seen in SA, SD patients show increasing levels of superordinate errors and erroneous naming of more typical members of a category as the disease progressed (e.g., “animal” for DOG or “horse” for ZEBRA), suggesting that knowledge of specific items decays before knowledge of broad categories (Bozeat et al., 2003; Woollams et al., 2008). Rogers, Lambon Ralph, Garrard, Bozeat, McClelland, Hodges and Patterson (2004) showed a similar pattern of naming errors in a computational model in which distributed semantic representations had been lesioned. Unlike SA patients, SD patients tend to show high item consistency from test to test, substantial effects of frequency and familiarity and are not assisted by phonemic cueing (Bird, Lambon Ralph, Patterson, & Hodges, 2000; Bozeat et al., 2003; Bozeat et al., 2000; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008). The conclusion is that this pattern of deficits points to a central amodal semantic deficit in SD, with degraded conceptual representations (Bozeat et al., 2003; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Rogers et al., 2004; Woollams et al., 2008): once a representation has decayed, it is not merely more difficult to access; it is simply not there to reach. In comparison, the item inconsistency, the significant benefits of phonemic cueing and the prevalence of associative errors found in SA point to an impairment of the ability to manipulate semantic information, with the central representational store far less degraded than in SD.

THEME 3:

The effect of tempo naming on semantic control and the place of semantic control within a wider executive network.

Under the heading of this theme, the procedure and background of the tempo naming methodology will be looked at, including the relationship of tempo naming to other speeded naming and dual-task procedures, and evidence provided to establish the rationale behind using it to mimic the behaviour of this particular patient group. Theme 3 will also introduce the more general debate of how semantic control fits with wider executive control mechanisms.

Development of the tempo task

The tempo paradigm grew out of an older tradition of speeded naming tasks such as deadline naming (Vitkovitch & Humphreys, 1991; Vitkovitch, Humphreys, & Lloyd-Jones, 1993), which are in general designed to increase the difficulty of picture naming for healthy participants, who otherwise perform more or less at ceiling on this task (Masterson & Druks, 1998; Szekely et al., 2003). In the tempo naming paradigm, a tempo is set up using a countdown with visual and/or auditory signals. After the countdown the target is presented on the next tempo ‘beat’, and the participant is asked to name the item on the following tempo beat; the tempo can also be set at different speeds. Tempo naming was initially developed for use with word reading (Kello & Plaut, 2000), where it was used to investigate strategic control of response initiation and to act as a window on the time course of phonological processing. Hodgson and Lambon Ralph (2008) then adapted the task to picture naming to make a direct comparison with deadline naming in Experiment 1, and in Experiment 2 tempo naming was used to investigate the effects of both correct and misleading phonemic cues on picture naming. Tempo picture naming was then developed further in this thesis to investigate differences between object and action naming (Chapter 2) and also to extend the use of cues in conjunction with picture naming (Chapter 3, Soni et al., 2009; Chapter 4, Soni et al., in press).

A previous speeded naming task with some similarities to the tempo paradigm is deadline naming, where participants are asked to name an item before a deadline indicated by audio and/or visual signals; the deadline can then also be set at different intervals (Vitkovitch & Humphreys, 1991; Vitkovitch et al., 1993). Both deadline and tempo naming generate faster RTs than standard naming (Hodgson & Lambon Ralph, 2008; Kello & Plaut, 2000; Vitkovitch & Humphreys, 1991; Vitkovitch et al., 1993), but whereas deadline naming can be achieved by simply naming an item as fast as possible, it could be argued that more attention and control are required to correctly perform the tempo task, where response timing is tightly specified to be neither too early nor too late. Higher error rates are also seen with both deadline and tempo naming, but in a direct comparison with normal participants tempo naming was found to produce more errors than deadline naming at similar speeds (20% vs. 18% respectively), including more associative semantic errors (13 vs. 10, Hodgson & Lambon Ralph, 2008), mimicking the pattern shown by SA stroke patients. In Experiment 2 of the same paper, Hodgson and Lambon Ralph focussed on tempo naming with the introduction of simultaneous cues, either correct initial phonemes of target pictures, neutral beeps, or initial phonemes of category co-ordinates of targets (e.g., /l/ for LION with a picture of a TIGER). They found that the fast condition produced significantly shorter RTs but higher error rates; the miscue condition produced significantly more semantic errors (40% of trials) than either the neutral (11%) or the correct (4%) cue conditions.

Tempo naming: theoretical basis and suitability for comparison with SA

Turning to the theory of how tempo naming achieves its results, we will initially look at the first experiment using the tempo paradigm, Kello and Plaut (2000). The task not only significantly reduced the accuracy of word naming and the latency of response initiation compared to standard word naming, but also decreased the duration of the response: it was not just begun earlier but pronounced more quickly overall. In order to simultaneously account for reduced latency and duration of responses and higher error rates, the authors propose that processing is not just truncated or stopped at an earlier point, but that the complete process is accelerated and compressed. In a connectionist network, this can be accomplished by changing the input gain to the processing units. Gain has a multiplicative function between input and output: when the value of gain is low, a small change in input has a small effect on output, whereas if gain is set higher, a small change in input has a much larger effect on output. Raising input gain is therefore able to accelerate processing because the transfer from input to output can be accomplished in fewer time steps (Kello & Plaut, 2000, 2003): increased gain can also account for increased error rates by amplifying noise as well as the input signal during processing.

Looking at the tempo picture naming paradigm, Hodgson and Lambon Ralph (2008) concur with the argument that processing is compressed rather than truncated. The error patterns observed in Experiment 2 mirror patterns shown by stroke aphasic patients with both correct (Howard & Orchard-Lisle, 1984; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009; Soni et al., in press) and incorrect cues (Lambon Ralph et al., 2000; Noonan et al., 2010; Soni et al., 2009; Soni et al., in press). Hodgson and Lambon Ralph offer two possible explanations for these effects, a simple speed/accuracy trade off and an account based on divided attention-executive resources, but argue that the speed/accuracy trade off is less likely because the pattern of error rates and types differs from that produced by the deadline naming in Experiment 1 (2008). They argue that tempo naming induces participants to expend part of their attention on the precise timing of their response, as well as naming targets correctly. Hodgson and Lambon Ralph propose that it is this division of executive processing resources which reduces ability to select the correct target from amongst several potential candidates, particularly when the phonemic cue is boosting the activation of a competitor, making the behaviour of normal participants similar to the semantic control impaired stroke aphasic patients (Hodgson & Lambon Ralph, 2008).

The tempo task directly interferes with executive control processes, thus making it a suitable method of emulating control-impaired SA patient behaviour as opposed to other semantic impairment, for example that seen in SD, where core representation rather than manipulation of semantic information is impaired.

Although participants are not expected to succeed in responding ‘on tempo’ at every trial, the tight specification on response timing requires constant attention, splitting processing capability between response selection and timing, in effect forming a kind of dual task. When two tasks are performed simultaneously, fewer processing resources are available for each (Newman, Keller, & Just, 2007). It could be argued that the dual nature of the tempo task disrupts semantic control in a way that is analogous to the impairments shown in SA.

Semantic control within wider executive control mechanisms

Many dual task studies are found elsewhere in the attention-executive control literature, often using neuroimaging techniques to explore which brain areas are involved both in tasks performed singly, and what extra activation exists when the tasks are attempted simultaneously. They are used to investigate the effect of divided processing resources on effective task performance, probing how an overarching ‘control’ type system regulates behaviour. In this section, several studies on wider executive control will be examined, including probing whether more constrained semantic control mechanisms could be neurologically and functionally part of the executive control system which regulates other areas of human cognition and behaviour.

Newman et al. (2007) used fMRI to investigate strategic control of attentional resources using auditory sentence comprehension and mental rotation of 3-D figures carried out as a dual task. Both tasks were simultaneously presented to all participants, but they were either asked to attend to one or both of the tasks. As was seen in the tempo paradigm, RTs and errors were significantly greater when attending to both tasks than when selectively attending. Neurologically, activations for non-attended tasks were lower than for attended tasks, showing that attentional resources were under strategic control to an extent. Attending sentences produced more bilateral activation in temporal language areas whereas attending rotations activated right lateralized occipital and parietal areas. Attending to both tasks produced a laterality shift in the temporal language regions, with smaller right hemisphere activation than when attending to the language task alone.

Activation was also underadditive – the ‘combined focus’ condition produced less activation than the sum of the two tasks when selectively attended to, showing that the act of attending to two tasks at once has a cost in terms of processing resources above and beyond what is used for each overt task. Prefrontal activations were greater in the dual task condition but not significantly so, however a network of areas is clearly acting together to achieve strategically divided attention in these participants. The left hemisphere bias for controlled focus on language tasks mirrors that seen in Research Theme 2, where controlled language tasks predominantly activated left hemisphere networks including temporal, parietal and frontal areas (Badre et al., 2005; Gold & Buckner, 2002; Gough et al., 2005).

A clearer demonstration of prefrontal involvement in dual task performance comes from Collette, Olivier, Van der Linden, Laureys, Delfiore, Luxen and Salmon (2005). They carried out a PET study using simple visual and auditory discrimination tasks relative to passive viewing and hearing in a subtraction design. These tasks evoked no prefrontal activation when carried out singly: the visual task activated the middle and superior occipital gyrus (BA 18 and 19) in the right hemisphere and the superior parietal gyrus (BA 7) bilaterally, and the auditory task evoked activation in the right superior and middle temporal gyrus (BA 22 and 21). Behaviourally, RTs for each single task were significantly faster than the dual task, again showing the cognitive cost incurred when performing two tasks simultaneously. Neurologically, dual task performance evoked activation in a series of primarily left sided frontal and parietal regions: the left inferior frontal sulcus (BA 9/46), the left anterior prefrontal cortex (BA 10 and BA 11/47), the left posterior middle frontal gyrus (BA 6), the left inferior parietal gyrus and intraparietal sulcus (BA 40) and the left cerebellum. The authors conclude that a network of frontal and parietal regions was involved in the executively demanding dual task paradigm, again calling to mind tempo, SA and semantic control data.

This study was particularly interesting in that it involved no language elements, being based on simple sensory discrimination, yet a strikingly similar network of left hemisphere regions are implicated as in the semantic control studies cited in Research Theme 2 (Badre et al., 2005; Gold & Buckner, 2002; Gough et al., 2005; Thompson-Schill & Botvinick, 2006; Thompson-Schill et al., 1997). The activation in the frontal and prefrontal cortices in the dual task condition in Collette et al. (2005) which was not present for either task alone is particularly notable, recalling the language-based semantic control activations in the above studies. There is also a strong similarity to the left-lateralized fronto-parietal regions of damage our SA patient group (see Table 3.1), who are impaired both on executive tests and the manipulation of semantic information. It seems that a very similar network of cortical regions is recruited whether tasks involve semantic or general control, and that damage to those areas results in impairment in controlled semantic processing.

Several papers delineate what they agree to be some core cognitive functions of the more general executive control system, namely shifting (between one task and another), updating (integrating new input with existing task performance) and inhibition (of prepotent responses, as in the Stroop task). Miyake, Friedman, Emerson, Witzki, Howerter and Wagner (2000) looked at behavioural correlates of these three core executive functions in normal participants. Latent variable analysis was used to examine the role of various tasks such as the Wisconsin Card Sorting Test (WCST, Milner, 1963; Stuss et al., 2000) and Tower of Hanoi (TOH), investigating which tasks tapped which core executive function. They found that the three executive functions were moderately correlated with each other, showing an overarching ‘executive system’, but that separate experimental tasks were more associated with one function than another (e.g., WCST to shifting, TOH to inhibition), demonstrating separable elements within that system.

Collette, Van der Linden, Laureys, Delfiore, Degueldre, Luxen and Salmon (2005) carried out a PET study to delineate specific cortical regions associated with updating, shifting and inhibition. All three tasks activated the right intraparietal sulcus (BA 40), the left superior parietal gyrus (BA 7) and the left lateral prefrontal cortex (left middle frontal gyrus, BA 10/46 and left inferior frontal gyrus, BA 45), which are deduced to play a role in general executive function. Furthermore, significant foci of activation associated with each task were seen in separate prefrontal areas, again indicating that executive function is made up of a number of individuated processes which act together to form an overarching control system. This network of brain areas activated by executive control type tasks again recalls the areas of damage shown by our SA patient group who are impaired at tasks involving controlled processing and also the network of regions associated with semantic control cited in imaging studies with normal participants (Badre & Wagner, 2004; Gold & Buckner, 2002; Gough et al., 2005; Thompson-Schill & Botvinick, 2006; Thompson-Schill et al., 1997; Thompson-Schill et al., 1998; Wagner et al., 2001).

Tying together some of the behavioural effects of semantic control impairments and more general executive control, one of the core executive functions mentioned above, inhibition, is reminiscent of the effects of miscued naming in the tempo paradigm (Hodgson & Lambon Ralph, 2008). When extraneous information in the form of a misleading phonemic cue is presented with a picture to be named, healthy participants made significantly more errors than when a neutral or a correct cue was presented. This clearly shows difficulty in the inhibition of the task irrelevant material associated with an experimental paradigm thought to stretch semantic control resources. Looking at individuals where damage to semantic control is permanent, significantly poorer scores on miscue trials shown by SA patients (Noonan et al., 2010; Soni et al., 2009; Soni et al., in press) are also evidence of impaired inhibition, with reduced suppression of competing alternatives during naming. Furthermore, the semantic control deficit in SA has also been shown to extend beyond the verbal domain into impaired object use (Corbett, Jefferies, Ehsan et al., 2009; Corbett, Jefferies, & Lambon Ralph, 2009), suggesting that impaired semantic control can affect not only language but motor activity as well. Where then would be the line between impaired semantic control in object use and impaired general control of a motor activity? Along with the tempo naming data and the neuropsychological evidence from SA, the message of ‘unity and diversity’ in executive control (Collette, Hogge, Salmon, & Van der Linden, 2006; Collette, Van der Linden et al., 2005; Miyake et al., 2000) suggests that it is at least possible that semantic control which operates on language forms part of a wider system of executive control. After all, stored semantic knowledge is important for many functions other than language, including effective use of objects in the environment, spatial orientation, and social interaction between people.

CHAPTER SYNOPSES

For the final section of the Introductory Chapter, we will examine how semantic cognition in speech production might be affected by the various manipulations carried out for the experiments in the following empirical chapters. A brief outline of the main findings will be included with each chapter synopsis. This section will outline how each study relates the broader research themes of the thesis.

Chapter 2: Grammatical class or imageability effect? Object and action naming in semantic aphasia and normal tempo naming

Various psycholinguistic properties such as imageability and argument structure distinguish objects and actions, and are also linked to different demands on controlled processing. Actions are averagely lower in imageability than objects, leading to the hypothesis that in a patient group with impaired semantic control, this would lead to critical difficulties with action naming. This hypothesis was tested by presenting two sets of pictured actions and objects to our SA group in Experiment 1, one where imageability is higher for objects than actions and other relevant variables are matched (the imageability confounded set) and one where imageability is matched between grammatical classes (the imageability controlled set). The patient data showed a significant object benefit in accuracy in the imageability-confounded lists that was not found when imageability was controlled. In Experiment 2, following the significant patient results, the imageability confounded set was also tested on a group of healthy participants in the tempo paradigm. Due to the detrimental effects of the tempo method on the semantic control system, an 'action deficit' was also predicted, and indeed a significant advantage in accuracy for the higher imageability object set emerged at the fast tempo.

Chapter 3: "L" is for tiger: Effects of phonological (mis)cueing on picture naming in semantic aphasia (Soni et al., 2009)

In this experiment the addition of correct (initial phoneme of target) and misleading (initial phoneme of a category co-ordinate) cues to an object naming paradigm manipulated the demand for controlled processing. In a system where semantics and phonology interact during speech production to some extent, correct cues boost the activation of target items, reducing the need for semantic control in retrieval. Conversely, the miscues are boosting a competitor (e.g., /l/ with TIGER should boost LION), which greatly increases the need for controlled processing in two ways. Firstly, the activated competitor must be inhibited; inhibition is one of the core executive control tasks identified by Collette et al. and Miyake et al. (2005; 2000). Secondly, the correct target must be retrieved against a background of increased competition and background noise, placing a greater demand on semantic control (Badre et al., 2005; Badre & Wagner, 2004; Thompson-Schill et al., 1997; Wagner et al., 2001). Indeed, correct and co-ordinate cues significantly increased and decreased accuracy in tempo picture naming (Hodgson & Lambon Ralph, 2008), and identical stimuli were used here with the SA patients to enable a direct comparison. The patients showed significant positive and overall cueing effects on accuracy, and a marginally significant negative cueing effect. In semantic errors, the positive and overall cueing effects were again significant: the rate of exact cued errors was significantly greater in the miscue than the neutral cue condition. Comparative analysis with the tempo data from Hodgson and Lambon Ralph (2008) showed no significant difference in semantic error rates between patients and normals at the slow tempo; at the fast tempo, normals actually produced significantly more semantic errors than patients.

Chapter 4: "W" is for bath: Can associative errors be cued? (Soni et al., in press)

The cued naming paradigm is further extended in Chapter 4 (Soni et al., in press) with the addition of both neutral phoneme cues (replacing the neutral beep used previously) and associative miscues: stimuli are tested both on the SA group (Experiment 1) and a group of healthy participants under tempo conditions (Experiment 2). The inclusion of associative miscues is particularly pertinent for our SA group, as associate errors are a prevalent and distinguishing feature of their naming errors (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008). It is also possible that the neutral phoneme may present problems for the SA group: although it does not directly increase competition by boosting a competitor, it adds a distraction to the naming process which is already impaired. The significant co-ordinate miscue effects still obtained with the neutral phoneme, showing that meaningful miscues disrupt naming more than the simple presence of random misleading phonology. Although the associative miscueing effect on accuracy was not significant, there was a reliable increase in the number of cued associate responses. The results from the tempo naming experiments showed similar patterns irrespective of rate of response, consistent with the notion that it is the tempo task itself that draws off executive resources. Reliable co-ordinate miscueing effects were seen in latency, accuracy and semantic errors, whereas the associate miscueing effect was confined to RT.

Chapter 5: Repetition priming of picture naming in semantic aphasia: The impact of intervening items (Soni et al., submitted).

Chapter 5 shifts focus to attempt to improve SA patients picture naming via experimental means, building upon the previous findings that correct cues boost accuracy in SA patients. This finding is extended into an assessment of repetition priming in SA, with the presentation of an entire stimulus rather than just an initial phoneme. If, as has been shown, a single phoneme is able to guide impaired semantic control mechanisms towards more accurate target selection, then priming with the whole stimulus in the same modality (picture naming) should have an even stronger beneficial effect. A further dimension explored in Chapter 5 which has relevance for our patient group is the lag between prime and target: due to their well documented difficulties with standard naming, a series of short lags (0, 1 and 7 items intervening) was judged to be the most sensitive. As a further investigation of priming effects, patients' and controls' reaction times were measured as well as accuracy and error types, providing a sensitive gradation of performance within correct trials. The patients' impaired semantic control would lead to the hypothesis that longer lags would have a smaller benefit for accuracy and RT than shorter lags due to the activation from more intervening items masking activation produced by the prime trial. The results bore this out, showing that at Lag 0, patients answered at similar speed and accuracy to controls, but that their performance tailed off sharply with even one intervening item (Lag 1), diverging even more at Lag 7. Overall, patients enjoyed a larger effect of priming than the controls: other work indicates that lower baseline performance allows repetition priming to have more effect (Cummings et al., 2006).

Chapter 6: Semantic and repetition priming in semantic aphasia: Do word primes have an effect?

Having shown beneficial effects for picture repetition primes in Chapter 5, Chapter 6 then considered the extent to which this effect would also obtain from word primes that were either identical or semantically related to the target. Lag 1 was used (a single intervening item) due to its significant effect on RT, accuracy and semantic errors in Chapter 5. As the prime trials were written words, to be read aloud (or repeated in the case of a reading error), this ensured that any priming of picture naming would be due to activation of the semantic representation via orthography/phonology, rather than the maintenance of items in working memory or an episodic memory trace (Wheeldon & Monsell, 1994). Patients' repetition priming effects from Chapter 5 were replicated with word primes in accuracy and semantic errors but not latency. Semantic priming has previously shown both facilitatory (Bajo, 1988; Fischler, 1977; McEvoy, 1988; Meyer & Schvaneveldt, 1971) and inhibitory effects (Alario, Segui, & Ferrand, 2000; Oppenheim, Dell, & Schwartz, 2010; Tree & Hirsh, 2003; Wheeldon & Monsell, 1994). Indeed, semantic priming effects were less clear, with no significant differences between primed and unprimed items in latency, accuracy or semantic error rates for patients or controls. There was however an interesting effect of session: patients improved their performance from fewer correct responses with primed than unprimed items at session 1 to a significant benefit from semantic priming by session 3. We propose that this incremental benefit from semantic primes is the results of sharpening of semantic access via the repeated presentation of the targets across session – essentially, longer term repetition priming of the target allowed a facilitative effect of semantic primes to emerge.

CHAPTER 2

GRAMMATICAL CLASS OR IMAGEABILITY EFFECT? OBJECT AND ACTION NAMING IN SEMANTIC APHASIA AND NORMAL TEMPO NAMING

ABSTRACT

Objects and actions differ on a number of psycholinguistic variables, suggesting that they may load differentially on control processes during picture naming. Matching imageability has also been shown to neutralise word class effects in both semantically impaired stroke patients and healthy participants. Experiment 1 showed an effect of grammatical class on accuracy in patients with semantic aphasia (SA) when imageability was confounded which was eliminated when it was matched across object and action stimuli. In Experiment 2, the same effect seen in the patients when imageability was confounded was also apparent in normal participants under tempo naming conditions when required to respond faster than usual. Implications for the representation of different item types in the brain are explored: support is given to theories that incorporate different proportions of component features rather than rigidly discrete grammatical classes.

INTRODUCTION

Nouns and verbs differ on a number of psycholinguistic properties including frequency, imageability, age of acquisition (AoA), name agreement and familiarity: an 'average noun' will be less frequent, more imageable, more familiar, and have higher name agreement and a lower age of acquisition than an 'average verb' (2000; Conroy, Sage, & Lambon Ralph, 2006). The grammatical classes 'noun' and 'verb' are linguistic groupings which have specific syntactic roles in sentence construction, and are distinct from the semantic classes of 'object' and 'action', or what these items represent in the world (Cappa & Perani, 2003). Objects and actions are subsets of nouns and verbs, perhaps the most psychologically and perceptually salient exemplars of their grammatical classes. This paper focuses on picture naming, so will refer mainly to actions and objects unless using terms from cited papers.

There are several semantic properties that differ between objects and actions. Objects have perceptible boundaries and are stable across time, whereas an action is a dynamic event, changing through time and space. Furthermore, there is a semantically 'looser fit' between the name of an action than is often the case with objects; a single action could be described in several ways (*walk, stroll, saunter*), with differences in meaning more about mood than physical qualities. Action names also vary according to the perspective highlighted, for example *buy* and *sell* describe the same interaction but from different standpoints: usually with objects, a rose is a rose is a rose.

Nouns and verbs also differ on syntactic properties like argument structure, with most verbs showing greater complexity than most nouns (Miller & Felbaum, 1991). In a study of Italian aphasic speakers, it was found in a picture naming task that both objects and actions with more complex argument structure were harder to name than words of either class with simpler argument structure (Collina, Marangolo, & Tabossi, 2001). Verbs seem to be more intrinsically linked to sentence structure than nouns, as indicated by correlations between deficits in single verb naming and poor sentence production in aphasic speakers (Berndt, Haendiges, Mitchum, & Sandson, 1997). In many languages, including English, morphology also loads more heavily on verbs than nouns (Conroy et al., 2006): there are more morphological variants of any given verb, which must agree on tense and number; nouns generally only vary on the singular/plural dimension. However, it cannot be assumed that verbs are just 'more difficult' than nouns, because some patient groups exhibit noun deficits in the presence of relatively spared verb naming (Hillis, Oh, & Ken, 2004; Miceli, Silveri, Nocentini, & Caramazza, 1988).

There is broad consensus that anterior lesions tend to lead to action naming deficits and posterior lesions tend to result in more difficulties with objects. Verb deficits tend to be found in nonfluent agrammatic patients (Miceli, Silveri, Villa, & Caramazza, 1984; Zingeser & Berndt, 1990), whose ‘telegraphic’ speech is characterised by lack of function words and inflectional morphemes like verb endings: lesions to Broca’s area are common in such cases. Furthermore, disproportionate difficulties with actions are often seen in degenerative conditions with a dysexecutive component such as frontal variant FTD (fronto-temporal dementia) or motor neurone disease (Bak & Hodges, 1997; Rhee, Antiquena, & Grossman, 2001; Silveri, Salvigni, Cappa, Della Vedova, & Pulopolo, 2003). The picture for patients with inferior performance with nouns is more mixed. Anomia, with consistent word-finding difficulties in the presence of fluent, grammatically appropriate speech, is most often associated with noun deficits (Cappa & Perani, 2003); this condition is usually associated with lesions in the temporal lobe (Damasio & Tranel, 1993; Jefferies, Lambon Ralph, Jones, Bateman, & Patterson, 2004). However, some cases of anomic patients with superior object naming have been observed (e.g. Luzzatti et al., 2001). Noun deficits are also found in patients with Wernicke’s aphasia (Conroy et al., 2006), who have comprehension problems in addition to relatively fluent speech (Kertesz & Poole, 2004). Overall, the picture for fluent aphasic disorders is one of worse performance with nouns, but the tendency is less strong than the correlation of nonfluency with poor verb performance (Conroy et al., 2006).

Despite the tentative consensus outlined above, there is a wide range of opinions on the neurological basis for the representation of object and action naming in the brain. Verb processing is usually shown to activate primarily frontal and parietal regions (Randall & Tyler, 2003; Shapiro, Shelton, & Caramazza, 2000; Tyler, Bright, Fletcher, & Stamatakis, 2004), whereas noun processing tends to activate more temporal areas (Cappa & Perani, 2003; Corina et al., 2005; Damasio & Tranel, 1993; Silveri, Perri, & Cappa, 2003). However, other studies show activations that cut across grammatical class, divided instead by task or semantic properties. For example, actions were shown to activate a dorsal premotor and posterior parietal network of areas in both picture naming and a grammatical class switching task (Berlingeri et al., 2008), whereas no common areas for object naming were activated in both tasks. Furthermore, there was an advantage for objects in picture naming but for actions in the class switching task. The slower category in each task was consistently associated with activation in the left inferior frontal gyrus, showing that this region could serve increased task demand rather than a specific grammatical category. Looking at semantic properties, Saccuman, Cappa, Bates, Arevalo, Della Rosa, Danna and Perani (2006) observed significant activations in a fronto-parietal network when both actions and objects involving manipulation were named as opposed to ‘non-manipulation’ actions and objects: they also failed to find a significant effect of grammatical class when all actions were compared with all objects. Data such as these indicate a distributed overall system rather than separate neural regions for grammatical classes (Crepaldi, Berlingeri, Paulesu, & Luzzatti, 2011; Martin, Ungerleider, & Haxby, 2000; Peers et al., 2005; Perani et al., 1999; Tyler, Russell, Fadili, & Moss, 2001).

Work on semantic control provides an interesting parallel to work with object and action naming. Imaging (Badre et al., 2005; Berlingeri et al., 2008; Thompson-Schill, Bedny, & Goldberg, 2005; Thompson-Schill et al., 1997; Wagner et al., 2001) and neuropsychological studies (Martin & Cheng, 2006; Thompson-Schill et al., 1998) suggest that left inferior frontal brain regions such as Brodmann Areas 44, 45, 47 and 6 (including Broca’s area) are involved in high demand controlled processing tasks such as verb generation or selection among competing alternatives. Previous work with SA patients suggests that as well as the inferior frontal locus for semantic control, temporoparietal regions are also recruited for controlled semantic processing. Damage to these posterior regions alone can also lead to impairment in control-type tasks such as tests of semantic association (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009; Soni et al., in press). This network of regions appears similar to those named in the studies above which contrast naming in different grammatical classes. Convergent evidence from behavioural, neuropsychological and imaging data therefore suggests that the action/object contrast is relevant when investigating semantic control. Combined with their areas of damage, previously observed semantic control difficulties make the patients with semantic aphasia (SA) in the current study suitable for an investigation of stimuli which might require differential levels of controlled processing, namely action and object naming. Exploration of this question was therefore the first goal of this study.

There are alternative accounts of why certain groups of items give the appearance of functional unity. The modular view is that their grammatical differences lead to the existence of two separate grammatical classes that have different properties and may also be represented independently in the brain. This position is represented by reports of patients who show double dissociations not only between noun and verb naming, but also simultaneously between input and output tasks (Caramazza & Hillis, 1991; Hillis & Caramazza, 1995; Miceli et al., 1988; Miceli et al., 1984). It is argued that autonomous brain regions are responsible for nouns and verbs, and that, for example, noun processing for receptive tasks is independent of noun processing in speech production (Caramazza & Hillis, 1991).

At the other end of the spectrum there is a strand of research which describes feature-based continua along which nouns and verbs occupy different positions by virtue of their inherent properties: grammatical ‘classes’ are seen as constructs rather than intrinsic components of neurological representations (Bird, Howard, & Franklin, 2000, 2003; Gordon & Dell, 2003). In the sensory functional theory or SFT (Bird, Howard et al., 2000), all linguistic items are represented by varying proportions of sensory and functional features: nouns receive more sensory input and verbs more functional. However, these distinctions operate within as well as between grammatical classes. Like actions, inanimate objects are said to be represented more by functional than sensory features and rely more on anterior brain areas, whereas animate objects are more weighted towards sensory features, subserved by temporoparietal regions (Bird, Howard et al., 2000; Davis et al., 2010). In a similar vein, Gordon and Dell (2003) describe a connectionist model which relies on the relative proportions of semantic and syntactic inputs to differentiate between ‘light’ verbs (e.g., ‘go’) and ‘heavy’ verbs (e.g., ‘fly’). The authors postulate the idea of ‘division of labour’, where items are represented by differing proportions of semantic and syntactic inputs.

In addition to differing semantic control demands or underlying feature types, several psycholinguistic properties may distinguish between object and action naming. High imageability and early age of acquisition (AoA) are qualities more associated with objects as a group than actions, and are known to promote fast accurate naming (Bird, Howard et al., 2000; Bird et al., 2003; Ellis & Lambon Ralph, 2000; Hodgson & Ellis, 1998; Holmes, Fitch, & Ellis, 2006; Morrison, Ellis, & Quinlan, 1992). High name agreement is also linked to fast efficient name selection (Vitkovitch & Tyrrell, 1995), which could again work in favour of object rather than action naming. It is suggested that properties like high imageability and name agreement and early AoA can lead to more automatic processing, reducing the need for deliberate controlled searching through semantic stores (Badre et al., 2005; Conroy et al., 2006; Martin & Cheng, 2006; Wagner et al., 2001), hence allowing faster and more accurate naming for highly imageable, early learned items.

Although high imageability and early AoA are commonly more associated with objects than actions, these properties can also cut across grammatical class. Imageability has been shown to be a strong predictor of success when naming nouns and verbs within specific categories or reading and writing each item type (Bird et al., 2003). Both aphasic patients and healthy control participants produced fewer nouns than verbs, and were slower and less accurate in verb categorisation, showing that an advantage for noun naming is not necessarily evidence of pathology. However, noun advantages were neutralised when imageability was controlled across stimulus type. Patients who had previously exhibited verb deficits also had difficulty producing both nouns and verbs of low imageability, showing that it was this factor rather than word class per se which caused poor naming. The authors concluded that many verb deficits previously observed in the literature (Caramazza & Hillis, 1991; Hillis et al., 2004; Miceli et al., 1988; Miceli et al., 1984) could have resulted from inadequate matching on imageability. Convergent evidence comes from another group of aphasic patients (Crepaldi et al., 2006). In order to avoid the generally higher imageability of picturable objects, this study included a task requiring the retrieval of actions and objects in a sentence context, allowing imageability to be matched between groups. Out of 16 patients who had previously displayed a selective deficit for naming action pictures, only two continued to show a class discrepancy in the sentence context retrieval task, while 14 did not. This confirms that in many cases, imageability rather than grammatical class is the operative factor in grammatical class differences.

The SA patients in the current experiment have shown strong effects of imageability in a comprehension task (Hoffman, Jefferies, & Lambon Ralph, 2010). Concrete (hence more imageable) words were comprehended better than abstract words, but this abstract impairment was reduced by giving sentence cues which guided semantic control with contextual constraints on meaning. It was argued that the naturally higher imageability of the concrete items reduced the requirement for cognitive control, analogous to the effect of the sentence cues for abstract items; this proved critical for effective comprehension in control-impaired SA patients. The sensitivity of these patients to imageability combined with differential levels of this variable across grammatical classes therefore formed the second motivation for this study.

EXPERIMENT 1: OBJECT AND ACTION NAMING IN SEMANTIC APHASIA

The motivation for the current study therefore came from several sources. The SA patient group have previously been assessed as having semantic control deficits (Jefferies et al., 2008), so testing their performance with stimuli that are likely to place differing demands on the semantic control system is valuable. It has also been shown that imageability level is predictive of naming and comprehension abilities in groups of aphasic stroke patients (Bird, Howard et al., 2000; Bird et al., 2003; Hoffman et al., 2010). Like ours, the patients in the above two studies have all suffered left frontal and/or temporoparietal haemorrhages, and are anomic to varying degrees: a range of aphasia types and degrees of fluency are also included. We expect that where imageability is not matched between grammatical classes, these SA patients will show an action naming deficit due to their control impairments. We want to assess the extent to which this impairment is due to intrinsically higher control demands for actions or due to differences on imageability; hence a second test will be conducted with lists matched for imageability.

METHOD

Patients

Seven aphasic stroke patients were recruited from stroke clubs or recommended by speech and language services in Greater Manchester, UK. The work was covered by ethical approval granted to Professor Lambon Ralph; as these patients have taken part in a number of studies, informed consent was obtained for the broader research programme. Patients with verbal comprehension deficits were enrolled in the study if they failed both word and picture versions of semantic association tests such as the Camel and Cactus Test or CCT (Bozeat et al., 2000): see Table 2.2 for individual scores. Each case had a chronic impairment from a CVA at least a year previous to the current study: a brief description of patients’ frontal and/or temporoparietal lesions can be found in Table 2.1. Four were TSA patients (transcortical sensory aphasic); the remainder had less fluent speech and/or poor repetition. Table 2.1 includes biographical details, a summary of lesion, CVA type and Boston Diagnostic Aphasia Examination (BDAE) aphasia classification (Goodglass & Kaplan, 1983): comprehension and fluency scores from the BDAE are also included.

Table 2.1: SA patients' biographical details, lesion summary and aphasia classification

Case	Age	Sex	Education (school leaving age)	Neuroimaging summary	CVA aetiology	Years since CVA	Aphasia type	BDAE Comprehension (%)	BDAE Fluency (%)	BDAE Repetition (%)
NY	67	M	15	L frontal/ temporal/ parietal	Not available	8	Conduction	47	37	40
HN	77	M	15	L temporal/ parietal/ occipital	Ischaemic infarct	2	Anomic/ TSA	100	65	50
JD	68	M	16	L putamen and capsule	Infarction with slight haemorrhage	11	Mixed trans-cortical	NT	NT	NT
PG	63	M	18	L frontal & capsular	Subarachnoid haemorrhage	8	TSA	20	40	80
SC	80	M	16	L occipital-temporal (& R frontal-parietal)	Haemorrhage	8	Anomic/ TSA	37	90	60
BB	59	F	16	L frontal & capsular (CT)	Subarachnoid haemorrhage	6	Mixed trans-cortical	10	17	55
ME	40	F	16	L occipital-temporal	Subarachnoid haemorrhage	9	TSA	33	100	100

BDAE = Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1983). Patients are arranged in order of naming scores in the 64 item battery, with NY the least and ME the most impaired (Bozeat et al., 2000).
TSA was defined as good or intermediate fluency/repetition and poorer comprehension and aphasia classifications were confirmed by an experienced speech and language therapist.
NT = test not taken.

Background neuropsychology and semantic testing

As shown in Table 2.2, patients were tested on forward and backwards digit span (Wechsler, 1997), the Visual Object and Space Perception (VOSP) battery (Warrington & James, 1991), the Coloured Progressive Matrices test of non-verbal reasoning (Raven, 1962). Executive skill and attention were tested with the Wisconsin Card Sorting test or WCST (Milner, 1963; Stuss et al., 2000), the Brixton Spatial Rule Attainment task (Burgess & Shallice, 1997), and Elevator Counting (with and without distraction) from the Test of Everyday Attention (Robertson et al., 1993). Phonological skill was assessed using word repetition from PALPA (Kay et al., 1992): 4/7 showed strong performance (> 91%); the remaining three repeated over 80% correctly. Semantic skills were tested using a number of assessments. For example, tests of semantic association included the Pyramids and Palm Trees (PPT, Howard & Patterson, 1992) and Camel and Cactus (CCT, Bozeat et al., 2000), where participants have to decide which of two (PPT) or four (CCT) items is most associated with a target, e.g. pyramid with a pine tree or a palm tree. Both PPT and CCT were assessed with word and picture versions. CCT forms part of a 64-item battery that also tested spoken picture naming and spoken word to picture matching on the same items. Other semantic tests comprised synonym judgement (Jefferies, Patterson, Jones, & Lambon Ralph, 2009), category fluency (animals, birds, fruit, household items, tools and vehicles) and letter fluency (letters F, A and S). As is immediately apparent from Table 2.2, all patients showed significant impairments across all tests tapping semantic knowledge.

Table 2.2: Background neuropsychological assessment of SA patients

Task/test	Max	Normal cut-off$^{\alpha}$	NY	HN	JD	PG	SC	BB	ME	mean
Background Neuropsychology:										
VOSP dot counting	10	8	10	8	10	**5**	10	10	**3**	8
VOSP position discrimination	20	18	20	19	20	20	**17**	18	**15**	18.43
VOSP number location	10	7	10	9	10	9	10	8	**2**	8.29
VOSP cube analysis	10	6	**5**	**4**	10	10	9	**2**	**4**	6.29
Raven's coloured matrices (percentiles)			50	20	30	50	50	50	**<5**	36.43
WCST (number of categories)	6	1^{β}	2	6	1	**0**	6	1	**0**	2.29
Brixton spatial anticipation (correct)	54	28	34	28	28	**26**	**25**	**23**	**11**	**25**
TEA counting without distraction	7	6	3	7	7	**0**	7	**4**	7	**5**
TEA counting with distraction	10	3	**2**	9	6	**3**	**1**	**0**	9	4.29
Digit span forwards	-	5	**3**	6	5	6	6	5	6	5.29
Digit span backwards	-	2	2	2	2	2	2	**0**	3	**1.88**
Semantic Tests:										
PALPA word repetition	80	80	**65**	**69**	**74**	**73**	**78**	**77**	80	**73.71**
Picture PPT	52	48.4	**47**	**35**	**46**	**42**	**50**	**41**	**29**	**41.43**
Word PPT	52	48.9	**42**	**44**	**NT**	**43**	**51**	**35**	**39**	**42.33**
Synonym judgement	96	90.1	**69**	**70**	**73**	**69**	**71**	**63**	**81**	**70.86**
Letter fluency	-	21.8	**5**	**19**	**5**	**2**	**24**	**0**	**14**	**9.86**
Category fluency	-	62.7	**25**	**63**	**31**	**4**	**17**	**13**	**25**	**25.43**
64 Item Naming	64	59.1	**55**	**50**	**49**	**46**	**28**	**10**	**5**	**34.71**
64 Item Spoken Word-picture Matching	64	62.7	**60**	**50**	64	**58**	**59**	**54**	**50**	**56.43**
64 Item Picture CCT	64	52.7	**36**	**54**	**38**	**44**	**46**	**38**	**13**	**38.43**
64 Item Word CCT	64	56.6	**39**	**54**	**38**	**40**	**56**	**30**	**34**	**41.57**

Patients are arranged in order of naming scores in the 64 item battery (Bozeat et al., 2000).
$^{\alpha}$ For semantic tests, this represents the control mean – 2SD.
$^{\beta}$ Cut-off for 50-74 year olds (regardless of educational level).
All impaired scores are shown in bold.
NT = Not taken.

Stimuli

Imageability is often poorly matched in studies that compare noun and verb naming, so great care was taken in selecting stimuli. Two pairs of lists were formulated from the Action and Object Battery (Masterson & Druks, 1998), one pair (the imageability confounded set) comprising objects and actions where the object group had significantly higher imageability levels than the actions ($t(29) = 39.137$; $p < .001$), and the other composed of object and action lists which were matched on imageability (the imageability controlled set). As well as imageability, the matching procedure took into account frequency[3], AoA[4], familiarity, visual complexity and name agreement: ratings were taken from Masterson and Druks (1998): see Table 2.3 for mean values and standard deviations for each list. Number of phonemes was not matched, as this was not considered to influence response selection: action names were on average longer, as the 'ing' form (e.g., 'dancing') was required to help distinguish between the grammatical classes. For the imageability confounded set, 30 objects and 30 actions were selected: see Appendices A 1 and 2 for items and norms. However, for the imageability controlled set, due to the generally higher imageability of objects, only 20 items from each class could be matched: see Appendix B 1 and 2 for full list. Furthermore, it was found that simultaneous matching on imageability, AoA and familiarity was impossible: when action imageability matched that of objects, AoA for actions was significantly lower ($t(19) = 3.693$; $p = .002$) and familiarity significantly higher ($t(19) = 2.285$; $p = .034$) than the object group. Hence these by necessity remained significantly different in the imageability controlled group.

Table 2.3: Mean stimulus norms (standard deviations shown in brackets)

Variable	Imageability confounded		Imageability controlled	
	Object mean	Action mean	Object mean	Action mean
Imageability	6.154 (0.30)	4.007 (0.43)	5.115 (0.40)	5.016 (0.25)
Frequency	1.051 (0.77)	1.048 (0.78)	1.003 (0.67)	1.26 (0.62)
AoA	2.451 (0.62)	2.589 (0.51)	3.001 (0.72)	2.409 (0.69)
Visual complexity	3.576 (1.12)	3.959 (0.59)	3.904 (1.05)	4.098 (0.69)
Familiarity	3.501 (1.48)	3.929 (1.33)	3.465 (1.45)	4.208 (1.42)
Name agreement	98.75 (2.34)	98.53 (1.95)	98.63 (2.22)	98.88 (1.72)

---

[3] The log lemma frequency from Francis and Kuçera (1982) was used, so all morphological variants of a verb were included as belonging to one item: otherwise, verb frequency tends to be underestimated.

[4] 'Real' AoA values were used (the proportion of children of a certain age who actually know a word, as opposed to rated values).

Procedure

Testing was carried out in the patients' homes. Both the imageability confounded set and the imageability controlled set were tested on the same occasion (total N = 100 items): set order was counterbalanced across participants. Pictures of common actions and objects were presented on paper, grouped into a block of actions and a block of objects for each set: it was necessary to group actions and objects separately to help the patients interpret the picture as denoting an action or object. Order of grammatical class presentation (actions or objects first) was counterbalanced across participants for each set independently. Instructions were given to name the item pictured; it was specified at the beginning of each block whether they would be actions or objects, and several practice trials which did not appear later in the experimental set were given at the beginning of each block. Participants were asked to give the 'ing' form of the verb when naming actions (e.g. "running", "dancing"). The experimenter recorded responses on a score sheet.

RESULTS

One item from the action list, DREAMING, was removed due to a particularly high error rate (>50%). Some responses were given which were not the intended targets but were nonetheless acceptable given the content of the pictures, such as "patting" for STROKING. These were termed legitimate alternatives or LAs. For the accuracy measure, slight dysfluencies which culminated in the correct answer, for example 'smo-smoking' or 'er, bee' were scored as correct, as were LAs. Morphological slips (e.g., 'bees' for BEE, or 'skate' for SKATING) were not counted as errors, as morphology was not the focus of this study; it was considered that the correct representation had been accessed, so this type of response was counted towards the accuracy total. Errors were classified as semantic[5], omission[6] or other[7]. Accuracy and semantic error rates were measured and converted to proportions (of number of trials) for further analysis, and are presented in Figures 2.1 and 2.2 respectively.

---

[5] E.g. "kneeling" for BENDING.

[6] No complete word response.

[7] Comprising phonological (e.g., "swelting" for MELTING) errors; visual errors (e.g., "pencil" for SWORD); responses naming only a part of a picture (e.g., "wig" for JUDGE); perseverations and unrelated responses.

Imageability confounded list

A univariate analysis of variance was carried out on the variable accuracy, with grammatical class as a fixed factor. Objects were named significantly more accurately than actions when imageability was confounded ($F(1,57) = 10.360$; $p = .002$): mean accuracy was .743 for objects and .620 for actions (see Figure 2.1). A parallel analysis was carried out with semantic errors as a dependent variable. The effect of grammatical class on semantic error rates when imageability was confounded was not significant ($F(1,57) < 1$), although this error type was more common for actions (mean = .197) than objects (mean = .162), as can be seen in Figure 2.2.

Imageability controlled list

A univariate analysis of variance was carried out on the variable accuracy, with grammatical class as a fixed factor. In this analysis, AoA and familiarity were entered as covariates, as these two variables could not be simultaneously matched with imageability. The effect of grammatical class on accuracy when imageability was controlled failed to reach significance ($F(1,36) = 2.597$); neither familiarity ($F(1,36) = 1.766$) nor AoA ($F(1,36) < 1$) reached significance as covariates. Mean accuracy was .614 for objects and .714 for actions: the significant advantage for objects shown in the imageability confounded was nullified when imageability was matched across grammatical class (see Figure 2.1). A parallel analysis was carried out with semantic errors as a dependent variable. The effect of grammatical class on semantic error rates when imageability was controlled also failed to reach significance ($F(1,36) = 1.329$), and neither familiarity ($F(1,36) < 1$) nor AoA ($F(1,36) < 1$) reached significance as covariates. Mean semantic error rates were .179 for objects and .122 for actions (see Figure 2.2).

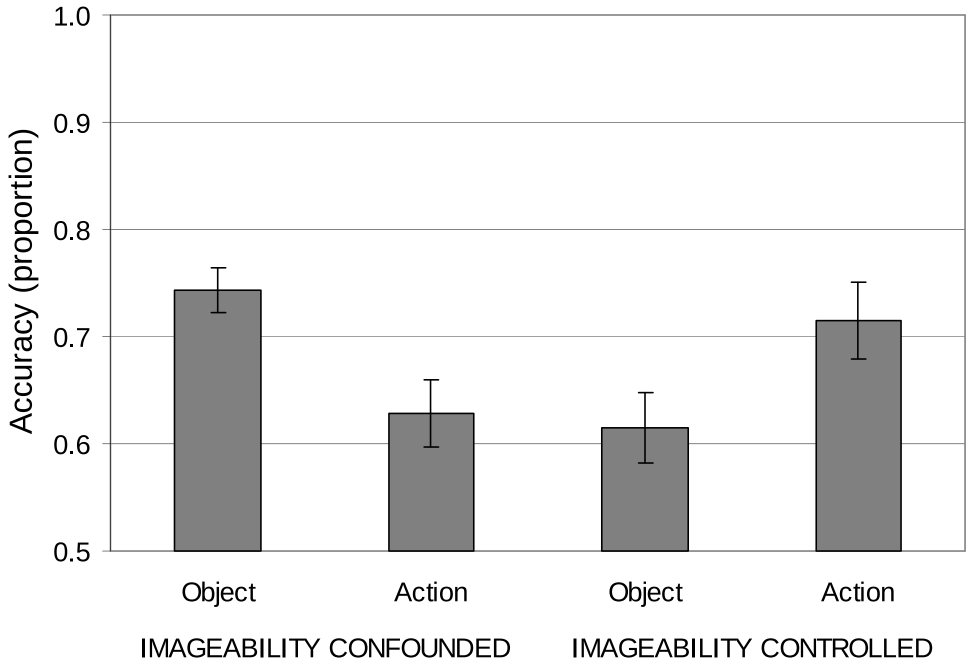


Figure 2.1: Patients' accuracy with objects and actions in imageability confounded and controlled sets (error bars represent standard error of the mean)

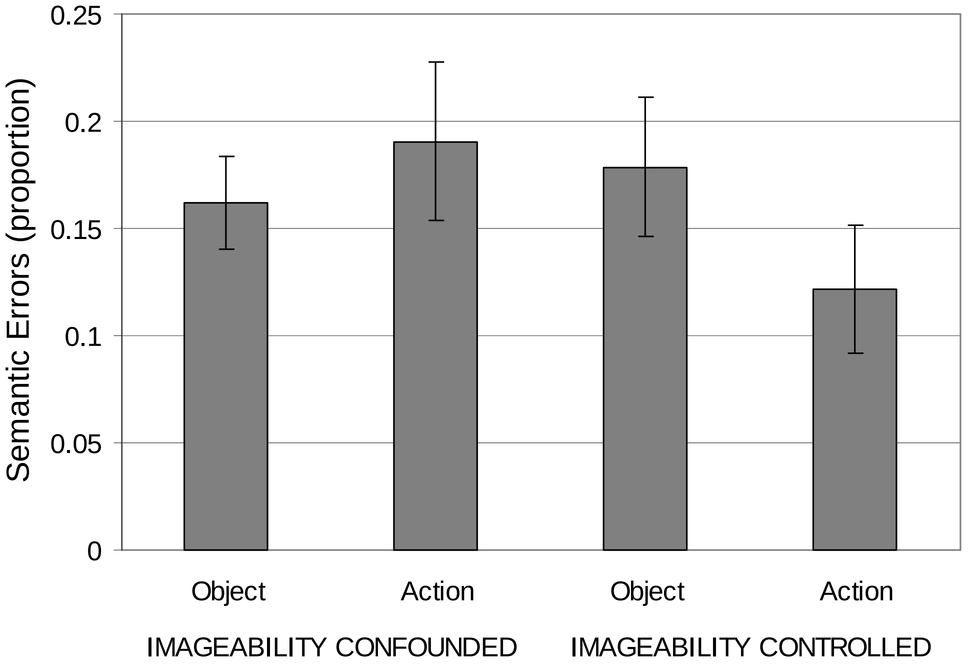


Figure 2.2: Patients' semantic error rates with objects and actions in imageability confounded and controlled sets (error bars represent standard error of the mean)

DISCUSSION

As anticipated, this group of patients showed an action deficit in picture naming for items where imageability was not explicitly controlled. This accords with the imageability effects seen with groups of stroke patients in Bird et al. (Bird, Howard et al., 2000; Bird et al., 2003) when comparing performance with different grammatical classes. Although there was no significant result in semantic error rates, the numerical trends were in the same direction as accuracy, with more semantic errors to actions than objects; these trends also suggest an effect of imageability.

Consistent with graded views of class effects, this difference disappeared completely for items where imageability was controlled. This null result indicated that these patients have particular trouble processing verbs due to their lower imageability, rather than any additional control processes required for action naming in and of itself. In the imageability controlled set, significant differences remained between grammatical classes for AoA and familiarity, but as covariates they showed no significant effects individually. It seems that imageability matched across class combined with lower AoA and higher familiarity for actions produced no significant differences between object and action naming.

EXPERIMENT 2: OBJECT AND ACTION NAMING WITH NORMAL PARTICIPANTS UNDER TEMPO NAMING CONDITIONS

Tempo naming has been thought to undermine semantic control in healthy participants in a way that is analogous to the semantic control deficits seen in SA patients above (Hodgson & Lambon Ralph, 2008). The task requires items to be named in a rigidly controlled timeframe, with responses timed to coincide with a rhythm or tempo set up by audio and visual cues prior to presentation of the stimulus to be named. The tempo can be set at a baseline speed and also at a faster speed in order to place further stress on the naming system: this method has been shown to increase error rates in normal participants to levels which mirror patient performance (mean error rate = 9%, Hodgson & Lambon Ralph, 2008). It is postulated that the requirement to time response initiation so precisely diverts semantic control resources that would otherwise be available for response selection, thus reducing accuracy. Tempo naming therefore has similarities to dual task paradigms (Collette, Olivier et al., 2005; Newman et al., 2007), which are also thought to interfere with controlled processing. Tempo naming has been used with object words and pictures (Hodgson & Lambon Ralph, 2008; Kello & Plaut, 2000), but has not yet been used with action picture naming. It is therefore relevant to combine a task that requires a high level of semantic control with stimuli that might also show a differential in controlled processing.

Following on from the significant benefit to accuracy in SA patients when naming higher imageability objects versus lower imageability actions, Experiment 2 tests the imageability confounded lists with healthy participants under tempo naming conditions. We would expect the tempo procedure to produce significantly shorter RTs at the fast tempo than those elicited by the baseline tempo, with concomitant reduced accuracy and raised error rates in the fast tempo. The demands of the task could also interact with different grammatical classes in different ways: if high imageability reduces the need for controlled processing, an advantage for object naming may be seen.

METHOD

Participants

Forty-two people (average age 30) volunteered to participate. All had no pre-existing neurological conditions, normal or corrected to normal vision, and were native speakers of English. Two were later removed from the analysis due to technical faults.

Stimuli

For the main tempo experiment, the imageability confounded action and object lists from Experiment 1 were used: details of these stimuli can be found in Appendices A 1 and 2.

Baseline naming pilot

Prior to the main experiment, the imageability confounded action and object stimuli were piloted in a standard naming paradigm to determine the ideal speed for the baseline and fast tempos (N=10); a wide variation of RTs across items was produced, hence it was decided to give items an individual tempo equal to its mean naming time: see Appendix A 1 and A 2 for baseline naming times. Several fast tempos were assayed; baseline minus 40% for each item gave the best results in terms of added difficulty and reduced accuracy.

Procedure

The main tempo experiment was presented on a Dell laptop computer using E-Prime (Schneider, Eschman, & Zuccolotto, 2002); some participants were tested in the lab, and some in their own homes. Participants sat approximately 70 cm in front of the screen, wearing a headset with earphones to play the auditory stimuli and a microphone to record responses. Pictures were presented via a tempo naming paradigm at two speeds, baseline and fast. Practice trials for each picture type were given (at the baseline speed only) until the examiner judged the task was being performed correctly: these items were not included in the main experiment.

The stimuli were presented in pure blocks of actions and objects to avoid ambiguity; block order was counterbalanced across subjects in a Latin square design. Participants saw each item only once, and first completed an action and object block at baseline speed and then at the faster tempo. Across the whole cohort of participants, each item was presented half the time at baseline speed, and half at the fast speed. The pictures within each block appeared in randomised order.

Instructions were given to participants to pay close attention to the tempo cues, as the tempo for each item would vary; participants were also instructed to name on tempo even at the expense of accuracy. The tempo was set by both auditory and visual cues; a countdown from five to one appeared in the centre of the screen, each number accompanied simultaneously by a beep. The target stimulus appeared in time with the sixth beep, and a question mark was presented with the seventh beep marking the specific time to give a response (see Figure 2.3).

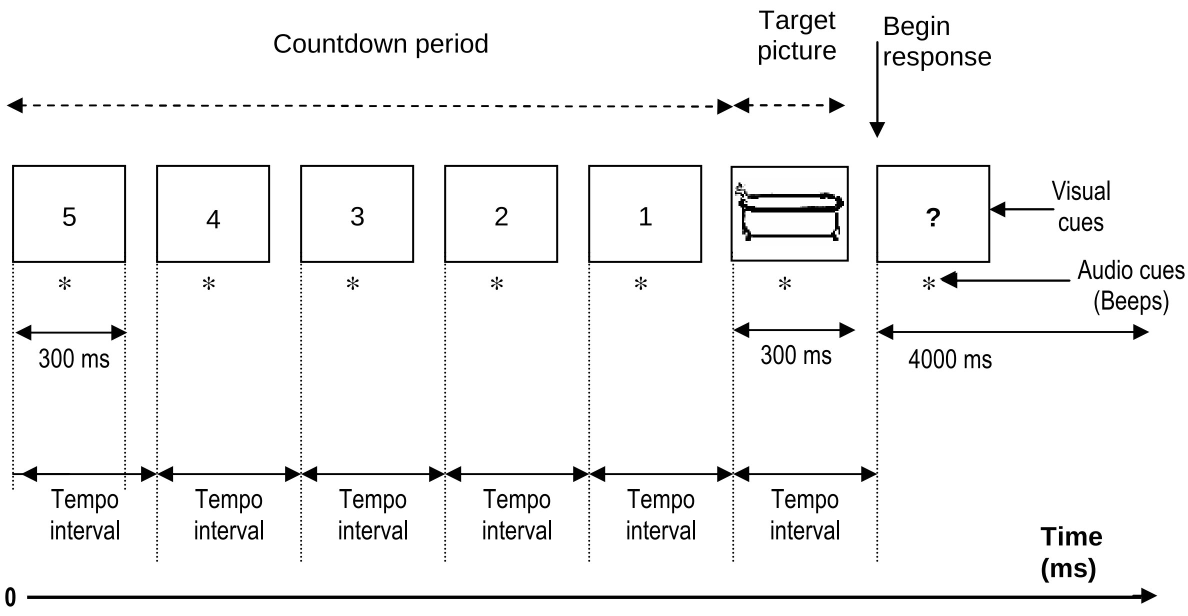


Figure 2.3: A representation of the tempo task

RESULTS

The same criteria and error classifications were used for the patients were used for scoring normal performance on the imageability confounded items. Voice key errors, dysfluencies and errors were removed from the RT analysis. LAs and responses where the root was correct but had inappropriate morphology were counted as correct for the accuracy measure but excluded from the RT analysis. A repeated measures ANOVA was carried out with tempo as a within participants factor and grammatical class as a between participants factor: each DV (latency, accuracy and semantic errors) was analysed separately.

Reaction times

For RT, there were significant main effects of tempo ($F(1,57) = 315.644$; $p < .001$) and grammatical class ($F(1,57) = 13.036$; $p = .001$), but no interaction between the two ($F(1,57) < 1$). Follow up univariate ANOVAs revealed that objects were named significantly more quickly than actions at the baseline ($F(1,57) = 9.589$; $p = .003$) and at the fast tempo ($F(1,57) = 14.333$; $p < .001$). See Figure 2.4 for relative latencies with objects and actions at each tempo.

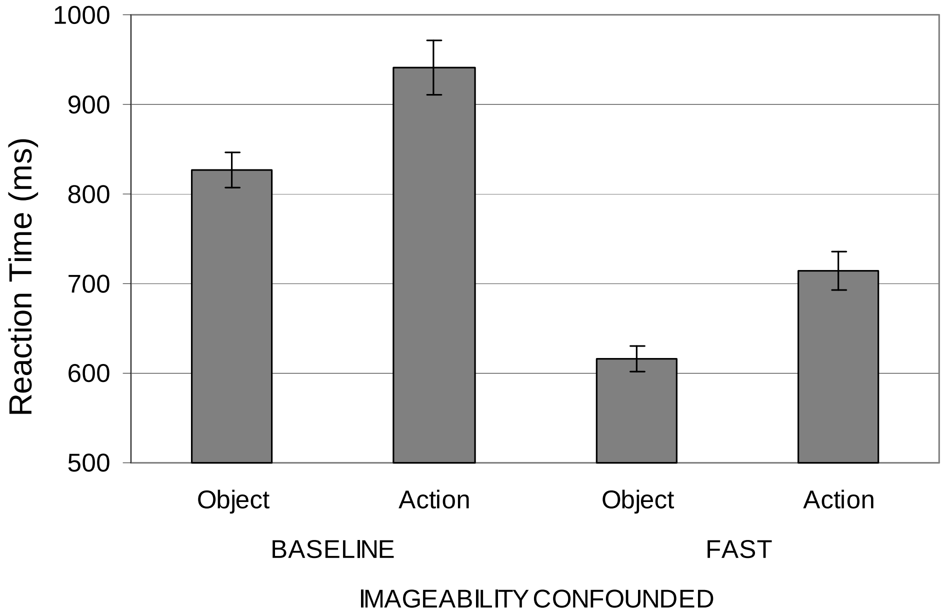


Figure 2.4: RT with objects and actions at both tempos (error bars represent standard error of the mean)

Accuracy

In accuracy, there was a significant effect of tempo (*F*(1,57) = 12.922; *p* = .001); the main effect of grammatical class approached significance (*F*(1,57) = 2.829; *p* = .098), as did the interaction between the two (*F*(1,57) = 12.922; *p* = .076). Follow up univariate ANOVAs revealed that there was no significant difference between object and action accuracy at the baseline tempo (*F*(1,57) < 1). However, at the fast tempo, objects were named significantly more accurately than actions (*F*(1,57) = 4.033; *p* = .049): see Figure 2.5 for accuracy with objects and actions at each tempo.

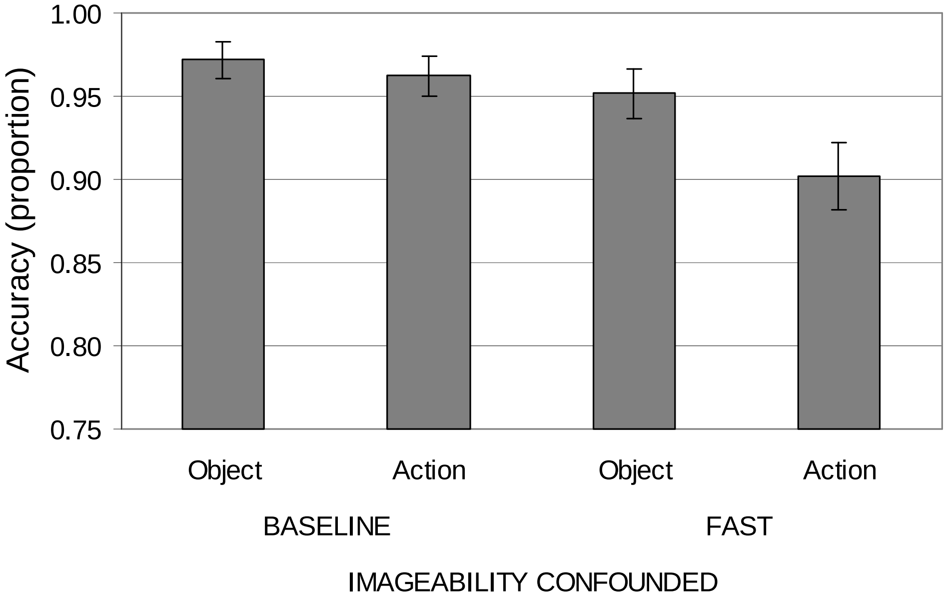


Figure 2.5: Accuracy with objects and actions at both tempos (error bars represent standard error of the mean)

Semantic errors

In semantic error rates, there were significant main effects of tempo (*F*(1,57) = 9.092; *p* = .004) and grammatical class (*F*(1,57) = 7.252; *p* = .009), but no interaction with word class (*F*(1,57) = 2.093; *p* = .153). Follow up univariate ANOVAs revealed significantly lower semantic error rates for objects than actions at the baseline (*F*(1,57) = 5.143; *p* = .027) and at the fast tempo (*F*(1,57) = 5.531; *p* < .022). See Figure 2.6 for semantic error rates with each stimulus type and tempo.

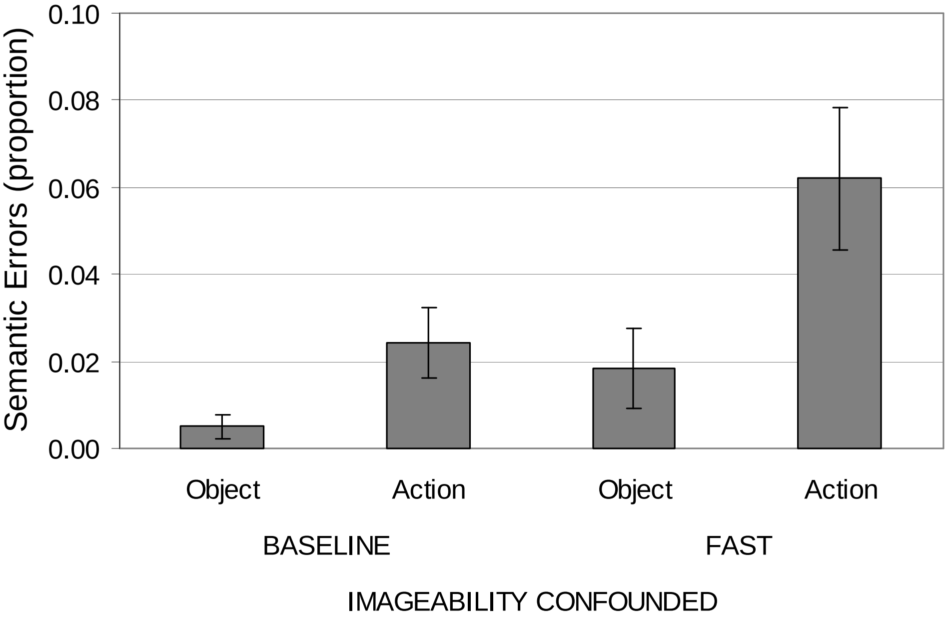


Figure 2.6: Semantic error rates with objects and actions at both tempos (error bars represent standard error of the mean)

DISCUSSION

As predicted, the tempo procedure was effective, producing significantly faster responses (collapsed across grammatical class) at the fast (665 ms) than at the baseline tempo (884ms). The lack of interaction between tempo and grammatical class in latency showed that both classes were affected equally by the tempo task, but when considering each tempo individually, objects were named significantly faster in both cases. The RT results showed better performance with objects, as did accuracy and semantic error rates in both patients and normals, indicating that the positive effects of high imageability in the object set were similar in both groups.

The tempo procedure also succeeded in significantly reducing accuracy in the fast than in the baseline condition when grammatical class was collapsed (96.7% vs. 92.7% as a proportion of all trials). The accuracy results were particularly interesting, as this was the only analysis where the interaction with word class approached significance in the normal data. The interaction and follow up tests showed that at the baseline tempo, there was no significant difference between object and action accuracy, although there was a small numerical object advantage (97.2% vs. 96.2% for actions), but at the fast tempo a wider gap opened up to produce a significant benefit for object stimuli (95.2%

vs. 90.2% for actions). This interaction between accuracy and tempo indicates that in addition to the strong effect of imageability seen in the object advantages in latency and semantic errors at each tempo, the tempo task had an additional effect. We suggest that the extra pressure of the fast tempo stretched executive resources, allowing the high imageability object set an advantage it did not gain at the baseline tempo. Equally, the combination of lower imageability with the heightened executive demands of the fast tempo led to reduced accuracy in action naming. This effect at the fast tempo mimicked the patient data from Experiment 1, where a significant object advantage was also seen in accuracy.

In semantic error rates, as in the other two measures, the fast tempo caused a significant detriment to performance when grammatical class was collapsed, with 1.4% semantic error rate (proportion of trials) in the baseline tempo and 4.0% in the fast tempo. A similar picture was observed to that shown in the latency analysis: the lack of interaction between tempo and grammatical class showed that objects and actions were affected equally by the faster tempo, but at each individual tempo a significant object advantage was seen, with fewer semantic errors to objects than actions. This completed an overall picture of better performance with objects than actions when imageability was confounded, even when the grammatical classes were matched on other relevant psycholinguistic variables. The lower semantic error rate for object naming again followed the trend of the patient results, but the effect was magnified from a numerical to a significant object advantage in the tempo data. This could reflect a low semantic error rate for high imageability items as a result of the efficient background semantic processing of the normal participants, despite the constraints of the tempo task.

In this chapter the tempo task, thought to induce difficulties with semantic control, was combined with stimuli at different levels of imageability, a variable that is thought to have an impact on the requirement for controlled processing (Hoffman et al., 2010). The advantage for items with high imageability in our data replicated imageability effects seen elsewhere with normal participants (Bird, Howard et al., 2000; Bird et al., 2003). It appeared that object stimuli gained a boost from their high imageability that allowed them to be processed in a fast, efficient manner. With regard to the effect of the tempo task on semantic control, the current data also support the argument that the tight timing specifications of the tempo task interfere with other controlled processing, as initially demonstrated in the cued naming experiments presented in Hodgson and Lambon Ralph

(2008). In the current experiment, this could have augmented the effect of low imageability to produce the significantly poorer performance observed with action naming seen almost across the board. However, the interaction with word class in tempo naming accuracy helps to demonstrate the independent effect of the tempo task over and above the effect of imageability.

COMPARATIVE ANALYSIS:

PATIENTS AND NORMALS WITH IMAGEABILITY CONFOUNDED SET

In comparing patient and normal performance with objects and actions where imageability was confounded, we will focus on the significant result from the patient data: accuracy. A repeated measures ANOVA was carried out with patients' and normals' accuracy at the baseline tempo as within subjects variables and grammatical class as a between subjects factor. There was a significant effect of group ($F(1,57) = 215.421$; $p < .001$), due to the much more accurate responses of normals than patients (.682 vs. .967 respectively). There was also a significant interaction with grammatical class ($F(1,57) = 8.381$; $p = .005$); although both groups performed better with objects, there was a greater discrepancy between objects and actions for the patients (patients N = .743 vs. baseline normals N = .972; patients V = .620 vs. baseline normals V = .962). Paired sample t-tests revealed that normal participants were significantly more accurate than patients with both object ($t(29) = 11.451$; $p < .001$) and action stimuli ($t(29) = 10.135$; $p < .001$).

A parallel repeated measures ANOVA was carried out between accuracy in patients and normals at the fast tempo. There was again a significant effect of group ($F(1,57) = 128.954$; $p < .001$), due to the much more accurate responses of normals than patients (.682 vs. .927 respectively). However, this time the interaction with grammatical class did not reach significance ($F(1,57) = 2.797$) indicating that unlike at the baseline tempo, the different grammatical classes had a similar effect on performance for each group (patients objects = .743 vs. fast normals objects = .952; patients actions = .620 vs. fast normals actions = .902). Paired sample t-tests revealed that normal participants were still significantly more accurate than patients with both object ($t(29) =10.207$; $p < .001$) and action stimuli ($t(29) = 7.310$; $p < .001$).

GENERAL DISCUSSION

The present study revealed three key findings. Firstly, patients with SA showed an effect of grammatical class in picture naming when imageability was not controlled. Secondly, this effect was eliminated when imageability was controlled, indicating that the class effect was driven by the higher control demands of low imageability items (Hoffman et al., 2010). Thirdly, the accuracy of normal participants' picture naming shows a class effect comparable to that of the SA patients when required to name at a faster than usual tempo, undermining semantic control resources.

We propose that semantic control impairments were induced in the normal group by the 'dual task' nature of the tempo procedure, which diverted executive resources to focus on the timing as well as the accuracy of responses. Due to the lower imageability of the action pictures in the imageability confounded set tested on both groups, it is probable that more executive resources were required to name actions than objects in this set. As imageability is a semantically informative variable, the inherent semantic control difficulties of the patients and the tempo-induced control impairment in the healthy participants produced particular difficulties with action naming in the imageability confounded set. The higher imageability of the objects should lead to more automatic processing (Bird et al., 2003), reducing the impact of semantic control difficulties and leading to the object naming advantage in accuracy observed in both groups.

The SA patients here all have left hemisphere frontal and/or temporoparietal lesions, for example the dorsolateral prefrontal cortex (DLPFC, BA 9, 46), the inferior frontal gyrus (IFG, BA 44, 45, 47), the angular (BA 39) and supramarginal (BA 40) gyri in the parietal lobe and the inferior temporal gyrus (BA 20). Although not every member of the SA group had lesions in each of these areas, across the group combinations of these areas were common. This range of areas comes up again when we examine dual task imaging studies in healthy participants. For example, Collette et al. (2005) showed that two simple (audio and visual) discrimination tasks that independently did not recruit frontal areas activated a left-sided network including frontal regions (including BA 46 and 47) and the inferior parietal gyrus (BA 40). Newman, Keller and Just (2007) also found that attending to two tasks (sentence comprehension and mental rotation of 3-D figures) produced a shift towards left hemisphere as opposed to bilateral activation for individual tasks, with a network of frontal prefrontal and temporal regions recruited in the dual condition.

There is some crossover between the cortical areas mentioned above and those frequently highlighted in studies looking at differences between action and object naming. In a review of neuropsychological and neuroimaging studies, Damasio and Tranel (1993) showed that the left DLPFC was frequently linked to action naming while all lexical-semantic processing activated the left temporal cortex. Aggujaro et al. (2006) found that in 20 Italian aphasic speakers, damage in those that showed verb impairments was concentrated either around left posterior temporal and inferior parietal regions or in extensive to left fronto-temporal lesions. However, other studies looking at action and object naming cite the same regions, but not necessarily split along a grammatical class divide. In an fMRI study with healthy participants, Berlingeri et al. (2008) tested actions and objects both in a classic picture naming format but also in a class-switching task, and found that the LIFG was activated by the grammatical class eliciting the longest RTs in each case, actions in picture naming but objects in class-switching. They concluded that the LIFG was associated with high task demand as opposed to a particular grammatical class. Hoffman et al. (2010) showed that impaired function in the ventrolateral prefrontal cortex (VLPFC) was associated with poor comprehension of abstract (lower imageability) relative to concrete (higher imageability) words. These difficulties were observed in both aphasic patients with VLPFC lesions and also in healthy participants when repetitive transcranial magnetic stimulation (rTMS) was applied to the same area.

There are several studies that stress the primacy of imageability rather than grammatical class in picture naming in both healthy participants and aphasic patients. Janssen, Melinger, Mahon, Finkbeiner and Caramazza (2010) showed evidence on the influence of grammatical class and imageability from the picture-word interference paradigm or PWI, where pictures are named in the context of simultaneously presented distractor words that may be presented visually or auditorily. Healthy participants named object pictures with both noun and verb distractor words that varied both in their relationship to the grammatical class of the picture and in their imageability: picture naming took place in both ‘bare noun’ and minimal sentence contexts. Janssen et al. (2010) observed that in both naming formats, distractor word imageability but not grammatical class affected picture naming latencies. Convergent neuropsychological evidence comes from a study by Crepaldi et al. (2006). Aphasic patients were tested both on action and object picture naming and on retrieval of nouns and verbs in a sentence context, in which imageability can be more readily matched across grammatical class. Out of 16 aphasic patients who were impaired at naming action pictures, 14 showed no remaining effect of grammatical class on naming in sentence context once noun and verb imageability were matched.

Imageability effects seen in the data from the current study and those cited above could be taken as support for theories that propose a continuum between actions and objects where differing proportions of component features rather than inherent boundaries separate grammatical classes (Bird, Howard et al., 2000; Bird et al., 2003; Gordon & Dell, 2003). It is suggested that imageability affects picture naming at the semantic level, perhaps because high imageability enriches semantic representations in terms of sensory-based features. Grammatical class on the other hand has an influence at the level of linguistic representations: it is a property of words, not things (Crepaldi et al., 2006). Semantic control is a system for manipulating semantic knowledge; hence it is likely to operate more on the information on the ‘real world’ properties of items than their linguistic representations. High imageability should therefore make an item particularly ‘visible’ to semantic control, leading to faster and more efficient processing than of lower imageability items. This leads directly to our hypothesis that SA patients whose semantic control is impaired or healthy participants with a task induced semantic control difficulty should display particular difficulties with low imageability items and a concomitant processing advantage for high imageability items. This hypothesis was borne out by our data, which showed that when stimulus imageability was low, as in the action stimuli in the imageability confounded list, naming in both groups was significantly less accurate than with higher imageability items (objects). Further, when imageability was controlled in the SA patients, the object naming advantage was nullified.

However, it cannot be claimed on the basis of our data that all dissociations of grammatical class can be ascribed to imageability, as there are also papers that show separable effects of imageability and grammatical class. Bedny and Thompson-Schill (2006) asked participants to make similarity judgements with stimuli from different grammatical classes during fMRI: nouns and verbs were matched on imageability, which varied continuously within class. There were main effects of grammatical class (increased activation in left superior temporal gyrus for verbal stimuli when imageability was matched) and imageability (increased activation in the left superior parietal and fusiform gyri for higher imageability items of either class) and an interaction between the two. Breaking down the interaction, a higher BOLD signal in the left middle temporal gyrus and the left inferior frontal lobe was associated with a reduction in noun but not verb imageability. In convergent neuropsychological evidence, Aggujaro et al. (2006) showed that two out of 16 aphasic patients who had previously shown difficulties with verbs continued to show impaired verb retrieval even after the effect of imageability was removed. Luzzatti, Aggujaro and Crepaldi (2006) also found that imageability interacted with retrieval of nouns and verbs in sentence contexts in verb impaired aphasic patients, but the dissociation between grammatical classes was not wholly accounted for by differences in imageability. The above examples show that both semantic and grammatical differences may distinguish between object and action naming and representations, leading to separable effects of grammatical class and semantic variables like imageability. If both such divisions exist, perhaps at different levels of processing, some patients could experience imageability effects, others effects of class and yet others effects of both, depending on the precise nature of their lesions and deficits. Similarly, some tasks may tap grammatical differences in normal participants, and others may involve processing at the semantic level. In all cases it is imperative that comparisons of grammatical class are strictly controlled for variables such as imageability, which can vary across and within grammatical class, in order that the origins of effects can be traced.

CONCLUSIONS

Our data suggest that SA patients have problems with action picture naming driven by difficulties with low imageability items as a consequence of impaired semantic control. This is consistent with graded accounts of class effects where underlying factors such as imageability or sensory and functional features tend to separate grammatical classes rather than intrinsic class boundaries (Bird, Howard et al., 2000; Bird et al., 2003; Gordon & Dell, 2003). Similar imageability effects were observed in healthy participants under tempo naming conditions. This comparable performance in normal participants showed that tempo naming could be a useful tool for exploring the role of semantic control processes in speech production.

JOURNAL OF NEUROLINGUISTICS, VOLUME 22, ISSUE 6

CHAPTER 3

“L” IS FOR TIGER: EFFECTS OF PHONOLOGICAL (MIS)CUEING ON PICTURE NAMING IN SEMANTIC APHASIA

ABSTRACT

Semantic aphasia (SA) refers to a subset of aphasic patients who exhibit multimodal semantic deficits (Jefferies & Lambon Ralph, 2006). Consistent with their underlying semantic control deficit, SA picture naming accuracy can be improved considerably with a correct phonological cue. The performance of normal individuals in the tempo picture naming paradigm reveals an increased impact of both correct and incorrect phonological cueing, and it has been suggested that this technique reduces resources available for semantic control in neurologically-intact participants (Hodgson & Lambon Ralph, 2008). We tested this hypothesis by considering the impact of both correct and incorrect phonological cues on picture naming in a case-series of SA patients, using exactly the same items as those presented to normal participants for tempo naming. The results confirmed the positive effect of correct cues and revealed for the first time the negative effects of category co-ordinate miscues amongst these patients in both overall accuracy and semantic error rates. The implications of our results for current speech production models are considered.

INTRODUCTION

The ability to harness semantic knowledge effectively in service of a task is dependent on two interactive component abilities: the representation of meaning and its utilisation in an appropriate manner. To date, many studies of semantic dementia (SD), a progressive disorder of semantic memory caused by anterior temporal lobe atrophy, have clearly demonstrated that the consequence of degradation of semantic representations is a multimodal semantic deficit (Bozeat et al., 2003; Bozeat et al., 2000). Multimodal semantic deficits have also been observed amongst some stroke aphasic patients (Chertkow, Bub, Deaudon, & Whitehead, 1997; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008) who most commonly have prefrontal and temporo-parietal infarcts. To distinguish this subset of aphasic patients from those who have modality-specific comprehension impairment alone, the label semantic aphasia (SA) was proposed as a short-hand term. Superficially, the pattern of performance seen in SA patients (especially those with transcortical sensory aphasia) might appear to resemble that seen in SD patients; however a direct comparison shows some key qualitative differences. The semantic impairment associated with SD reflects a progressive degradation of core, amodal semantic representations (Bozeat et al., 2003; Bozeat et al., 2000; Rogers et al., 2004). In contrast, impaired semantic performance in SA arises as a result of difficulties with online shaping of activation generated by intact semantic representations (Jefferies & Lambon Ralph, 2006).

These different underlying impairments to semantically-driven behaviour produce contrasting patterns of performance on semantic testing. Specifically, SA patients differ from SD patients in terms of the consistency of their performance across semantic tests with differing task requirements (low in SA but high in SD) and an absence of effects of familiarity/frequency for SA but strong effects in SD (Jefferies & Lambon Ralph, 2006). There is also a correlation in SA but not SD between tests of executive function and semantic measures (Jefferies & Lambon Ralph, 2006), supporting the notion that the deficits observed in SA arise from an inability to effectively utilise semantic knowledge as a result of compromised control processes.

The different nature of the semantic cognition impairments in SD and SA are also apparent in picture naming (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008). All models of speech production would concur that the process of picture naming involves identification of the depicted object within the semantic system and retrieval of the phonological form corresponding to its name. Hence any disruption to the semantic system will undermine picture naming in terms of compromising input to the phonological system. The semantic control impairment observed amongst SA patients is reflected in the presence of associative naming errors, such as *"nuts"* for SQUIRREL, which indicate that details of the correct target are still being reached, but an inappropriate element is selected (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008). Such naming responses are almost never observed in SD patients, whose commission errors are most often category co-ordinate responses (Soni et al., 2009).

Unlike SD, SA is not a uniform condition with a single organic origin; rather, it is a common set of deficits occurring across a somewhat heterogeneous population. Patients were included in this SA case series if they failed both word and picture versions of semantic association tests such as the Camel and Cactus Test or CCT (Bozeat et al., 2000) and/or the Pyramids and Palm Trees Test or PPT (Howard & Patterson, 1992). Their lesion locations are provided in Table 3.1, with scans for five of the seven patients provided in Appendix A in the Supplementary Materials. As can be inferred from the variability in lesion location in our case series, we are do not assign semantic control ability to a single site. Problems with semantic control co-occur with frontal and/or temporo-parietal lesions (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Soni et al., 2009), pointing to a distributed system. Transcortical sensory aphasic patients with either frontal or parietal lesions show a similar pattern of deficits regardless of lesion area (Berthier, 2001), and similar deficits in non-language attentional function occur with both frontal or parietal lesions (Peers et al., 2005). In imaging studies with normal participants, the manipulation of semantic information also appears to rest on a network of parietal and frontal regions (Cristescu, Devlin, & Nobre, 2006; Devlin et al., 2003; Gough et al., 2005), as do non-language executive control functions such as inhibition of task-irrelevant material (Collette et al., 2006; Collette, Olivier et al., 2005; Collette, Van der Linden et al., 2005).

Consistent with the notion of an underlying control impairment, the picture naming performance of SA patients shows a much larger improvement in performance than SD patients when provided with a correct phonological cue, such a /t/ for a picture of a tiger (Howard & Orchard-Lisle, 1984; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Wilshire & Saffran, 2005). A corollary of the improved SA performance with correct phonological cues is that an appreciable decrement should be observed when the cue corresponds to a semantically related target (e.g., providing /l/ with TIGER should boost activation of the competitor *lion*). A number of stroke aphasic patients with intact comprehension have been found to show significant effects of correct cueing (EST, Kay & Ellis, 1987; GM, Lambon Ralph, Sage, & Ellis, 2000; LM, Howard & Gatehouse, 2006) and miscueing (LS, Lambon Ralph, Sage, & Ellis, 2000). In one case of comprehension impairment that seemed limited to verbal stimuli, pronounced effects of both cueing and miscueing were also apparent (JCU, Howard & Orchard Lisle, 1984). Most comparable to the SA patients considered here are two cases reported by Howard and Gatehouse (2006), both of whom showed impaired verbal and nonverbal comprehension. One case (JGr) showed effects of both cueing and miscueing using initial phonemes, whereas the other (KS) showed only an effect of miscueing. Given variations in the cueing effects observed in these case studies, the first aim of the present study was therefore to apply this method to a case series of SA patients in order to confirm the positive and demonstrate the predicted negative cueing effects for the first time in this population.

Although error rates in standard picture naming are generally low for normal participants, effects of phonological cueing on picture naming performance have been observed (Hodgson, 1999; Hodgson & Lambon Ralph, 2008; Nicholas, Obler, Albert, & Goodglass, 1985), and these effects can be enhanced using the tempo naming paradigm (Hodgson & Lambon Ralph, 2008; Kello & Plaut, 2000), where items must be named in time with a specific rhythm or tempo. Using this technique, Hodgson and Lambon Ralph (Experiment 2, 2008) observed a significant increase in picture naming errors amongst normal participants at a more rapid than usual tempo, including differential effects from correct and misleading phonemic cues. A comparison to more traditional deadline naming demonstrated a higher rate of semantic errors in tempo naming irrespective of response speed (Hodgson & Lambon Ralph, Experiment 1). This suggests that the attention to the timing of the response could function to make tempo naming a kind of dual task (Collette, Olivier et al., 2005; Newman et al., 2007), diverting resources from an executive control capacity, and producing an increased sensitivity to cueing akin to that seen in SA patients. Hence the second aim of our study was to assess this hypothesis by testing the impact of positive and negative cueing upon the picture naming performance of a group of SA patients using precisely the same materials employed by Hodgson and Lambon Ralph (2008), which are listed in Appendix B in the Supplementary Materials.

METHOD

Participants

Seven SA patients were recruited from stroke clubs or recommended by speech and language services in Greater Manchester, UK. They were a subset of those reported in other work on this patient group (Jefferies, Baker, Doran, & Lambon Ralph, 2007; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008). Each patient had a chronic impairment from a CVA at least a year previous to the current study. Table 3.1 includes biographical details and detailed lesion information.

Table 3.1: SA patients’ biographical details, lesion characteristics and patterns of co-occurrence

Patient	Age	Sex	Educ leaving age	Years since CVA	Lesion size (% of template damaged)[a]	Frontal damage	Temporo parietal damage	DLPFC		orbIFC	trIFG	opIFG	STG	MTG	ITG	FG	POT	AG	SMG	TP
								BA 9	BA 46	BA 47	BA 45	BA 44	BA 22	BA 21	BA 20	BA 36	BA 37	BA 39	BA 40	BA 38
NY	67	M	15	8	14	✓	✓	1	1	2	2	2	1	-	-	-	-	2	2	-
HN	77	M	15	2	6	✗	✓	-	-	-	-	-	-	2	1	-	2	w	-	-
JD[b]	68	M	16	11		✗	w													
PG[c]	63	M	18	8		✓	w													
SC	80	M	16	8	8	✗	✓	-	-	-	-	-	-	-	2	-	2	2	w	-
BB[d]	59	F	16	6	3	✓	✓	-	-	2	2	2	2	-	-	-	-	-	-	-
ME	40	F	16	9	5	✗	✓	-	-	-	-	-	-	2	2	2	2	w	w	-
% patients with grey matter damage								20	20	40	40	40	40	40	60	20	60	40	20	0
% patients with grey or white matter damage								20	20	40	40	40	40	40	60	20	60	80	60	0

Patients are arranged in order of naming scores in the 64 item battery (Bozeat et al., 2000).

[a] Lesion size was estimated by overlaying a standardised grid of squares onto each patient’s template and working out the percentage of squares damaged relative to the complete undamaged template.

Anatomical abbreviations: DLPFC = dorsolateral prefrontal cortex; orbIFG = pars orbitalis in inferior frontal gyrus; trIFG,= pars triangularis in inferior frontal gyrus; opIFG = pars opercularis in inferior frontal gyrus; TP = temporal pole; STG = superior temporal gyrus; MTG = middle temporal gyrus; ITG = inferior temporal gyrus; FG = fusiform gyrus; POT = posterior occipitotemporal area; SMG = supramarginal gyrus; AG = angular gyrus.

Quantification of lesion: 2 = complete destruction/serious damage to cortical grey matter; 1 = partial destruction/mild damage to cortical grey matter; w = damage confined to white matter immediately underlying cortex.

[b] No scan available. Description of lesion: L putamen and capsule.

[c] No scan available. Description of lesion: L frontal and capsular.

[d] BB showed additional signs of ventricular enlargement in the left hemisphere.

Background neuropsychology and semantic testing

As seen in Table 3.2, patients were tested on forward and backwards digit span (Wechsler, 1997), the Visual Object and Space Perception (VOSP) battery (Warrington & James, 1991), the Coloured Progressive Matrices test of non-verbal reasoning (Raven, 1962). Executive skill and attention were tested with the Wisconsin Card Sorting test (Milner, 1963; Stuss et al., 2000), the Brixton Spatial Rule Attainment task (Burgess & Shallice, 1997), and Elevator Counting (with and without distraction) from the Test of Everyday Attention (Robertson et al., 1993), with a number of patients impaired on these measures. Phonological skill was assessed using word repetition from PALPA (Kay et al., 1992): 5/7 showed strong performance (> 91%). Semantic skills were tested using a number of assessments, for example word and picture versions of PPT (Howard & Patterson, 1992) and CCT (Bozeat et al., 2000). Other semantic tests comprised synonym judgement (Hodgson & Lambon Ralph, 2008), and category and letter fluency. As shown in Table 3.2, all patients showed significant impairments across a range of semantic tests.

Table 3.2: Background neuropsychological assessment of SA patients

Task/test	Max	Normal cut-off[α]	NY	HN	JD	PG	SC	BB	ME	mean
Background Neuropsychology:										
VOSP dot counting	10	8	10	8	10	**5**	10	10	**3**	8
VOSP position discrimination	20	18	20	19	20	20	**17**	18	**15**	18.43
VOSP number location	10	7	10	9	10	9	10	8	**2**	8.29
VOSP cube analysis	10	6	**5**	**4**	10	10	9	**2**	**4**	6.29
Raven’s coloured matrices (percentiles)			50	20	30	50	50	50	**<5**	36.43
WCST (number of categories)	6	1[β]	2	6	1	**0**	6	1	**0**	2.29
Brixton spatial anticipation (correct)	54	28	34	28	28	**26**	**25**	**23**	**11**	**25**
TEA counting without distraction	7	6	**3**	7	7	**0**	7	**4**	7	**5**
TEA counting with distraction	10	3	**2**	9	6	3	**1**	**0**	9	4.29
Digit span forwards	-	5	**3**	6	5	6	6	5	6	5.29
Digit span backwards	-	2	2	2	2	2	2	**0**	3	**1.88**
Semantic Tests:										
PALPA word repetition	80	80	**65**	**69**	**74**	**73**	**78**	**77**	80	**73.71**
Picture PPT	52	48.4	**47**	**35**	**46**	**42**	50	**41**	**29**	**41.43**
Word PPT	52	48.9	**42**	**44**	NT	**43**	51	**35**	**39**	**42.33**
Synonym judgement	96	90.1	**69**	**70**	**73**	**69**	**71**	**63**	**81**	**70.86**
Letter fluency	-	21.8	**5**	**19**	**5**	**2**	24	**0**	**14**	**9.86**
Category fluency	-	62.7	**25**	63	**31**	**4**	**17**	**13**	**25**	**25.43**
64 Item Picture Naming	64	59.1	**55**	**50**	**49**	**46**	**28**	**10**	**5**	**34.71**
64 Item Spoken Word-picture Matching	64	62.7	**60**	**50**	64	**58**	**59**	**54**	**50**	**56.43**
64 Item Picture CCT	64	52.7	**36**	54	**38**	**44**	**46**	**38**	**13**	**38.43**
64 Item Word CCT	64	56.6	**39**	**54**	**38**	**40**	**56**	**30**	**34**	**41.57**

Patients are arranged in order of naming scores in the 64 item battery (Bozeat et al., 2000).
[a] For semantic tests, this represents the control mean – 2SD.
[β] Cut-off for 50-74 year olds (regardless of educational level).
All impaired scores are shown in bold.
NT = Not taken.

Stimuli

The picture stimuli and cues, both positive (correct initial phoneme) and negative (initial phoneme of a category co-ordinate), were those used by Hodgson and Lambon Ralph (2008). Testing was carried out in the patients' homes using a laptop. Each picture appeared simultaneously with its sound cue; it remained on screen until a response was given, and the tester repeated the sound cue when necessary.

Procedure

The experiment was presented using E-Prime (Schneider et al., 2002), with participants sitting around 80cm from the screen. There were three cueing conditions; correct (initial phoneme of target), neutral (short beep), and incorrect (initial phoneme of category co-ordinate). The entire test was split into three versions presented on three separate occasions, with the order of presentation of each version alternated across patients. Each version comprised 20 items presented with each cue type, yielding 60 trials per version. Across the three versions, each set of 20 items was rotated through all three cueing conditions, meaning that every item appeared in every condition, yielding 180 observations per patient by the end of the three testing sessions. Within each test session, the cue conditions were mixed randomly, so the cue type could not be predicted on each trial. Patients were informed that the task was simply to name the picture in all cases.

RESULTS

The patients' first responses were scored and, following the method of Hodgson and Lambon Ralph (2008) any errors were coded as either semantic, omission or other (the complete error taxonomy can be found in Appendix C in the Supplementary Materials). The patients' scores were converted to a proportion of the number of trials per condition. As we had explicitly directional hypotheses concerning the effects of cueing, the p-values reported for the patient data are one-tailed, with all other p-values provided as two-tailed.

Picture naming accuracy

Naming accuracy data were initially analysed using a one-way repeated measures ANOVA on the variable cue type (correct / neutral / miscue). There was a significant effect on accuracy ($F(2, 12) = 5.22$; $p = .012$), with the highest accuracy seen for correct cues (.78), followed by neutral cues (.71), and then miscues (.62). Correct cues produced significantly more accurate responses than the miscues (*t*(6)= 2.75; *p* = .017); correct cues produced significantly more accurate responses than neutral cues (*t*(6) = 2.13; *p* = .039); and the disadvantage for the miscues relative to the neutral cues was marginally significant (*t*(6) = 1.70; *p* = .069).

Semantic error rates

Semantic errors (.17 of responses) were significantly more frequent than null responses (0.6, *t*(6) = 3.30; *p* = .008) and other errors (0.7, *t*(6) = 5.97; *p* < .001). As for accuracy, an ANOVA considering only semantic errors demonstrated a significant effect of cue type (*F*(2, 12) = 3.86; *p* = .026), with fewest errors produced to correct cues (.11 of responses), followed by neutral cues (.17), and then miscues (.23), as can be seen in Figure 3.1. Semantic error rates were significantly lower for correct cues than miscues (*t*(6) = -2.47; *p* = .024), and also for correct cues than neutral cues (*t*(6) = -2.20; *p* = .035). Although the difference between neutral cues and miscues was not reliable when all semantic errors were considered (*t*(6) = -1.24; *p* = .131), this difference was significant when the proportions of semantic errors that corresponded to the particular category co-ordinates used in the miscue condition were compared (17% vs. 33% respectively, *t*(6) = -2.26; *p* = .032).

COMPARISON WITH TEMPO PICTURE NAMING

As in the patient data above, Hodgson and Lambon Ralph (2008, Experiment 2) found semantically related responses to be the most common form error in their participants, so only these responses will be considered here. Figure 3.1 shows the comparison of semantic error rates for the SA patients and the normal participants in each tempo condition. A two-way ANOVA with cue type (correct / neutral / miscue) as a within participants factor and group (patient / normal) as a between participants factor was conducted for each tempo condition.

Consideration of the slow tempo showed that the patients made marginally more semantic errors than the normal participants (.17 vs .12, *F* (1, 32) = 3.59; *p* = .067). Cue type significantly affected semantic error rates (*F* (2, 64) = 15.57; *p* < .001), with most semantic errors to miscues (.23), then neutral cues (.13), and correct cues (.07). The interaction of this cueing effect with group was not significant (*F*(2, 64) = 1.66, *p* = .199). As can be seen in Figure 3.1, for normal participants at the slow tempo, fewest errors were produced to correct cues (.03), followed by neutral cues (.09), and then miscues (.24). Semantic error rates were significantly lower for correct cues than miscues (*t*(26) = -6.15; *p* < .0005), for correct cues than neutral cues (*t*(26) = -3.02; *p* = .006), and for neutral cues than miscues (*t*(26) = -5.00; *p* < .0005).

Consideration of the fast tempo showed that the patients and normal participants produced a comparable number of semantic errors (.17 vs .18, *F* (1, 32) < 1). Cue type significantly affected semantic error rates (*F*(2, 64) = 24.09; *p* < .001), with most semantic errors to miscues (.31), then neutral cues (.14), and correct cues (.08). However, there was also a significant interaction between cue type and group (*F*(2, 64) = 7.03; *p* = .009). As can be seen in Figure 3.1, for normal participants at the fast tempo, fewest errors were produced to correct cues (.04), followed by neutral cues (.11), and then miscues (.40). Semantic error rates were significantly lower for correct cues than miscues (*t*(26) = -8.51; *p* < .0005), for correct cues than neutral cues (*t*(26) = -5.31; *p* < .0005), and for neutral cues than miscues (*t*(26) = -7.22; *p* < .0005). Comparisons concerning group differences revealed that in response to the correct cue, patients produced significantly more semantic errors than normals (.11 vs. .04, *t*(32) = 2.72; *p* = .011); in the neutral condition, patients tended to make more semantic errors than normals (.17 vs .11, *t*(32) = 1.89, *p* = .068); in the miscue condition, patients actually produced substantially fewer semantic errors than normals (.23 vs. .40, *t*(32) = -1.95; *p* = .060).

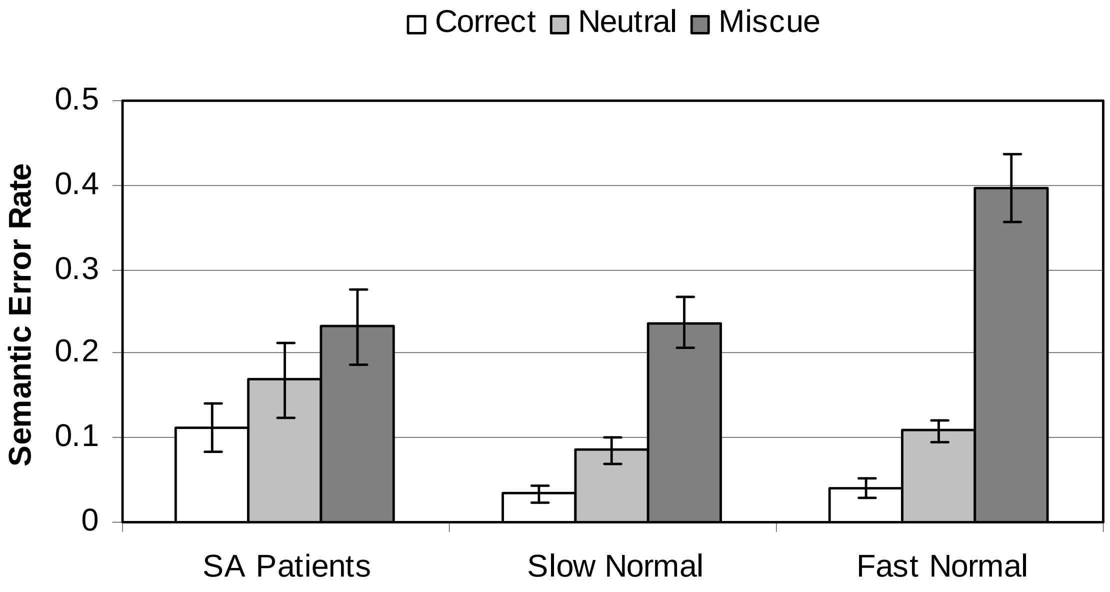


Figure 3.1: Semantic error rates (proportions of trials/condition) in each cue condition for patients in the present study and the normal participants in the tempo naming study of Hodgson and Lambon Ralph (2008, Experiment 2). Error bars represent +/- standard error

DISCUSSION

In accordance with the hypothesis that semantic control deficits make patients more susceptible to manipulations such as phonological cueing, our data show that giving a correct cue to SA aphasic patients resulted in significantly more accurate responses than either a neutral or an incorrect cue. This supports previous work where cueing has been shown to have a beneficial effect for SA patients (Jefferies et al., 2007, 2008) and extends it by demonstrating the impact of miscueing with the initial phoneme of a category co-ordinate for the first time in this patient group. These cueing effects are consistent with the working hypothesis that this subset of patients have intact semantic representations but do not utilise them in a task appropriate way (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Soni et al., 2009). Further support is given to this idea by the strong correlations obtained between the cueing effects seen in overall accuracy and performance on the measures of executive functioning provided in Table 3.2 (overall cueing effect and WCST: $\rho = -.824$, $p = .011$; positive cueing effect and Brixton: $\rho = -.883$, $p = .004$; negative cueing effect and TEA without distraction: $\rho = -.670$, $p = .050$)

The cueing effects we obtained were largely driven by differences in semantic error rates, consistent with the view that these patients' anomia arises from their semantic control impairment. The presentation of misleading phonemes did not appear to disrupt the phonological integrity of patients' responses, as there was a very low level of phonological errors (.003 as proportion of all trials), suggesting that phonological representations and processing are relatively intact in these patients. Thus, as predicted, it would seem that the phonological cues provide an external influence that either appropriately or inappropriately constrains the semantic activation driving picture naming. While we are of the view that semantic control is underpinned by a network of frontal and temporo-parietal regions, consideration of Table 3.1 shows that although frontal lesions were not universal, damage to the temporo-parietal cortex or the white matter immediately beneath is was common to all patients.

The cueing effects we observed in the semantic error rates of SA patients were in fact comparable to those reported by Hodgson and Lambon Ralph (2008, Experiment 2) for their slow tempo of 800ms. This supports their hypothesis that the tempo naming procedure itself places a load on executive processing in normal participants, using resources which would otherwise be available to direct semantic activation, including inhibition of competing semantic representations. Strikingly, for the faster tempo of 600ms, the cueing effects observed for the normal participants were in fact significantly larger than those obtained in this patient group. This result could be seen as a reflection of the integrity of the semantic control processes operating amongst the normal individuals, such that activation of both correct targets and competitors in response to an initial phoneme cue is highly efficient.

Implications for models of speech production

It is our view that cascading activation and interactive feedback could allow phonological cues to influence semantic processing (Dell & O'Seaghdha, 1992; Dell et al., 1997; Foygel & Dell, 2000; Rapp & Goldrick, 2000; Schwartz et al., 2006). Cascading activation refers to a process in which activation of several semantic candidates flows to phonology before a target has been selected for production. Interactive feedback reverberates between semantic and phonological processing, so phonemic cues can boost the activation of semantic representations which are consistent with them (Dell et al., 1997; Foygel & Dell, 2000; Lambon Ralph et al., 2002; Lambon Ralph et al., 2000). In these models, the correct cue both promotes the target and demotes competitors. Miscues, by contrast, will promote one of the semantically-related items at the cost of the target name. For example, on viewing a picture of a TIGER, semantic representations of related large felines like PUMA, LION and LEOPARD receive partial activation (Damian & Martin, 1999; Dell et al., 1997; Foygel & Dell, 2000; Lambon Ralph et al., 2000). All the potential candidates begin to activate their phonological forms and normally the target leads this phonological "race". If the correct cue /t/ is provide, it will boost activation of target "*tiger*" at both the semantic and phonological levels, meaning that it is more likely to reach threshold, and to do so sooner, than if no cue had been given: hence the advantage for the correct cue condition. If, however, the incorrect cue /l/ has been given, the semantic and phonological representations of alternative responses such as "*lion*" or "*leopard*" will be activated, which may cause them to reach threshold sooner than the correct target, resulting in a semantic error, hence the disadvantage in the miscue condition.

The miscueing effect we have reported here could be considered as comparable to the disadvantage obtained found with semantically related distractors in the picture word interference paradigm, when the stimulus onset asynchrony between picture and distractor is either simultaneous or +/-100ms (Caramazza & Costa, 2000, 2001; Costa, Alario, & Caramazza, 2005; de Zubaricay, Wilson, McMahon, & Muthiah, 2001; Glaser & Glaser, 1989; Levelt et al., 1999; Wilshire, Keall, Stuart, & O'Donnell, 2007). However, the crucial difference is that in our cued naming paradigm, only a single distractor phoneme is presented, whereas in picture word interference, a whole distractor word is provided.

Although a discrete feedforward serial model of speech production such as that proposed by Levelt et al. (1999) may be able to accommodate effects of single phoneme cues on RT, it does not seem to incorporate any mechanism by which such cues could affect accuracy, at least on the assumption that perception of a phonemic cue does not activate all of the semantic representations consistent with it. Even without biasing semantic activation, a correct phonemic cue might speed word form assembly once the selected lemma has passed to phonology. However, if the incorrect lemma is selected at the semantic level, then pre-activation of the correct initial phoneme at the phonological level would merely slow production of an incorrect response. Similarly, even if a miscue does not affect semantic activation, the pre-activation of an incorrect phoneme at the phonological level will delay activation of the phonemes of the target lemma.

Nonetheless, most of the phonemes of the correct response should eventually become activated, meaning that this account cannot explain why almost a third of the patients' errors (32%) in the miscue condition comprised the miscued competitor (e.g. "lion" for TIGER). We therefore propose that models of speech production incorporating cascaded and interaction processing provide a more natural and parsimonious explanation of the cueing effects seen in the accuracy of SA patients and normal participants under tempo naming conditions.

In summary, the presentation of phonemic cues and miscues was successful in affecting picture naming accuracy in a case series of SA patients with semantic control impairments. Given the similarity of the patients' performance to that of normal participants under slow tempo conditions, support was given to the hypothesis that the tempo paradigm itself, rather than the more rapid responding that it can be used to induce, is effective in disrupting semantic control processes and thereby mimicking SA patient performance.

CHAPTER 4

“W” IS FOR BATH: CAN ASSOCIATIVE ERRORS BE CUED?

ABSTRACT

Semantic aphasia (SA) refers to a condition in which the control processes associated with the use of semantic information become compromised. This condition compromises patients' abilities to accurately name pictures, and they produce semantic errors in the form of co-ordinate items, such as "shower" for BATH. Previous research has demonstrated that these patients are sensitive to phonemic cues during picture naming, whether they promote the correct response (e.g., /b/) or the incorrect semantically related response (e.g., /sh/). A similar pattern is observed in normal participants when asked to perform tempo picture naming, in which the timing constraints undermine semantic control processes. SA patients are also known to produce associative errors in picture naming, such as "water" for BATH. In this study, we extended previous work on phonemic cueing in SA patients and in normal participants in two ways: firstly, by using associative miscues to promote associative errors (e.g., /w/), and secondly, to confirm miscueing effects still hold when assessed relative to a neutral condition of an unrelated phoneme rather a simple beep. The results revealed that associative miscues are effective in reducing accuracy and promoting semantic errors in SA patients. Correlations between associative cueing effects and executive tests showed that the impact of associative miscues was more pronounced in those with greater semantic control impairment. Associative miscueing was also seen for normal participants during tempo picture naming, including a latency cost. Both the associative and also the co-ordinate miscueing effects were still apparent when the neutral condition consisted of an unrelated phoneme. The implications of these results for models of speech production and semantic representation are outlined.

INTRODUCTION

Semantic memory is made up of two components: representations, by which meanings are stored in the brain; and semantic control, which allows stored information to be manipulated for the task in hand. These two elements can be independently impaired, as shown by the contrasting patterns of performance in semantic dementia (SD) and semantic aphasia (SA). Patients of both types are impaired in picture naming, but there are some important differences. These patient groups differ in their susceptibility to positive and negative cueing (Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009), such that SA patients show improved performance with correct phonemic cues and additional impairment when misleading cues are given, whereas SD patients are minimally affected by phonemic cueing. Another qualitative difference is the presence of associative errors in SA but not SD naming (Jefferies & Lambon Ralph, 2006), where the erroneously named item has a semantic relationship to the target but is from a different category, for example "nuts" for SQUIRREL. These two features combine to suggest that it should be possible to miscue associative errors in patients with SA: a major goal of the first experiment of this study was to explore this hypothesis. If an associate miscue effect is found, it would challenge the recent proposals that representational frameworks for concrete items do not include associative relationships (Crutch, Connell, & Warrington, 2009; Crutch & Warrington, 2005). If associative cues reduce accuracy and even promote specific associative errors, this would indicate that associative relationships are integral to the semantic representations of concrete items, as well as the co-ordinate relationships previously demonstrated (Soni et al., 2009).

Associative errors form a sizeable proportion of all semantic errors in SA naming, 27% of semantic errors compared with 1% for the SD group (Jefferies & Lambon Ralph, 2006). The production of an associative error indicates that the core representation has been reached (e.g., knowledge of squirrels is essential to make the connection to nuts), but an incorrect element has been selected. Associatively related errors require detailed semantic knowledge concerning the target, and hence cannot be accounted for by proposing that representations have become degraded, in contrast to the co-ordinate errors often observed in SD naming (Woollams, Cooper-Pye, Hodges, & Patterson, 2008). Associative naming errors could, however, be explained by postulating impaired control processes in the presence of relatively preserved semantic representations, which we suggest is a defining characteristic of SA. Consistent with this account, SA patients' ability to produce correct responses varies according to the requirements of the task, demonstrating that a particular representation may be successfully accessed given appropriate contextual support, such as a correct phonemic cue (Jefferies et al., 2008; Noonan, 2010; Soni et al., 2009). In addition, strong correlations were obtained in Soni et al. (2009) between the cueing effects in accuracy and performance on measures of executive functioning (overall cueing effect and WCST: ρ = .824, p = .011; positive cueing effect and Brixton: ρ = .883, p = .004; negative cueing effect and TEA without distraction: ρ = .670, p = .050). Such correlations expose the connection between poor executive function and impaired semantics in these patients, and suggest that although representations are relatively intact, manipulation and selection of semantic material is impaired.

The patients included in the above and current studies have all suffered lesions in frontal and/or temporoparietal areas (see Table 4.1 and Appendix 4A), leading to the hypothesis that a fronto-parietal network of brain regions is responsible for the manipulation and control of semantic information, separate to the storage of semantic representations (Jefferies, Baker et al., 2007; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Noonan, 2010; Soni et al., 2009). The idea of a distributed network is supported by Berthier's (2001) study of transcortical sensory aphasia (TSA) patients with both temporoparietal and frontal lesions, including Broca's area. Using language scores from the Western Aphasia Battery or WAB (Kertesz, 1982), he compared three groups of TSA patients, two with either purely anterior or posterior lesions and a third with lesions including both areas. In nearly all the WAB subtests used, no significant differences were found between any of the groups, indicating that despite differences in lesion site, their functional profiles were very similar. Our group of seven patients contains four cases of TSA (HN, PG, ME and SC): of these, PG has a left frontal and capsular haemorrhage; the remainder have posterior lesions including left temporal, parietal and occipital areas. The other three SA patients have varied aphasia classifications (BB: mixed transcortical, L frontal and capsular lesion; NY: conduction, L frontal/temporal/parietal lesion; EW: no diagnosis given but fluent speech with occasional semantic paraphasias, L occipital/temporal/parietal lesion), but all seven have been judged as functionally similar due to a multimodal semantic deficit indicated by failure on both written and verbal versions of semantic association tests (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008). Despite their varied lesion sites and aphasia classifications, the fact that all these SA patients have difficulties with semantic control suggests that any network subserving this function must have distributed neurological bases.

To date, studies using miscued naming have used initial phonemes from a co-ordinate of the target (Hodgson & Lambon Ralph, 2008; Howard & Gatehouse, 2006; Howard & Orchard-Lisle, 1984; Jefferies, Baker et al., 2007; Lambon Ralph et al., 2000), for example /sh/ (for "shower") with a picture of a BATH. Previous research (Noonan, 2010; Soni et al., 2009) has shown that category co-ordinate cues interfere with SA patients' naming. In Soni et al. (2009), a significant overall cueing effect on accuracy was seen between co-ordinate miscues and correct cues and the negative cueing effect between miscues and neutral cues was marginally significant. This cueing effect was driven by differences in semantic error rates, showing that the cues were acting at the level of semantics in these patients; as in accuracy, the overall cueing effect on semantic errors was significant. Although the miscueing effect did not reach significance when all semantic errors were considered, a significant effect was seen when considering the proportions of semantic errors that corresponded to the cued item, such as "shower" with a cue of /sh/ to a picture of a BATH (32% for miscue vs.17% for neutral cue).

It remains possible, however, that in the SA patient group the miscueing effect results from the provision of any incorrect phonology, rather than arising solely in the context of the semantically directive phonemes used in the co-ordinate miscues. This possibility will therefore be controlled in the current study by the introduction of an unrelated phonemic cue, replacing the beep as a neutral condition. A set of pictures taken from standardised test material is accompanied by newly developed phonemic cues; as well as the unrelated or neutral phoneme cue, each picture is linked to initial phonemes from correct target names, co-ordinates and associates. The finding of an associative cueing effect would extend our knowledge of the nature of semantic representations for concrete objects, showing that they include both categorically and associatively related information.

In two linked experiments we investigate the effect of associative and other cues in both SA patients and normal participants. Initially in Experiment 1 we attempt to replicate the results of our previous study concerning the impact of correct and co-ordinate cues but with a neutral phoneme condition. Then we attempt to increase the incidence of associative semantic errors in naming shown by SA patients in Jefferies et al. (2006), and test whether specific associative errors can be deliberately cued. Normal picture naming performance under tempo conditions (Hodgson & Lambon Ralph, 2008) showed some similarities with miscued naming in SA patients (Hodgson & Lambon Ralph, 2008; Soni et al., 2009) in that both groups showed significant correct and co-ordinate cueing effects and produced some associative errors. In Experiment 2 we therefore tested normal participants under tempo picture naming conditions in order to validate previous effects of co-ordinate cueing using the neutral phoneme condition, and explore the possibility that associative cues may also have a disruptive effect upon performance in this task.

EXPERIMENT 1:

CUED PICTURE NAMING WITH SEMANTIC APHASIC PATIENTS

In this experiment we aim to replicate previously observed category co-ordinate miscueing effects, but using the neutral phoneme rather than the beep, as this will establish that previously reported miscueing effects are due to the semantically relevant nature of the miscues, not just disruption from incorrect phonology. In addition, a novel miscue is introduced that has not yet been employed with SA patients: the associative miscue. We predict that this will produce a decrement in performance similar to that seen for category co-ordinate cues, in terms of semantic errors generally and cued responses specifically.

METHOD

Participants

Seven SA patients were recruited from stroke clubs or recommended by speech and language therapy services in Greater Manchester, UK. They were a subset of those reported in other work on this patient group, (Jefferies, Baker et al., 2007; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008). Patients were enrolled if they failed both word and picture versions of semantic association tests such as the Camel and Cactus Test or CCT (Bozeat et al., 2000) and/or the Pyramids and Palm Trees Test or PPT (Howard & Patterson, 1992). Each patient had a chronic impairment from a CVA at least a year previous to the current study. Four were diagnosed with transcortical sensory aphasia (TSA), with poor comprehension, fluent speech and good repetition.

The remainder had less fluent speech and/or poorer repetition in addition to impaired comprehension. Table 4.1 includes biographical details and comparison of anterior versus posterior lesions; Table 4.2 shows performance in perceptual, executive and semantic tests.

Table 4.1: SA patients’ biographical details, lesion characteristics and patterns of co-occurrence

Patient	Age	Sex	Educ leaving age	Years since CVA	Lesion size (% of template damaged)[a]	Frontal damage	Temporo parietal damage	DLPFC		orbIFC	trIFG	opIFG	STG	MTG	ITG	FG	POT	AG	SMG	TP
								BA 9	BA 46	BA 47	BA 45	BA 44	BA 22	BA 21	BA 20	BA 36	BA 37	BA 39	BA 40	BA 38
NY	67	M	15	8	14	✓	✓	1	1	2	2	2	1	-	-	-	-	2	2	-
HN	77	M	15	2	6	✗	✓	-	-	-	-	-	-	2	1	-	2	w	-	-
PG[8]	63	M	18	8		✓	w													
EW	73	F			2	✗	✓	-	-	-	-	-	-	-	2	-	2	-	-	-
SC	80	M	16	8	8	✗	✓	-	-	-	-	-	-	-	2	-	2	2	w	-
BB[b]	59	F	16	6	3	✓	✓	-	-	2	2	2	2	-	-	-	-	-	-	-
ME	40	F	16	9	5	✗	✓	-	-	-	-	-	-	2	2	2	2	w	w	-
% Patients with grey matter damage								17	17	33	33	33	33	33	67	17	67	33	17	0
% Patients with grey or white matter damage								17	17	33	33	33	33	33	67	17	67	67	50	0

Patients are arranged in order of naming scores in the 64 item battery (Bozeat et al., 2000).
Quantification of lesion: 2 = complete destruction/serious damage to cortical grey matter; 1 = partial destruction/mild damage to cortical grey matter; w = damage confined to white matter immediately underlying cortex. Anatomical abbreviations: DLPFC = dorsolateral prefrontal cortex; orbIFG = pars orbitalis in inferior frontal gyrus; trIFG,= pars triangularis in inferior frontal gyrus; opIFG = pars opercularis in inferior frontal gyrus; TP = temporal pole; STG = superior temporal gyrus; MTG = middle temporal gyrus; ITG = inferior temporal gyrus; FG = fusiform gyrus; POT = posterior occipitotemporal area; SMG = supramarginal gyrus; AG = angular gyrus. [a] Lesion size was estimated by overlaying a standardised grid of squares onto each patient’s template and working out the percentage of squares damaged relative to the complete undamaged template. [b] BB showed additional signs of ventricular enlargement in the left hemisphere.

---

[8] No scan available. Description of lesion: L frontal & capsular.

Background neuropsychology and semantic testing

As shown in Table 4.2, patients were tested on forward and backwards digit span (Wechsler, 1997), the Visual Object and Space Perception (VOSP) battery (Warrington & James, 1991), the Coloured Progressive Matrices test of non-verbal reasoning (Raven, 1962). Executive skill and attention were tested with the Wisconsin Card Sorting test (Milner, 1963; Stuss et al., 2000), the Brixton Spatial Rule Attainment task (Burgess & Shallice, 1997), and Elevator Counting (with and without distraction) from the Test of Everyday Attention (Robertson et al., 1993). Phonological skill was assessed using word repetition from PALPA (Kay et al., 1992): 4/7 showed strong performance (> 91%); the remaining three repeated over 80% correctly. Semantic skills were tested using a number of assessments, for example word and picture versions of PPT (Howard & Patterson, 1992) and Camel and Cactus or CCT (Bozeat et al., 2000). Other semantic tests comprised synonym judgement (Warrington, McKenna, & Orpwood, 1998), and category and letter fluency. As shown in Table 4.2, all patients were significantly impaired on semantic tests.

Table 4.2: Background neuropsychological assessment of SA patients

Task/test	Max	Normal cut-off$^{\alpha}$	NY	HN	PG	EW	SC	BB	ME	mean
Background Neuropsychology:										
VOSP dot counting	10	8	10	8	**5**	10	10	10	**3**	8
VOSP position discrimination	20	18	20	19	20	20	**17**	18	**15**	18.43
VOSP number location	10	7	10	9	9	10	10	8	**2**	8.29
VOSP cube analysis	10	6	**5**	**4**	10	7	9	**2**	**4**	**5.86**
Raven's coloured matrices (percentiles)			50	20	50	-	50	50	**<5**	37.5
WCST (number of categories)	6	1^{β}	2	6	**0**	-	6	1	**0**	2.5
Brixton spatial anticipation (correct)	54	28	34	28	**26**	33	**25**	**23**	**11**	**25.71**
TEA counting without distraction	7	6	**3**	7	**0**	-	7	**4**	7	**4.67**
TEA counting with distraction	10	3	**2**	9	3	**-**	**1**	**0**	9	4
Digit span forwards	-	5	**3**	6	6	**4**	6	5	6	5.14
Digit span backwards	-	2	2	2	2	2	2	**0**	3	**1.86**
Semantic Tests:										
PALPA word repetition	80	80	**65**	**69**	**73**	**64**	**78**	**77**	80	**72.29**
Picture PPT	52	48.4	**47**	**35**	**42**	50	50	**41**	**29**	**42**
Word PPT	52	48.9	**42**	**44**	**43**	53	51	**35**	**39**	**43.86**
Synonym judgement	96	90.1	**69**	**70**	**69**	**76**	**71**	**63**	**81**	**71.29**
Letter fluency	-	21.8	**5**	**19**	**2**	**20**	24	**0**	**14**	**12**
Category fluency	-	62.7	**25**	63	**4**	**-**	**17**	**13**	**25**	**24.5**
64 Item Picture Naming	64	59.1	**55**	**50**	**46**	**45**	**28**	**10**	**5**	**34.14**
64 Item Spoken Word-picture Matching	64	62.7	**60**	**50**	**58**	**57**	**59**	**54**	**50**	**55.43**
64 Item Picture CCT	64	52.7	**36**	54	**44**	**45**	**46**	**38**	**13**	**39.43**
64 Item Word CCT	64	56.6	**39**	**54**	**40**	**48**	**56**	**30**	**34**	**43**

Patients are arranged in order of naming scores in the 64 item battery (Bozeat et al., 2000).
$^{\alpha}$ For semantic tests, this represents the control mean – 2SD.
$^{\beta}$ Cut-off for 50-74 year olds (regardless of educational level).
All impaired scores are shown in bold.
NT = Not taken.

Stimuli

A survey was conducted with psychology undergraduates in return for course credits in order to assemble items that showed both a strong co-ordinate and a strong associate. An initial list of 300 words was drawn from Morrison, Chappell and Ellis (1997) was divided into three groups of 100. Each list of 100 words was given to 30 people, half of whom were asked to produce three co-ordinates for each item, and the other half three associates. The results were collated without regard to order of response, and repeated answers were not permitted. If a participant gave no responses to an item, they were excluded from that item's calculation; a small number of extra respondents filled in the missing cases.

Forty eight items emerged that had both a co-ordinate and an associate given by more than 40% of respondents, and which also scored more than 90% on name agreement. To obtain a neutral phoneme for each target, a phoneme was selected from amongst those that did not correspond to the first phoneme of any of the responses to that item. This preliminary work resulted in a stimulus set with four cueing conditions: correct (initial phoneme of target), neutral phoneme, co-ordinate (initial phoneme of highest scoring co-ordinate), and associative (initial phoneme of highest scoring associate). See Appendix B in the Supplementary Materials for stimuli and their co-ordinates, associates and cue phonemes, and Appendix C in the Supplementary Materials for target norms.

Procedure

The experiment was presented in patients' homes on a laptop using E-Prime (Schneider et al., 2002), with patients sitting approximately 80cm from the screen. The test was split into two sections containing 96 pictures, presented at least a week apart. Each section contained 24 items with each cue type, correct, neutral phoneme, co-ordinate and associative - this within subjects design meant that across the whole test each picture was seen in each cue condition. Within each test session, the cue conditions were mixed randomly, so the cue type could not be predicted on any trial. Patients were informed that pictures would be accompanied by a letter sound; the letter might be helpful or distracting, but the task was simply to name the picture in all cases. Pictures were black and white line drawings taken from standard picture sets (Snodgrass & Vanderwart, 1980; Szekely et al., 2003). Each trial began with a fixation cross for 500ms; the picture then appeared in the centre of the screen, remaining visible until the experimenter initiated the next trial via a button press. The sound cue was presented once via the laptop speakers, and repeated as required by the experimenter. Responses were written on score sheets for later analysis.

RESULTS

Legitimate alternative names (e.g. “sweater” for JUMPER) were classified as correct; errors were classified as either semantic[9], omission or other[10]. All probabilities from reported t-tests are one-tailed, due to prior prediction of effect direction. Accuracy and error rates were calculated as a proportion of the number of trials per condition.

Co-ordinate miscue comparison

As per Soni et al. (2009), we used a one-way repeated measures ANOVA on the variable cue type (correct/neutral/co-ordinate) for accuracy, shown in Figure 4.1. There was a significant effect of cue type ($F(2,12) = 5.193$; $p = .024$), with the highest accuracy in the correct condition, followed by neutral phoneme then co-ordinate cues (.765, .622 and .601 respectively). Planned comparisons showed a significant overall cueing effect between correct and co-ordinate cues ($t(6) = -3.215$; $p = .009$) and a significant effect of correct cues relative to neutral ($t(6) = 2.107$; $p = .04$), but no effect of miscues relative to neutral ($t(6) < 1$).

---

[9] Semantic error subtypes: co-ordinate (e.g., “climbing frame” for SWING); associative (e.g., “gold” for RING); subordinate (e.g., “Bible” for BOOK); superordinate (e.g. “fruit” for GRAPES); informative circumlocutions (e.g., “you light them” for CANDLE).

[10] Other error subtypes: visual (e.g., “TV” for MICROWAVE), phonological (e.g., “town” for TOWEL), perseverative and unrelated errors (e.g., “comb” for SHEEP), inaccurate circumlocutions (e.g., “begins with s” for HARP) and naming of picture parts (e.g., “toe” for FOOT).

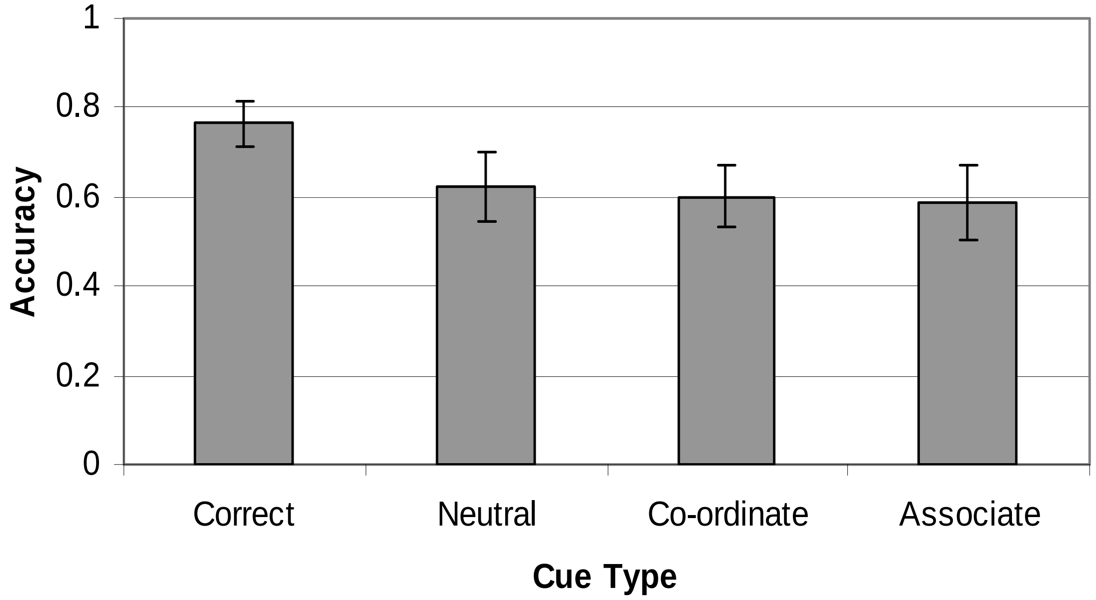


Figure 4.1: Patients' accuracy (proportion of trials per condition) according to cueing condition. Error bars represent +/- standard error

In a parallel ANOVA on semantic errors, shown in Figure 2, the effect of cue type did not quite reach significance ($F(2,12) = 2.406$; $p = .132$), but numerical trends were the same as overall accuracy with the lowest mean proportion of errors in the correct condition, followed by neutral phoneme then co-ordinate cues (.143, .152 and .217 respectively). Planned comparisons showed a significant overall cueing effect between correct and co-ordinate cues ($t(6) = 2.885$; $p = .015$); the miscueing effect of co-ordinate miscues relative to neutral phonemes approached significance ($t(6) = 1.637$; $p = .077$), but no significant effect of correct cues relative to neutral was found ($t(6) < 1$).

The incidence of exact cued errors in the co-ordinate condition (e.g., "shower" for BATH) was also compared to the baseline incidence of the same errors in the neutral condition and a significant difference was found ($t(6) = 2.905$; $p = .014$), with a higher incidence of cued errors in the co-ordinate than in the neutral condition (.071 vs. .027 respectively).

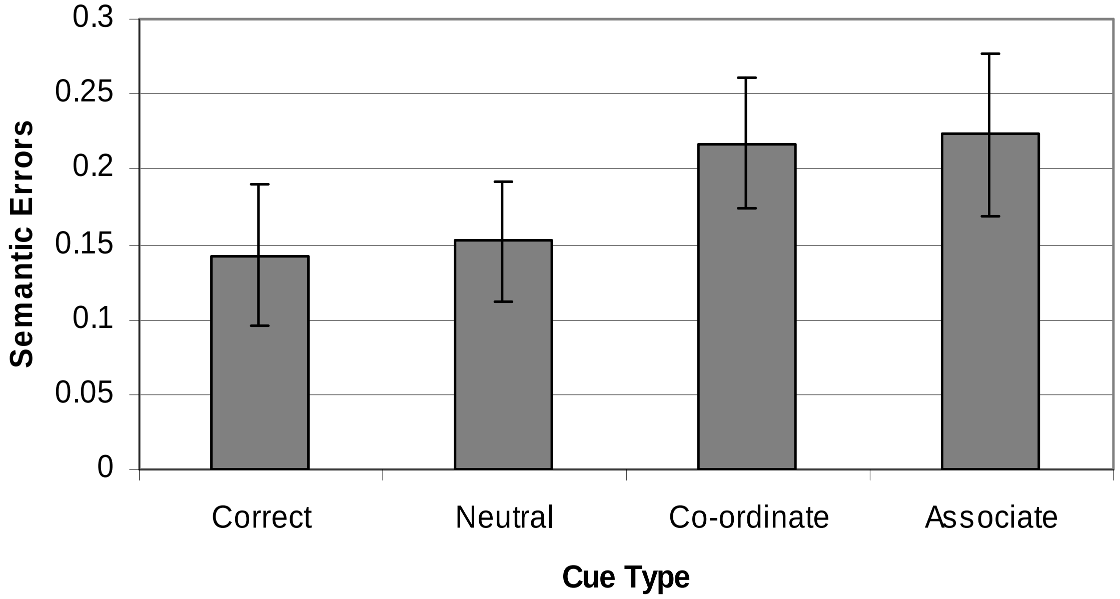


Figure 4.2: Patients' semantic errors (proportion of trials per condition) according to cueing condition. Error bars represent +/- standard error

A further ANOVA conducted on omission errors, shown in Figure 4.3, revealed a significant effect of cue type (*F*(2,12) = 4.405; *p* = .037) such that correct cues still produced the lowest rate, but neutral phonemes produced more omissions than co-ordinate miscues (.086, .199 and .158 respectively). Planned comparisons revealed an overall cueing effect between correct and co-ordinate cues (*t*(6) = 2.322; *p* = .029), and a positive effect of correct cues relative to neutral phonemes (*t*(6) = 2.226; *p* = .034), but no significant difference between neutral and co-ordinate cues (*t*(6) = 1.216).

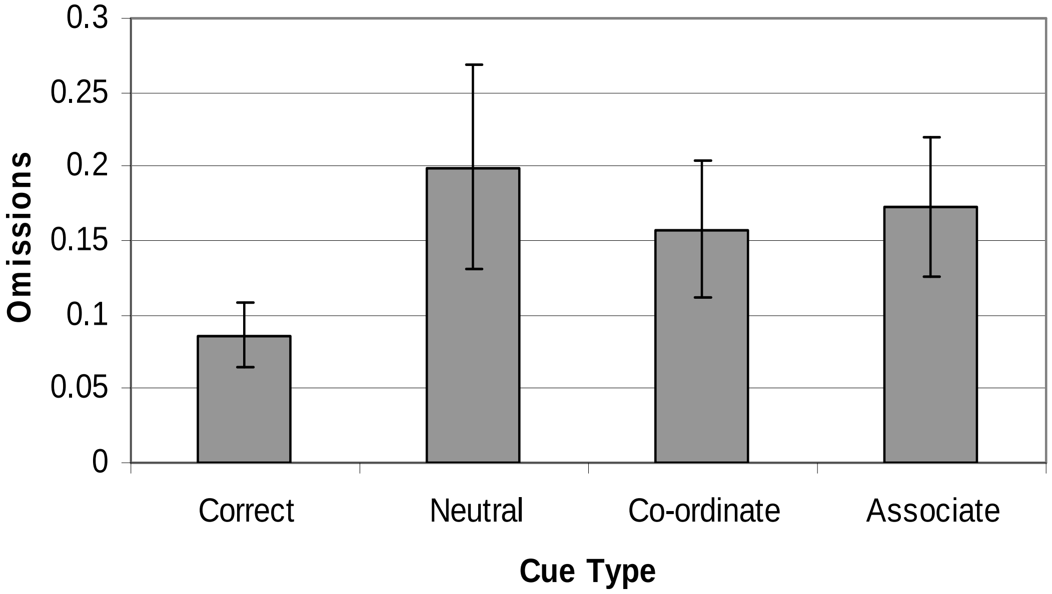


Figure 4.3: Patients' omission errors (proportion of trials per condition) according to cueing condition. Error bars represent +/- standard error

Associative miscue comparison

Only overall and negative cue effects will be reported in the associative comparison as positive cueing effects (correct condition-neutral condition) refer to data already reported above. A one-way repeated measures ANOVA on the variable cue type (correct/neutral/ associative) was used for accuracy, shown in Figure 4.1. There was a significant effect of cue type ($F(2,12) = 5.527$; $p = .010$), with the highest mean proportion accuracy in the correct condition, followed by neutral phoneme then associative cues (.764, .622 and .586 respectively). Planned comparisons showed a significant overall cueing effect between correct and associative cues ($t(6) = 3.230$; $p = .009$), but no effect of miscues relative to neutral ($t(6) < 1$).

In a parallel ANOVA on semantic errors, shown in Figure 4.2, the effect of cue type did not reach significance ($F(2,12) = 2.326$; $p = .140$), but numerical trends were the same as overall accuracy with the lowest mean proportion of errors in the correct condition, followed by neutral phoneme then associative cues (.143, .152 and .223 respectively). Planned comparisons showed a significant overall cueing effect between correct and associative cues (*t*(6) = 2.077; *p* = .042); the miscueing effect of associative miscues relative to neutral phonemes approached significance (*t*(6) = 1.747; *p* = .067).

The incidence of exact cued errors in the associative condition (e.g., “water” for BATH), was also compared to the baseline incidence of the same errors in the neutral condition, but this difference did not reach significance (*t*(6) = 1.395, *p*=.106), though rates were higher in the associative than in the neutral condition (.057 vs. .021 respectively).

A further ANOVA conducted on omission errors, shown in Figure 4.3, revealed a marginally significant effect of cue type (*F*(2,12) = 5.020; *p* = .063); correct cues still produced the lowest rate, but neutral phonemes produced more than associative miscues (.086, .199 and .173 respectively). Planned comparisons revealed an overall cueing effect between correct and associative cues (*t*(6) = 2.772; *p* = .016), but no significant difference between neutral and associative cues (*t*(6) = 1.417; *p* = .103).

DISCUSSION

For the co-ordinate cueing condition, accuracy showed an overall and a positive cueing effect, the lack of negative cueing effect showing that for these patients, the neutral phonemes produce almost as much interference as semantically meaningful miscues. This contrasts with the results of Soni et al. (2009) who used a beep instead of a phoneme as their neutral condition, and found a significant miscueing effect in accuracy. For semantic errors, the miscueing effect was apparent, with the proportion of exact cued errors being significantly higher in the miscue than neutral condition: this confirms the extra effect of phonemes which actually boost competitors, over and above the effect of any misleading phonology. Interestingly, omission errors were as high for the neutral phoneme as the miscue condition, suggesting that the phonemes which are not related to competing responses appear to lead to ‘empty territory’ where no response is available. Taken together, these results confirm a co-ordinate miscueing effect for this patient group, and the neutral phoneme condition further reveals that provision of any incorrect phonology is detrimental to patient performance.

As in Soni et al. (2009), several significant correlations were observed between correct and co-ordinate cueing effects, and measures of executive function: positive cueing effect on accuracy with TEA with distraction (ρ = -.968, *p* < .001, one-tailed); overall co-ordinate cueing effect on accuracy TEA with distraction (ρ = -.735, p = .048, one-tailed); positive cueing effect on semantic error rates with TEA with distraction (ρ = .882, p = .010, one-tailed); and the negative cueing effect on accuracy with TEA with distraction was also borderline significant (ρ = .638, p = .087, one-tailed). These correlations confirm previous findings with a beep neutral condition (Soni et al., 2009), and demonstrate that the impact of cueing became more pronounced in those with more compromised semantic control systems. Moreover, there are also interesting near-significant correlations between accuracy in the neutral phoneme condition and the Wisconsin Card Sorting Test (ρ = .706; p = .059) and the Brixton test (ρ = .643; p = .060). These correlations indicate that those patients with weaker semantic control were also more susceptible to the disruptive effects of the incorrect unrelated phonology provided by the neutral phoneme cue.

For the associative cueing comparison, there was a significant overall cueing effect but no significant miscueing effect on accuracy. The overall cueing effect on semantic error rates was significant, and the negative cueing effect was marginally so. Although the proportion of exact cued errors was not significantly higher in the associative miscue than neutral condition, they were numerically so. Again, omission errors were as high for the neutral phoneme as the associative miscue condition.

These results indicate for the first time that associative miscues increase the rate of semantic errors and promote associative error responses. Although the associative cueing effect is somewhat weaker than the co-ordinate cueing effect, we conclude that this is because the co-ordinate miscues were both categorically and associatively related to the target, whereas the associative miscues were specifically from different categories to the target. It may also be that Crutch and Warrington’s claim for the primacy of co-ordinate relationships in the semantic representations of concrete items (2005) is partially accurate, leading to a greater effect from co-ordinate miscues. Despite this slight attenuation of effect compared to the co-ordinate condition, there were strong correlations between associative cueing and tests of executive function. WCST scores correlated with both overall (ρ = .851, p = .016, one-tailed) and negative (ρ = .794, p = .030, one-tailed) associative cueing effects on semantic error rates, and the negative associative cueing effect on accuracy was correlated with TEA with distraction (ρ = .798, p = .028, one-tailed). These novel findings confirm that associative cues act in a similar way to co-ordinate cues, with degree of semantic control again determining susceptibility to miscues of this type.

The shared naming impairment seen in this group of patients, and particularly the elicitation of specific errors by both co-ordinate and associative cues, suggests that their selection processes have become more labile as a result of their semantic control impairment, and are therefore guided by the presence of misleading phonemic cues towards erroneous responses. The correlations of cueing effects with performance on executive measures support the interpretation that these effects arose as a result of a failure of controlled semantic processing. In addition, the marginally significant correlations between executive function and accuracy in the neutral phoneme condition show that these patients also find it difficult to ignore incorrect unrelated phonology. We conclude from the varied lesion locations shown by this group (see Table 4.1 and Appendix 4A) that semantic control is subserved by a distributed network of brain regions that includes both frontal and temporoparietal areas (Berthier, 2001; Collette, Olivier et al., 2005).

EXPERIMENT 2:
CUED TEMPO NAMING WITH NORMAL PARTICIPANTS

Normal participants usually perform very well in standard picture naming tasks (e.g., Bird et al., 2003; Hodgson & Ellis, 1998; Morrison et al., 1992; Szekely et al., 2003), so some modification of the basic paradigm is necessary to elicit enough errors for analysis. The tempo naming procedure, in which participants are asked to name items in accordance with a rhythm set up using audio and visual cues, has been shown to raise error rates in normal participants in both word reading (Kello & Plaut, 2000) and picture naming (Hodgson & Lambon Ralph, 2008). Hodgson and Lambon Ralph (2008) showed that phonemic cues had a significant effect on both latency and error rates in the tempo paradigm, with correct cues resulting in faster and more accurate performance, and co-ordinate miscues producing slower and more errorful naming than neutral beeps.

It has been suggested that tempo naming interferes with semantic control (Hodgson & Lambon Ralph, 2008; Soni et al., 2009).We hypothesise that the focus on response timing as well as naming acts as a kind of dual task; dual task studies with normal participants have implicated a network of frontal and parietal regions similar to those compromised in the SA patient group. Collette et al.'s (2005) PET study showed that two tasks which did not recruit frontal regions independently produced left-sided prefrontal activation (BA 9/46, BA 10/47 and BA 6) when performed simultaneously, and left-sided activation was also seen in parietal regions (BA 40). The authors concluded that a fronto-parietal network sustains executive functioning, including selection processes which are an integral part of the current cued naming experiment. Evidence for a laterality shift to left hemispheric dominance when performing concurrent tasks is seen in Newman, Keller and Just's (2007) fMRI study, suggesting a parallel is likely between normal function during dual tasks and the left-lateralized lesions in the SA patient group. It appears that the dual nature of the tempo task disrupts semantic control, making participants less successful at selecting the target response from among competing alternatives in a way that is analogous to the impairments shown in SA.

Experiment 1 confirmed the presence of a co-ordinate miscueing effect in the patients even when a neutral phoneme rather than a beep is used. Previous research has used the tempo picture naming task to induce co-ordinate miscueing effects comparable to those seen in these patients (Hodgson & Lambon Ralph, 2008); however these studies have used a beep as a neutral condition. It is of interest to assess whether both positive and negative cueing effects pertain in normal tempo naming with co-ordinate versus neutral phoneme cues. Experiment 1 also revealed an associative miscueing effect in the SA patients for the first time. We therefore predict a detrimental effect of both co-ordinate and associative miscues upon normal tempo naming performance in Experiment 2. Given that occasional associative errors have been previously observed by Hodgson and Lambon Ralph (2008) in normal tempo picture naming, we further expect to elicit associative errors with the associative miscues, mirroring the pattern of performance seen in the SA patients. A detrimental effect from associative miscues would confirm that associative relationships form part of the semantic representations of our stimulus items in healthy as well as semantically impaired individuals, countering the argument that the representations of concrete items are based on categorical relationships alone (Crutch et al., 2009).

METHOD

Participants

Forty two university students were recruited who had English as their first language and normal or corrected to normal vision. They were given a small remuneration for their time. Data from six bilingual English speakers were discarded.

Stimuli

The items and cues from Experiment 1 were also used for Experiment 2. Additionally, a second set of 48 items (see Appendix D in the Supplementary Materials) was selected to use in a preliminary test to determine the mean naming time for each participant: for clarity these stimuli will be referred to as the matched list. The International Picture Naming Project database (Szekely et al., 2003) was used to determine RTs for the list of target items and the matched list[11], then the two lists were matched for AoA, log frequency, visual complexity, name agreement, number of phonemes and RT (See Appendix E in the Supplementary Materials).

Baseline naming speed

The matched list was presented using Eprime (Schneider et al., 2002) on a Dell desktop computer, with a microphone and serial response box attached. The style of presentation was matched as closely as possible to the subsequent tempo procedure; pictures were presented for 300ms, and followed by the appearance of a question mark. When a vocal response was given, the question mark was replaced by a fixation cross. Wrongly named items, hesitations (where a response was preceded by “er” or similar) and mistrials (where the microphone failed to trigger) were all excluded from the calculation of the mean RT. After each response the experimenter pressed a button on the serial response box to indicate whether the response was correct or not, and then the next target picture appeared on the screen. Several practice trials were given to accustom the participant to the task demands. At the end of the 48 items, a feedback screen appeared, giving the mean RT for correct naming, and the number and percentage of correct trials.

Tempo naming study

---

[11] Reaction time data were unavailable for eight items, four from each list. The lists were matched without these values.

Pilot testing determined that baseline minus 30% elicited more errors than baseline tempo alone, yet was still achievable as an experimental task: all participants were therefore run at a fast tempo of baseline minus 30%. The main experiment used a within participants design, so each participant saw each picture in all four cueing conditions at each of the two tempos, making 8 presentations in all, split across two experimental sessions. The different cue conditions were mixed and presented in random order, while the order of fast and baseline tempos was counterbalanced across participants.

The experiment was presented using E-Prime (Schneider et al., 2002) on a Dell desktop computer. A countdown from five to one was initiated using simultaneous visual (decreasing numbers) and audio (cue phonemes) signals. Each number was presented for 300 ms, interleaved with blank white screens. The interval between the onset of each number and cue phoneme was set to each participant's baseline naming speed or baseline minus 30% in the fast condition. At the tempo beat following '1' in the countdown, the target picture and accompanying cue were presented, again for 300ms. On the following tempo beat, a question mark appeared; the audio cue was again presented, but the question mark remained on the screen until a vocal response was made or for four seconds if there was no response. Instructions were given that the participants should attempt to give their response simultaneously with the appearance of the question mark, not to pre-empt it or wait for it to appear before responding. A diagrammatic representation of the tempo naming task is provided in Figure 4.4.

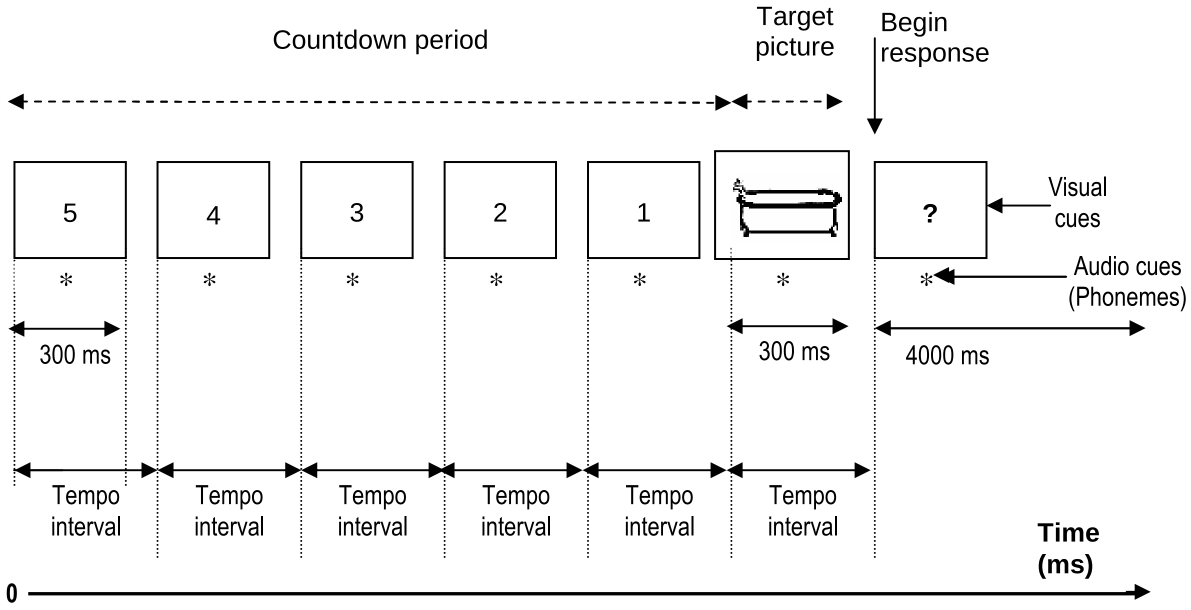


Figure 4.4: A schematic representation of the tempo task

After each trial, a feedback screen appeared telling the participant how late or early (in milliseconds) their response was compared to the tempo (or that no response had been detected); they were advised to try to use this feedback to hone the timing of their responses. However, it was not expected that they would respond perfectly on tempo for each trial, particularly as different cues were expected to have different effects on RT; this was merely a way of increasing the difficulty of the task and diverting processing resources. After each feedback screen, the experimenter initiated the next trial via the serial response box. Responses and mistrials were noted on paper for later analysis.

RESULTS

RTs of more than 3 standard deviations from any individual's mean naming time were excluded from the RT analysis (1.1% of measurements were lost from the baseline tempo and 1.8% from the fast tempo). Participants' accuracy and error rates were computed as a proportion of trials per condition. Due to prior prediction of directional cueing effects, all probabilities reported from t-tests are one-tailed. The incidence of omissions was very low (0.5% or less in all cue conditions), and revealed no significant differences between cue conditions, hence these will not be considered further.

Co-ordinate miscue comparison

Following Hodgson and Lambon Ralph (2008), RT data were analysed using a 3 (cue type: correct/neutral/co-ordinate) by 2 (tempo: baseline, fast) fully repeated measures ANOVA. There were significant main effects of both tempo ($F(1,33) = 500.918$; $p < .001$) and cue ($F(2,66) = 4.917$; $p = .035$). Overall, participants were faster as tempo increased (810ms vs. 628ms). The cue by tempo interaction was not significant ($F(2,66) < 1$). The mean RTs for each cue condition collapsed across tempo were: correct = 714 ms, neutral phoneme = 716 ms, co-ordinate = 727 ms. Planned comparisons revealed a significant overall cueing effect between correct and co-ordinate cues ($t(33) = -2.294$; $p = .014$) which was driven by a significant negative effect of co-ordinate miscues compared to neutral phonemes ($t(33) = -4.178$; $p < .001$), with no benefit from correct cues ($t(33) < 1$). RTs for all conditions are provided in Figure 4.5.

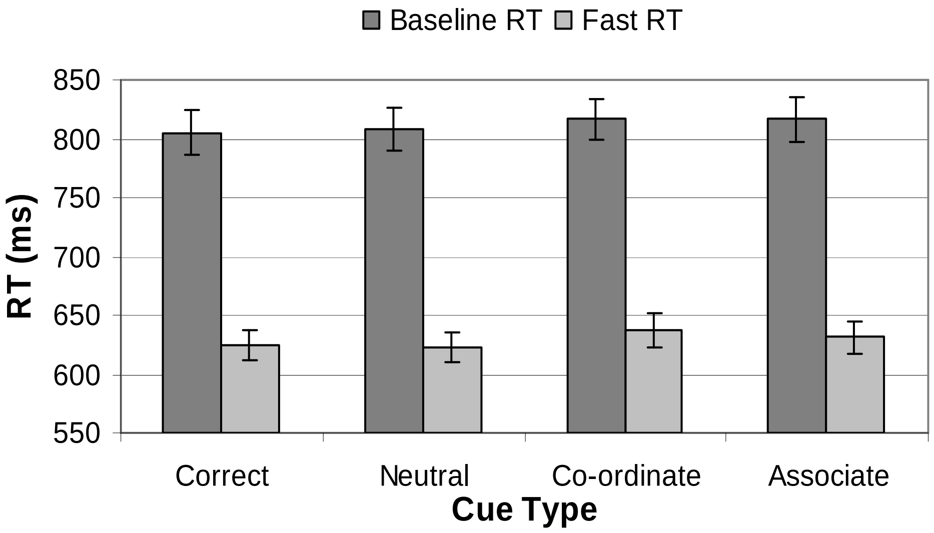


Figure 4.5: Normal participants' reaction times (RT) according to cueing condition for the baseline and fast tempo. Error bars represent +/- standard error

A parallel analysis of accuracy revealed main effects of tempo ($F(1,33) = 7.082$; $p = 0.012$) and cue ($F(2,66) = 14.437$; $p < .001$). Overall, participants showed higher accuracy at the baseline than the faster tempo (.962 vs. .951). There was no interaction ($F(2,66) < 1$), so overall mean accuracy will be reported for each cue condition: correct = .968, neutral phoneme = .956, co-ordinate = .945. Planned comparisons revealed a significant overall cueing effect ($t(33) = 4.697$; $p < .001$), a significant positive cueing effect from correct cues compared with neutral ($t(33) = 4.697$; $p < .001$), and a significant negative cueing effect from co-ordinate miscues compared with neutral ($t(33) = 3.147$; $p = .002$). Accuracy for all conditions is presented in Figure 4.6.

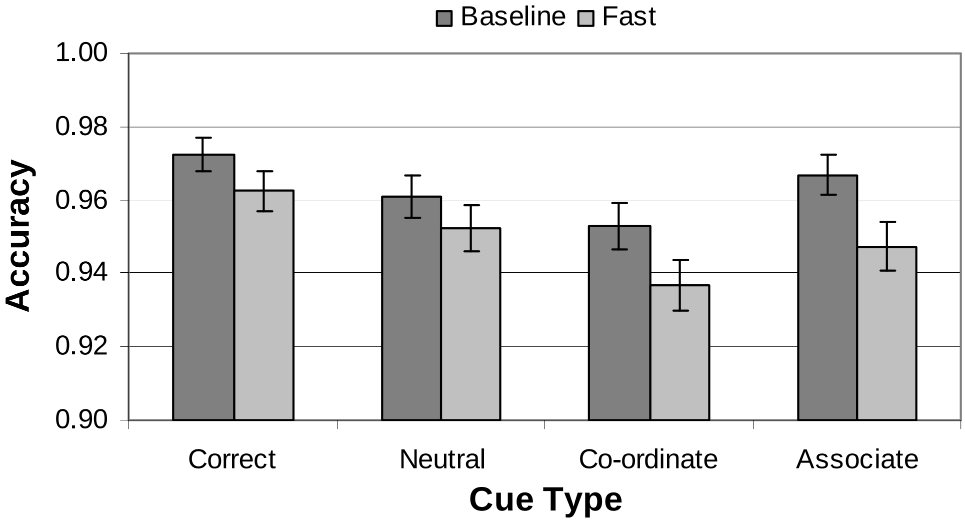


Figure 4.6: Normal participants' accuracy (proportion of trials per condition) according to cueing condition for the baseline and fast tempo. Error bars represent +/- standard error

Analysis of semantic errors revealed significant main effects of both tempo (*F*(1,33) = 6.501; *p* = 0.016) and cue (*F*(2,66) = 14.221; *p* < .001). Overall, participants showed higher semantic error rates at the faster tempo (.033 vs. .042). The interaction between tempo and cue was not significant (*F*(2,66) < 1). Semantic error rates for each cue condition collapsed across tempo were: correct = .028, neutral phoneme = .037, co-ordinate = .048. Planned comparisons revealed a significant overall cueing effect (*t*(33) = 3.464; *p* < .001), with both a significant positive cueing effect from correct cues compared to neutral (*t*(33) = 2.385; *p* = .012) and a significant negative cueing effect from co-ordinate miscues compared to neutral (*t*(33) = 4.703; *p* < .001). Semantic error rates for all conditions are displayed in Figure 4.7.

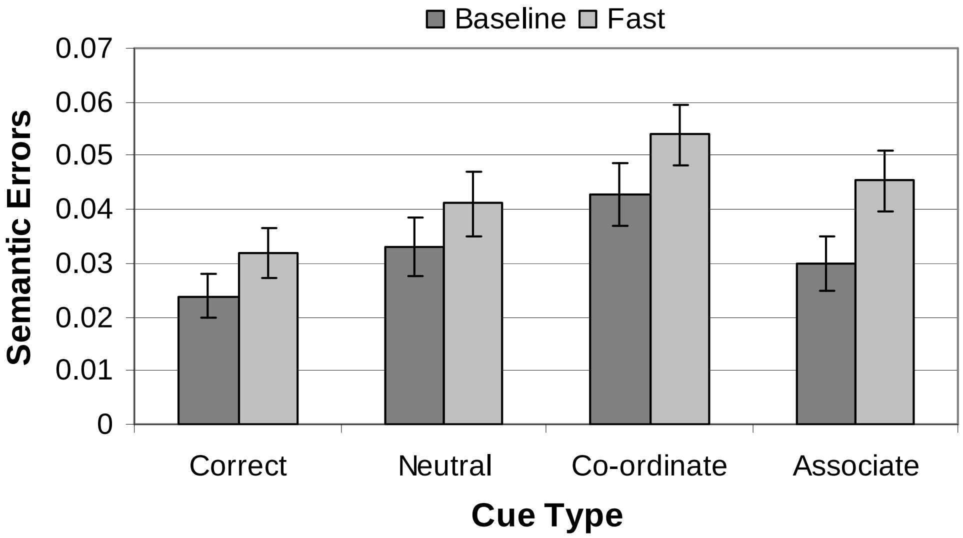


Figure 4.7: Normal participants' semantic errors (proportion of trials per condition) according to cueing condition for the baseline and fast tempo. Error bars represent +/- standard error

As in the patient data, the incidence of exact cued errors in the co-ordinate condition (e.g., "shower" for BATH) was compared to the baseline incidence of the same errors in the neutral condition. Collapsing across tempo, a significant difference was found ($t(33) = 3.793$; $p < .001$), with a higher incidence of cued errors in the co-ordinate than the neutral condition (.026 vs. .016 respectively).

Associative miscue comparison

In order to assess the associative cue condition in the same way as the co-ordinate condition, data were analysed using a 3 (cue type: correct/neutral/associative) by 2 (tempo: baseline, fast) repeated measures ANOVA with all factors considered within subjects. A significant main effect was found for tempo ($F(1,33) = 441.097$; $p < .001$) but not for cue ($F(2,66) = 2.351$; $p = .125$). Overall, participants responded faster as tempo increased (810ms vs. 626ms). The interaction between cue and tempo was not significant ($F(2,66) < 1$). RTs for each cue condition collapsed across tempo were: correct cue = 714 ms, neutral phoneme = 716 ms, associative cue = 724 ms, with data according to tempo condition provided in Figure 4.5. Planned comparisons revealed a significant overall cueing effect between correct and associative cues ($t(33) = 1.794$; $p = .042$), driven by a significant negative effect of associative miscues compared to neutral phonemes ($t(33) = 3.194$; $p = .002$).

A parallel analysis of accuracy revealed main effects of tempo (*F*(1,33) = 10.337; *p* = .003) and cue (*F*(2,66) = 4.622; *p* = .013). Overall, participants were more accurate at the baseline tempo (.967 vs. .954). There was no interaction (*F*(2,66) = 1.597; *p* = .210) so mean accuracy proportions for each cue condition will be reported: correct cue = .968, neutral phoneme = .956, associative cue = .957; data according to tempo condition is provided in Figure 4.6. Planned comparisons revealed a significant overall cueing effect between correct and associative cues (*t*(33) = 2.483; *p* = .009), driven by a significant positive effect on accuracy from correct cues compared with neutral (*t*(33) = 2.721; *p* = .005). There was no significant negative cueing effect on accuracy (*t*(33) < 1).

Analysis of semantic errors revealed significant main effects of both tempo (*F*(1,33) = 8.183; *p* = .004) and cue (*F*(2,66) = 4.484; *p* = .008). Overall, participants produced more semantic errors at the faster tempo (.029 vs. .039). The interaction between tempo and cue was not significant (*F*(2,66) < 1), so overall mean semantic error proportions for each cue condition will be reported: correct cue = .028, neutral phoneme = .037, associative cue = .038; see Figure 4.7 for data according to tempo condition. Planned comparisons revealed a significant overall cueing effect between correct and associative cues (*t*(33) = 2.666; *p* = .006), a significant positive cueing effect from correct cues compared to neutral (*t*(33) = 2.385; *p* = .012), but no significant negative cueing effect from the associative compared to neutral cue (*t*(33) < 1).

The incidence of exact cued errors in the associative condition (e.g., “water” for BATH) was again compared to the baseline incidence of the same errors in the neutral condition. At mean tempo, a significant difference was found (*t*(33) = 1.977; *p* = .028), with a higher incidence of cued errors in the associative than in the neutral condition (.0028 vs. .0009 respectively).

DISCUSSION

Despite the consistent main effects of tempo and cue type, there was no evidence of any interaction between the two, so the following discussion will therefore focus on the differences between cue conditions with data collapsed across baseline and fast tempos. The tempo naming procedure was effective in both reducing reaction times, decreasing accuracy and increasing semantic error rates. However, these effects were consistent across all cue types.

The co-ordinate miscues were found to significantly increase RTs compared to neutral phonemes. In accuracy and semantic error rates, both positive and negative cueing effects were found, and the increase in exact cued errors in the co-ordinate miscue condition relative to the neutral phoneme was significant. These results establish the reliability of the co-ordinate miscue effect when a neutral phoneme rather than a beep is used and demonstrate for the first time that the co-ordinate miscues do indeed result in production of their intended targets.

These results are comparable to those of Hodgson and Lambon Ralph (2008) in that the tempo procedure speeded responding, decreased accuracy and increased semantic errors. However, they diverge in that no interaction between tempo and cue type was observed: in their study, the fast tempo resulted in a disproportionate increase in semantic errors in the miscue condition. Error rates in the current study were also rather low across the board (3.2% to 5.5% at mean tempo). We suggest that the differences between the two studies are due to repetition priming in the current experiment. In Hodgson and Lambon Ralph (2008) items were presented only once to each subject: in the current study, the fully within subjects design entailed a total of eight presentations of each picture to every participant, one for each cue/tempo combination. In addition, half the participants completed the slow tempo first, hence would have seen the target four times before attempting the fast tempo; it seems that this produced enough repetition priming to offset any additional increase in semantic errors.

The associative miscues were found to significantly increase RTs. Overall associative cueing effects on accuracy and semantic error rates were significant, and although the negative cueing effects in accuracy and semantic errors were not reliable, there was nevertheless a significant increase in the proportion of associative error responses in the miscue relative to the neutral phoneme condition. These results therefore provide the first demonstration of associative miscueing amongst normal healthy participants.

As with the patients, the associative cueing effect was somewhat weaker than the co-ordinate cueing effect, in both latency and error rates. We suggest that this is due to an ‘associative boost’ for the co-ordinate cue items (Lucas, 2000): co-ordinate miscues share both a co-ordinate and associative relationship with the target (e.g., BATH and SHOWER), whereas the associative miscues were not from the same category (e.g., BATH and WATER). As with the patient data, it is also possible that associate relationships form a lesser part of semantic representations for concrete items than categorical relationships, although both elements clearly make a contribution.

Although the current study does not directly investigate neural activation, the results are in line with other experiments which implicate a network of left hemisphere frontal and parietal regions to carry out executively demanding tasks, particularly when two tasks are carried out simultaneously (Collette, Olivier et al., 2005; Collette, Van der Linden et al., 2005; Newman et al., 2007). These data offer further support for the argument that tempo naming interferes with semantic control in a similar way to the physical frontal and temporoparietal damage in the SA patient group (Hodgson & Lambon Ralph, 2008; Soni et al., 2009). The focus on response timing partially diverts executive processing resources, allowing the misleading phonemic cues to guide name selection towards erroneous responses.

COMPARISON BETWEEN PATIENT AND TEMPO DATA

As in both Hodgson and Lambon Ralph (2008) and Soni et al. (2009), semantic errors were the most prevalent error type, so only these responses will be considered here. Following Soni et al. (2009), the between groups comparison considers both patients vs. baseline tempo and patients vs. fast tempo, in order to show how each tempo relates to the patient data. A two-way ANOVA was carried out with cue (correct/neutral/miscue) as a within participants factor and group (patients/normals) as a between participants factor at each tempo for both the co-ordinate and associative miscue comparisons.

In the co-ordinate cue comparison for both baseline and fast tempos (respectively) there were significant main effects of cue ($F(2,78) = 12.630$; $p < .001$; $F(2,78) = 13.004$; $p < .001$) and group ($F(1,39) = 53.691$; $p < .001$; $F(1,39) = 45.806$; $p < .001$), and a significant interaction between the two ($F(2,78) = 5.294$; $p = .007$; $F(2,78) = 4.542$; $p = .014$), showing that the cue types had different effects for each group. Planned comparisons revealed that patients made significantly more semantic errors than the normals at baseline and fast tempos in all three cueing conditions: correct (.143 vs. .024; $t(6) = 2.538$; $p = .044$; .143 vs. .032; $t(6) = 2.366$; $p = .055$); neutral (.152 vs. .033; $t(6) = 2.994$; $p = .023$; .152 vs. .041; $t(6) = 2.787$; $p = .030$); and co-ordinate (.217 vs. .043; $t(6) = 3.945$; $p = .007$; .217 vs. .054; $t(6) = 3.697$; $p = .010$). As can be seen in Figure

4.8, the proportionally greater rise in patients' semantic errors in the co-ordinate condition compared to a moderate rise for the normal participants caused the interaction between cue and group.

For associative cueing at both baseline and fast tempos (respectively), there were significant main effects of cue (*F*(2,78) = 9.746; *p* < .001; *F*(2,78) = 11.609; *p* < .001) and group (*F*(1,39) = 53.619; *p* < .001; *F*(1,39) = 42.881; *p* < .001), and a significant interaction between the two (*F*(2,78) = 8.636; *p* < .001; *F*(2,78) = 7.012; *p* = .002), again showing that the cue types had different effects for each group. Planned comparisons revealed that patients made significantly more semantic errors than the normals at baseline and fast tempos in the associative cue condition (.223 vs. .030; *t*(6) = 3.555; *p* = .012; .223 vs. .045; *t*(6) = 3.269; *p* = .017) in addition to the correct and neutral comparisons reported above. As with the co-ordinate miscue, a disproportionate rise in semantic error rates for patients in the associative condition led to the interaction between cue and group.

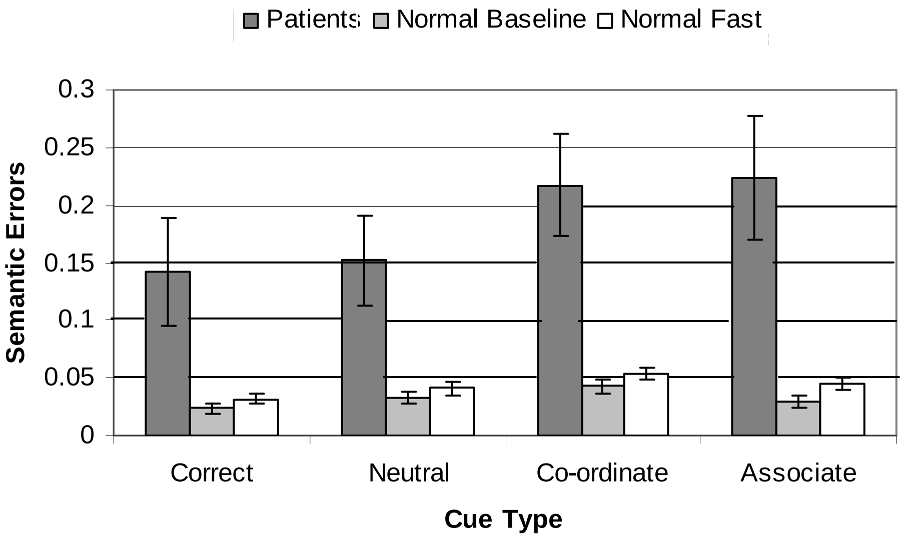


Figure 4.8: Semantic error rates (proportion of trials per condition) in each cue condition for patients and normal participants at each tempo. Error bars represent +/- standard error

GENERAL DISCUSSION

The current pair of experiments extends previous work on cued and miscued picture naming by both SA patients and normal participants under tempo conditions. For the patients, accuracy revealed significant overall cueing effects for co-ordinate and, for the first time, associative miscues. Semantic errors showed reliable negative cueing effects for both co-ordinate and associative miscues. Notably, the rate of omission errors for the new neutral phoneme cues was found to be as high as for both types of miscue. The performance of normal participants in the tempo naming task also revealed significant overall cueing effects in latency, accuracy and semantic error rates, and these did not vary with the pace of responding. For both co-ordinate and associative miscues, a negative cueing effect was apparent in naming latency. For the co-ordinate miscues, negative cueing effects were also apparent in accuracy and semantic errors. In addition, for patients and normal participants both miscue conditions evoked specific error responses at a greater rate than their spontaneous production in the neutral condition. As will be considered further below, these results have implications concerning the involvement of control processes in speech production and the nature of semantic representations of concrete objects.

The positive cueing effects shown here support previous work which suggests that correct cues boost the activation of the target relative to competing alternatives, leading to more effective name selection (Hodgson & Lambon Ralph, 2008; Jefferies et al., 2008; Lambon Ralph et al., 2000; Soni et al., 2009). Experiment 1 confirms that SA patients are strongly influenced by phonemic cues which are drawn from the initial letters of co-ordinate competitors to the target (e.g., /sh/ from “shower” for BATH). A significant overall cueing effect was seen on accuracy and semantic errors, with co-ordinate cues significantly better than neutral cues at deflecting patients towards specific cued semantic errors (7.1% vs. 2.7% of trials per condition respectively). This supports earlier patient data from Soni et al. (2009), where SA patients showed significantly lower accuracy and higher semantic error rates with co-ordinate than correct cues; work with SA patients in Noonan et al. (2010) also showed significant differences in naming accuracy between correct, neutral and co-ordinate cues. Taken together, this evidence supports the hypothesis that while correct cues boost target activation producing significantly improved naming, co-ordinate miscues boost the activation of competitors such that they are produced instead of the target (Lambon Ralph et al., 2000; Noonan, 2010; Soni et al., 2009). As in Soni et al. (2009) the correlations of co-ordinate cueing effects in accuracy and semantic error rates with executive measures such as TEA with distraction highlight the role of semantic control in supporting picture naming performance.

Experiment 2 shows comparable effects in normal participants where co-ordinate cues produced significant overall and negative cueing effects in latency, accuracy and semantic errors and there were again significantly more specific cued errors produced in the co-ordinate than neutral condition (2.6% vs. 1.6% of trials per condition respectively). Differential performance between correct, miscue and neutral phoneme conditions extend the findings in the patient data to normal participants: meaningful incorrect phonology has an effect over and above phonology that is simply incorrect. The current data support previous cued naming results from normal participants in Hodgson and Lambon Ralph (2008), where significant effects of both tempo and cue showed that co-ordinate cues detrimentally affect latency and accuracy when naming under tempo conditions. Additionally, in both the current and Hodgson and Lambon Ralph data, semantic errors were the most common error type, suggesting that the tempo paradigm interferes with name selection from amongst several competing semantically related alternatives.

However, Hodgson and Lambon Ralph (2008) showed an interaction between cue type and tempo caused by a disproportionate rise in errors to co-ordinate cues in the fast tempo condition, whereas the current data, despite strong main effects of tempo and cue type, failed to reveal any interactions between the two. A further difference was that error rates in the present study were much lower on average (4% overall; 6% for co-ordinate miscues) than in Hodgson and Lambon Ralph (9% overall; 18% for co-ordinate miscues). We suggest that these differences arise from repetition priming due to the within subjects design of the current Experiment 2, which gave rise to repeated presentations of stimuli in different cue and tempo conditions. This procedure was adopted as it mimicked that used with the patients in Experiment 1, and it is interesting to note that the patients did not seem to benefit from target repetition in the same way as the normal participants. This design contrasts with that used by Hodgson and Lambon Ralph, where each picture was presented only once, so no opportunity was given for self correction on subsequent presentations. Nevertheless, the significant effects of cue type confirm the strength of phonemic cueing as a method to influence naming success in normal participants.

In the current comparative analyses significant effects of group showed that patients' semantic error rates remained well above those shown by normal participants at both baseline and fast tempo: this differs from Soni et al. (2009), where the semantic error rate of the healthy participants was comparable with patient performance at the baseline tempo, and error rates actually exceeded patient levels at the fast tempo. We argue that this divergence is also an effect of repetition priming in the normal participants, keeping error rates very low in comparison to patients. Significant interactions between group and cue type showed that the cue types have different effects on each group, with miscuing more marked amongst the patients. The function of the tempo paradigm is to emulate SA performance through hampering normal name selection by requiring focus on response timing as a concurrent task, and as in Soni et al. (2009) we saw that this was successful even at baseline tempo.

The use of associative cues with picture naming (e.g., /w/ from "water" for BATH) represents a novel development over previous cued naming studies where miscues were selected solely for their categorical relation to the target (Hodgson & Lambon Ralph, 2008; Howard & Gatehouse, 2006; Howard & Orchard-Lisle, 1984; Lambon Ralph et al., 2000; Noonan, 2010; Soni et al., 2009). In Experiment 1, patients showed an overall associative cueing effect in both accuracy and semantic errors and there was a numerical trend towards greater prevalence of exact cued errors in the associative than their baseline occurrence in the neutral condition (5.7% vs. 2.1% of trials per condition respectively). This is the first demonstration that specific naming errors which are associatively related to the target (e.g., "water" for BATH) can be deliberately induced, indicating that associatively related knowledge informs the selection process when naming concrete items. Furthermore, the correlations of executive measures such as WCST and TEA with cueing effects in accuracy and semantic error indicate that semantic control impairments result in an increased susceptibility to associative miscues, in line with previous studies of correct and co-ordinate cued naming in SA (Jefferies & Lambon Ralph, 2006; Soni et al., 2009).

In Experiment 2, normal participants exhibited a significant slowing of RTs with associative cues relative to neutral cues, suggesting that a longer latency may be required for suppression of irrelevant material before the correct response can be made (Hodgson & Lambon Ralph, 2008; Soni et al., 2009). In accuracy and similarly in semantic error rates, there were also significant overall cueing effects between correct and associative cues, though the negative cueing effects did not reach significance. However, the incidence of exact cued errors (e.g., “water” for BATH) was significantly greater in the associative condition than at the baseline level in the neutral condition. We suggest that the greater success of associative cues in increasing the relative rate of exact cued errors amongst normals participants than patients is a consequence of an effective semantic control system – when an error does occur, then these miscues raised the activation of associates to the level at which they were selected in preference to the target. Although the cue is misinformation, it is processed rapidly and efficiently within the intact system.

It is likely that the significantly compromised naming in the presence of phonemic miscues for both SA patients and normal participants under tempo conditions results from compromised semantic control systems. In the case of the SA patients, this results from brain damage to frontal and temporoparietal regions: previous work with TSA patients showed no differential effects between anterior and posterior lesion sites, indicating that these areas act as a coherent network (Berthier, 2001). We can infer from the significant correlations between cueing effects and performance on executive measures that semantic control is impaired rather than semantic representations themselves. The presence of associative errors (“water” for BATH) also shows that the target representation (BATH) is still operational, though an incorrect element was selected (WATER), a further indication of poorly controlled processing.

The similarities seen here between normal and patient data in addition to previous work on the neural correlates of performance during dual task paradigms (Collette, Olivier et al., 2005; Collette, Van der Linden et al., 2005; Newman et al., 2007) allow the inference that semantic control in the normal participants is subserved by the network of frontal and temporo-parietal regions that has been damaged in the SA patients. Furthermore, tempo naming is an effective way to temporarily impair semantic control in a task involving selection between a number of potentially active items and inhibition of extraneous information (miscues), two tasks which are known to have a relatively high demand for executive resources, recruiting both frontal and parietal regions

(Collette, Van der Linden et al., 2005; Thompson-Schill et al., 2005; Thompson-Schill et al., 1997).

The Neutral Cue in Speech Production

The development of the neutral phoneme in the current work extends the cued naming paradigm from the neutral beep condition used in previous studies (Hodgson & Lambon Ralph, 2008; Soni et al., 2009). The provision of phonology in all cueing conditions allows a clearer comparison between the effects of correct, unrelated and meaningful incorrect cues. Experiment 1 shows that any incorrect phonology can disrupt naming for the SA patient group, exemplified by the significant positive cueing effect and the high level of omission errors in the neutral phoneme condition (19.9% of trials per condition vs. 8.6% for correct, 15.8% for co-ordinate, and 17.3% for associative cues). It seems likely that while the meaningful miscues boost the activation of strong competitors, neutral phonemes, selected for their lack of connection with any target-related items, appear to lead the SA group to relatively empty territory in the semantic network, where no items reached the threshold for activation (Rogers et al., 2004), resulting in an omission error. In Experiment 2, the neutral cue produced significantly faster responses than both co-ordinate and associative miscues, though no positive cueing effects were found on latency. Significant differences were seen in both accuracy and semantic error rates between correct, neutral and co-ordinate cues, although the negative cueing effect did not reach significance for the associative cues. These data support the differential effects of the cue types seen in the patient data. The continued effects of miscues on accuracy and semantic errors in both groups validate the hypothesis that semantically meaningful miscues lead to systematic disruption of selection processes which are not just an effect of mismatched auditory and visual information: unrelated phonology destabilises naming, but meaningful incorrect phonology disrupts it further.

Associative Cueing in Semantic Access

The data from the current experiments show that there are clear effects of associative cues on naming in both semantically impaired and normal participants; however, the effects were evidently not as strong as those arising from co-ordinate cues. There are several factors which could account for this. One which has already been alluded to is the potential ‘associative boost’ to co-ordinate cues which are both categorically and associatively related to the target, giving them greater impact than the ‘pure’ associative cues. Secondly, there is a perspective which suggests that associative knowledge does not form part of the semantic representations of concrete objects (Crutch et al., 2009; Crutch, Ridha, & Warrington, 2006; Crutch & Warrington, 2005). Instead, concrete objects are represented in terms of categorical, feature based information, whereas abstract items are represented by associative networks. However, it can be inferred from the current data on both semantically impaired and normal participants that associative knowledge is indeed brought to bear when naming concrete items even when it is not required by the task, otherwise associative cueing effects such as reduced accuracy and extended latency, and in particular the elicitation of specific associates as errors, could not occur. Perhaps the situation is best represented by a continuum where both categorical and associative strands inform the representations of concrete and abstract items: categorical information has more weight for concrete items, and associatively related knowledge is relatively more important for abstract items, where there is necessarily less featural input (Andrews, Vigliocco, & Vinson, 2009).

Convergent evidence on associative and categorically related distractors comes from the picture-word interference or PWI paradigm. A semantic interference effect (SIE), where the presentation of a distractor disrupts picture naming, has frequently been found in normal participants using categorically related distractors with either simultaneous target/distractor presentation or negative stimulus onset asynchrony (SOA), where distractor precedes target (Caramazza & Costa, 2000, 2001; Costa et al., 2005; de Zubaricay et al., 2001; Glaser, 1992; Glaser & Glaser, 1989; Levelt et al., 1999; Wilshire et al., 2007). This accords with the diminished performance found in co-ordinate cued naming with simultaneous target/cue presentation (Hodgson & Lambon Ralph, 2008; Howard & Gatehouse, 2006; Lambon Ralph et al., 2000; Soni et al., 2009). However, associatively related distractors have been shown to have either no effect with simultaneous presentation (Mahon, Costa, Peterson, Vargas, & Caramazza, 2007) or a facilitative effect on target naming at longer negative SOAs (Costa et al., 2005; La Heij, Dirkx, & Kramer, 1990; Lupker, 1988). In the current experiment we did find an effect from simultaneous target/associative cue presentation, but the evidence from PWI suggests it is likely to be weaker than that seen with co-ordinate cues, as borne out by our data.

CONCLUSIONS

Our data offer support for models of speech production that are at least partially interactive (Dell & O'Seaghdha, 1992; Dell et al., 1997; Foygel & Dell, 2000; Rapp & Goldrick, 2000; Schwartz et al., 2006), in contrast to a discrete system in which semantic processing is hypothesised to be complete before any phonological processing begins (Levelt et al., 1999). In a cascaded system, activation from several potential candidates is passed from semantics to phonology before a final candidate is selected (Dell et al., 1997). In a fully interactive system, activation reverberates between semantic and phonological levels, eventually resulting in a single candidate exceeding the threshold for production (Lambon Ralph et al., 2000). In either system, several candidates are available during phonological processing and hence the potential exists to improve or impair selection by presentation of a correct or semantically related phonemic cue. Our results demonstrate that this speech production system is dependent upon the integrity of a distributed network of frontal and temporoparietal regions involved in semantic control. If brain damage or task demands disrupt the functioning of this network, accurate picture naming is compromised. Effective semantic control is therefore essential for managing the complex task of successful speech production.

CHAPTER 5

REPETITION PRIMING OF PICTURE NAMING IN SEMANTIC APHASIA: THE IMPACT OF INTERVENING ITEMS

ABSTRACT

Background: We present an experiment that explores the nature of repetition priming of picture naming in a group of semantic stroke aphasic patients. The study was designed to extend previous investigations of repetition priming effects amongst other stroke aphasic patients and patients with semantic dementia (SD). This work builds upon previous work with semantic aphasic (SA) patients that shows enhanced picture naming performance due to correct phonemic cues.

Aims: To assess the extent to which semantic control deficits observed during SA patients' picture naming are resolved by prior exposure to an identical stimulus and to determine the optimal lag between prime and target to maximise naming success.

Methods and Procedures: The procedure was carried out with five stroke patients who had all failed verbal and picture versions of tests of semantic association, revealing difficulties with manipulation of semantic information, and their performance was compared to five age- and education-matched controls. 180 pictures to be named were presented individually on a computer screen in two sessions at least a week apart, with half preceded by an identical item in session one and the other half preceded by an identical item in session two. Three lags (0, 1 and 7 items intervening) were embedded in the pseudo-random structure such that it was unpredictable whether the next trial would be a repeat or not.

Outcomes and Results: Considerable repetition priming was observed in this SA patient group, bringing their performance up to control level at lag 0. Priming with a very short lag between prime and target (0-1 item) significantly reduced latency. Accuracy was significantly increased and semantic errors decreased with up to 7 intervening items. Controls also benefited from repetition priming, but showed little variation in latency, accuracy or errors over this range of short lags.

Conclusions: For patients with problems manipulating semantic information, repetition priming was an effective way to boost naming performance, though increasing the number of intervening items had a progressively detrimental effect. The observed repetition priming effects are interpreted within a connectionist model of speech production.

INTRODUCTION

Behavioural facilitation by a previous encounter is one of the most powerful and widely studied effects in psycholinguistics (Francis, Corral, Jones, & Saenz, 2008; Stark & McClelland, 2000; Wheeldon & Monsell, 1992), and occurs across multiple tasks (Cumming, Graham, & Patterson, 2006; Howard, Patterson, Franklin, Orchard-Lisle, & Morton, 1985; Vitkovitch, Rutter, & Read, 2001). Repetition also forms the basis for much impairment-directed speech and language therapy for deficits such as anomia seen amongst aphasic patients (Fillingham, Sage, & Lambon Ralph, 2005; Helmick & Wipplinger, 1975; Hengst et al., 2010; Nickels, 2002a; Raymer & Ellsworth, 2002), although experimental investigations of repetition priming (RP) amongst patients have been relatively rare (e.g., Cumming et al., 2006; Howard, Hickin, Redmond, Clark, & Best, 2006; Martin & Laine, 2000).

Semantic aphasia (SA) is a multimodal semantic deficit characterised by a failure of control processes rather than damage to central semantic representations (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009). Anomia is a common feature of SA which can be alleviated by the provision of correct phonemic cues (Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009). Previous work showing substantial cueing effects in SA suggests that this patient group should be particularly receptive to repetition priming in picture naming. Here we consider for the first time the extent and longevity of repetition priming effects in a small case-series of SA patients.

Work with SA patients in the verbal domain has highlighted the impact of both correct and misleading phonemic cues upon picture naming (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009); other studies have focused more on comprehension (Noonan et al., 2010) and the non-verbal domain (Corbett, Jefferies, & Lambon Ralph, 2009). Altogether, tests indicate a central amodal semantic impairment in SA resulting from poor semantic control, namely an impaired ability to harness semantic information appropriate to the task in hand. SA patients’ performance provides a demonstration of the importance of semantic control allowing effective use of intact semantic representations.

Cued naming experiments where pictures and single phonemes are presented simultaneously have helped to illustrate the semantic control difficulties of SA patients, and also to distinguish them from other groups with central semantic impairment such as semantic dementia (SD). Using cues that were either correct initial phonemes or initial phonemes from category co-ordinates or associates, it was found that correct cues significantly improved picture naming in SA patients (Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009), in contrast with SD patients in a similar experiment who gained no significant benefit from correct cueing (Jefferies & Lambon Ralph, 2006). Phonemic cues were able to enhance activation of targets, showing that poor semantic control can be ameliorated, allowing SA patients to access semantic representations which still exist but are hard to reach, whereas correct cues were ineffective for SD patients whose core representations are degraded. Further work has shown that SA responses to miscue trials were significantly less accurate than with correct cues, with a stronger and more reliable effect from co-ordinate than associate miscues (Noonan et al., 2010; Soni et al., 2009; Soni et al. in press).

Given that a semantic control deficit leads to heightened sensitivity to cueing in SA, the question arises – how well would they prime from repeated stimuli? This can be seen as an extension of the correct cueing paradigm: instead of merely giving the initial phoneme, the entire name is elicited on the priming trial and then again on a subsequent trial. An important component of repetition priming in normal populations is that as well as an effect on accuracy, there is a concomitant benefit to RT: primed items are produced significantly more quickly than unprimed (Lachman & Lachman, 1980; Mitchell & Brown, 1988; Wheeldon & Monsell, 1992). Although there can be methodological difficulties when measuring latency in patients, reaction time measures have been used to quantify repetition priming effects in other patient groups (Bird, Lambon Ralph et al., 2000; Cumming et al., 2006), hence reaction times were measured in the present work in addition to accuracy and error types.

Although picture naming has been used as a priming task in studies with one or two patients in the contextual priming procedure, where several items are presented in an array (Laine & Martin, 1996; Martin & Laine, 2000; Renvall, Laine, Laakso, & Martin, 2003; Renvall, Laine, & Martin, 2007), repetition priming of single item picture naming has not been explored using a case-series approach, nor has it been explored with SA patients. Furthermore, in the contextual priming procedure, no feedback was given as to the correctness of the naming responses on priming trials, and the presence of multiple items may have obscured the link between picture and name for each individual item. Previous investigations of repetition priming amongst groups of aphasic patients have used either a lexical decision task throughout (Bird, Lambon Ralph et al., 2000; Cumming et al., 2006) or WPM in the priming trials (Howard et al., 2006). In the current study the production task of single item picture naming with feedback was used for both the prime and target trials, as this procedure ensures both activation of an item's correct semantic representation and strengthening of the mapping from concept to phonological form, thus maximising the potential for repetition priming effects.

Previous considerations of RP effects among aphasic patients have suggested that the number of intervening items, or lag, is a crucial factor. In Cummings et al. (2006) a lexical decision task was used with SD patients, with variable lag between prime and target (0, 3, 9 or 23 items intervening). Knowledge of words was manipulated by using a word set previously tested on other SD patients and classified as 'known' or 'degraded'. All types of words showed RP relative to nonwords (a lexicality effect), but the knowledge of words also interacted with lag: known words did show priming but degraded words showed 'hyperpriming' (greater than expected RP relative to control performance) at the shorter lags (0 and 3 intervening items) but not longer (9 and 23). Hence it appears that the hyperpriming effect for degraded words decays relatively quickly to match the smaller priming effect shown for known words.

In addition to SD, stroke aphasic patients have also exhibited RP effects: both those with semantic impairments, for whom semantic errors are proportionally greatest in naming, and those with "post-semantic" impairments, whose primary error type is phonological (Howard et al. 2006). Howard et al. used the priming task of spoken word to picture matching (WPM), achieved by pointing at an item in an array on a computer screen. Patients did not produce the item name (though they did hear it in spoken WPM), nor did they receive feedback on the performance during the task. All patients showed some RP effects, but lag was again seen to have a differential effect: patients who were considered to have a semantic impairment only show RP at short lags (2-3 minutes) while those with a post-semantic impairment showed facilitation at both short and long lags (up to 25 minutes). However, the post-semantic group performed significantly better than the semantically impaired group on spoken, written and concrete WPM, allowing the interpretation that poorer processing of primes accounted for the briefer priming effects in patients with greater semantic impairment. Furthermore, the patients never produced the name themselves but respond by pointing, minimising priming of meaning to form mappings. In this study, we maximised the likelihood of such priming by ensuring all patients produced the correct picture name, whether spontaneously or via their good repetition skills.

Given that RP is observed in semantically impaired groups and that lag has been shown to have a differential effect in semantically impaired groups, what lag would maximise priming effects for SA patients? Given their semantic control impairment, it seemed most likely that short lags would be most effective, with very few intervening items to disrupt or obscure the activation produced by the prime: thus, lags of 0, 1 and 7 items were selected. The use of both lags 0 and 1 was to attempt to delineate between a true facilitation from RP (lag 1) and an effect which could be gained merely by residual phonological activation from the previous trial (lag 0); it could also reveal any possible refractory effects of having produced an item’s name on the immediately preceding trial (lag 0).

METHOD

Participants

Five SA patients were recruited from stroke clubs or recommended by speech and language services in Greater Manchester, UK. They were a subset of those reported in other work on this patient group (Jefferies, Baker et al., 2007; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Soni et al., 2009). Patients were enrolled if they failed both word and picture versions of semantic association tests such as the Camel and Cactus Test (CCT, Bozeat et al., 2000) and/or the Pyramids and Palm Trees Test (PPT, Howard & Patterson, 1992). Each patient had a chronic impairment from a CVA at least a year previous to the current study. Four were diagnosed with transcortical sensory aphasia (TSA) or anomic aphasia, with poor comprehension, fluent speech and good repetition. Patient BB had less fluent speech in addition to impaired comprehension. Table 5.1 includes biographical details, some details of lesion and aphasia type.

Control participants

A set of control participants was also tested with the same materials, matched individually to each patient by age and years of education (n=5). They were selected from a departmental database of available healthy participants in South Manchester: all had English as a first language, normal or corrected to normal vision and no adverse neurological history.

Table 5.1: SA patients' biographical details, lesion type and patterns of co-occurrence

Patient	Age	Sex	Education leaving age	Years since CVA	Frontal damage	Temporo parietal damage	Aphasia diagnosis
HN	77	M	15	2	×	✓	Anomic/TSA
PG*	63	M	18	8	✓	w	TSA
SC	80	M	16	8	×	✓	Anomic/TSA
BB	59	F	16	6	✓	✓	Mixed transcortical
ME	40	F	16	9	×	✓	TSA

Patients are arranged in order of naming scores in the 64 item battery (Bozeat et al., 2000).
w = damage confined to white matter immediately underlying cortex.
* = no scan available. Description of lesion: L frontal and capsular.

Background neuropsychology and semantic testing

Patients were tested on forward and backwards digit span (Wechsler, 1997), the Visual Object and Space Perception (VOSP) battery (Warrington & James, 1991), the Coloured Progressive Matrices test of non-verbal reasoning (Raven, 1962). Executive skill and attention were tested with the Wisconsin Card Sorting test (Milner, 1963; Stuss et al., 2000), the Brixton Spatial Rule Attainment task (Burgess & Shallice, 1997), and Elevator Counting (with and without distraction) from the Test of Everyday Attention (Robertson et al., 1993). Semantic skills were tested using a number of assessments. For example, tests of semantic association included the Pyramids and Palm Trees Test (PPT, Howard & Patterson, 1992) and Camel and Cactus Test (CCT, Bozeat et al., 2000), where participants have to decide which of two (PPT) or four (CCT) items is most associated with a target, e.g. pyramid with a pine tree or a palm tree. Both PPT and CCT were assessed with word and picture versions. CCT forms part of a 64 item semantic battery which also tested spoken picture naming and spoken word to picture matching on the same items. Other semantic tests comprised synonym judgement (Jefferies et al., 2009), category fluency (animals, birds, fruit, household items, tools and vehicles) and letter fluency (letters F, A and S). As is immediately apparent from Table 5.2, all patients showed significant impairments across a variety of tests tapping semantic knowledge.

Table 5.2: Background neuropsychological assessment of SA patients

Task/test	Max	Normal cut-off$^{\alpha}$	HN	PG	SC	BB	ME	mean
Background Neuropsychology:								
VOSP dot counting	10	8	8	**5**	10	10	**3**	**7.2**
VOSP position discrimination	20	18	19	20	**17**	18	**15**	**17.8**
VOSP number location	10	7	9	9	10	8	**2**	**7.6**
VOSP cube analysis	10	6	**4**	10	9	**2**	**4**	**5.8**
Raven's coloured matrices (percentiles)			20	50	50	50	**<5**	35.0
WCST (number of categories)	6	1$^{\beta}$	6	**0**	6	1	**0**	2.6
Brixton spatial anticipation (correct)	54	28	28	**26**	**25**	**23**	**11**	**22.6**
TEA counting without distraction	7	6	7	**0**	7	**4**	7	**5.0**
TEA counting with distraction	10	3	9	3	**1**	**0**	9	4.4
Digit span forwards	-	5	6	6	6	5	6	5.8
Digit span backwards	-	2	2	2	2	**0**	3	**1.8**
Semantic Tests:								
PALPA word repetition	80	80	**69**	**73**	**78**	**77**	80	**75.4**
Picture PPT	52	48.4	**35**	**42**	50	**41**	**29**	**39.4**
Word PPT	52	48.9	**44**	**43**	51	**35**	**39**	**42.4**
Synonym judgement	96	90.1	**70**	**69**	**71**	**63**	**81**	**70.8**
Letter fluency	-	21.8	**19**	**2**	24	**0**	**14**	**9.56**
Category fluency	-	62.7	63	**4**	**17**	**13**	**25**	**24.4**
64 Item Picture Naming	64	59.1	**50**	**46**	**28**	**10**	**5**	**27.8**
64 Item Spoken Word-picture Matching	64	62.7	**50**	**58**	**59**	**54**	**50**	**54.4**
64 Item Picture CCT	64	52.7	54	**44**	**46**	**38**	**13**	**39.0**
64 Item Word CCT	64	56.6	**54**	**40**	**56**	**30**	**34**	**42.8**

Patients are arranged in order of naming scores in the 64 item battery (Bozeat et al., 2000).
α For semantic tests, this represents the control mean – 2SD.
$^{\beta}$ Cut-off for 50-74 year olds (regardless of educational level).
All impaired scores are shown in bold.
NT = Not taken.

Control participants

Five control participants were drawn from a pool of volunteers. Each one was individually matched with a patient on age and education leaving age. All controls had normal or corrected to normal vision and no history of neurological damage.

Stimuli

One hundred and eighty black and white line drawings of common natural and man-made objects were selected from standard picture sets (Snodgrass & Vanderwart, 1980; Szekely et al., 2003). The stimuli were then divided into three lists (one for each lag condition) matched on name agreement (mean = 0.98; SD = 0.03, from the International Picture Naming Project (IPNP): Szekely et al., 2003), reaction time (mean = 871 ms; SD = 114 ms, from IPNP: Szekely et al., 2003), number of syllables (mean = 1.53; SD = 0.72, from IPNP: Szekely et al., 2003), number of phonemes (mean = 4.03; SD = 1.50, from IPNP: Szekely et al., 2003), frequency (mean = 3.23; SD = 1.43, from CELEX lexical database: Baayen, Piepenbrock, & Gulikers, 1995), AoA (overall mean = 2.07; SD = 0.94, from the MacArthur Communicative Development Inventory (CDI): Fenson et al., 1994) and visual complexity (mean = 16304 kilobytes (KB); SD = 8027 KB, from IPNP: Szekely et al., 2003). Items and norms for each list plus matching statistics can be found in Appendices A to G of the Supplementary Materials. Each of the three lists was further divided into two sections (A and B) matched to each other on the same variables: this was to enable testing to take place over two sessions. If set A was repeated in session 1, then set B formed the ‘control’ or unprimed items; this assignment was reversed on the second test occasion, hence all items were seen in each session but in different conditions.

Procedure

The experiment was presented using E-Prime (Schneider et al., 2002) on a laptop, with participants sitting around 80cm from the screen. Testing occurred over two sessions at a minimum of two weeks apart and was carried out in the patients’ homes. There were three lag conditions, lag 0 (no intervening trials), lag 1 (one trial intervening) and lag 7 (seven trials intervening). Each item was seen in only one lag condition by each participant but separate versions of the test were constructed such that all items appeared in all lag conditions, counterbalanced across the group. A number of semantically-unrelated filler items were also included in each test in order to fill the number of trials intervening between lags. Each test consisted of 270 items to name (primes, targets and fillers); the lags were interleaved in a varied manner so that the possibility of a repeated item was unpredictable. The task instructions noted that the pictures would appear on the screen one at a time; some might be shown more than once, but the participant should just try to name the picture in each case. The tester marked responses on a printed scoresheet and also recorded test sessions on a Sony IC digital recorder for later use in measuring reaction times. Reaction times, accuracy and error rate and type were measured; RTs were measured using Wavepad Sound Editor software (NCH, Swiftsound, : www.nch.com.au/wavepad).

At the onset of each picture an audio beep was played for 300ms, to serve as a marker for RT measurement. The picture appeared on screen for a maximum of 5 seconds after which the screen went white; as soon as a correct response was given the tester initiated the next picture with a button press. If no response had been given the patient would be prompted for an answer; if no response was made or an error was produced, the tester would say the correct name and ask the participant to repeat it, ensuring that a correct production was obtained for all prime items.

RESULTS

Dependent variables were analysed using a fully repeated measures ANOVA with within-participants factors of priming (2 levels: repeated and unrelated prime), lag (3 levels: 0, 1 and 7), and the between-participants factor group (2 levels: patients and controls). Initial analyses revealed minimal effects of session, therefore all analyses are reported with data collapsed across this variable. ANOVAs were also carried out separately for each group with the same within-participants factors of priming and lag. Initially, the results for the overall comparison ANOVA will be reported in order to ascertain whether patients behaved significantly differently to controls. ANOVAs for each group will then be reported, followed by planned comparisons to elucidate the details of any interactions. All probabilities reported for t-tests are 1-tailed due to prior prediction of a facilitative effect of repetition priming. Most F-values reported are with sphericity assumed; however, Huynh-Feldt values are reported as appropriate to correct for violations of sphericity. Errors were defined according to the following classification: semantic[12] , omission[13] , or other[14].

---

[12] E.g., co-ordinate, “kite” for BALLOON; associate, “cup” for SPOON; superordinate, “animal” for TIGER; or correct circumlocutions, “you light them” for CANDLE

[13] No complete word answer, or “don’t know”

Reaction Times

Only reaction times for correct responses were analysed. For the group comparison ANOVA on RTs there was a significant 3-way interaction between lag, priming and group (*F*(1,8) = 11.819; *p* = .006), showing that priming had the greatest effect on patients at the shortest lag, diminishing swiftly with longer lags, whereas controls' performance remained more stable throughout, as can be seen in Figure 5.1. There was also a significant 2-way interaction between lag and group (*F*(2,13) = 5.069; *p* = .031), showing that, collapsed across priming, patient performance slowed at longer lags compared to similar performance across all lags by controls; the 2-way interaction between priming and group was also marginally significant (*F*(1,8) = 5.062; *p* = .055), indicating a trend towards greater priming for patients than controls when lag conditions were collapsed. The main effect of group was significant (*F*(1,8) = 11.261; *p* = .01), showing that patients responded significantly more slowly than controls (1609 ms vs. 767 ms respectively).

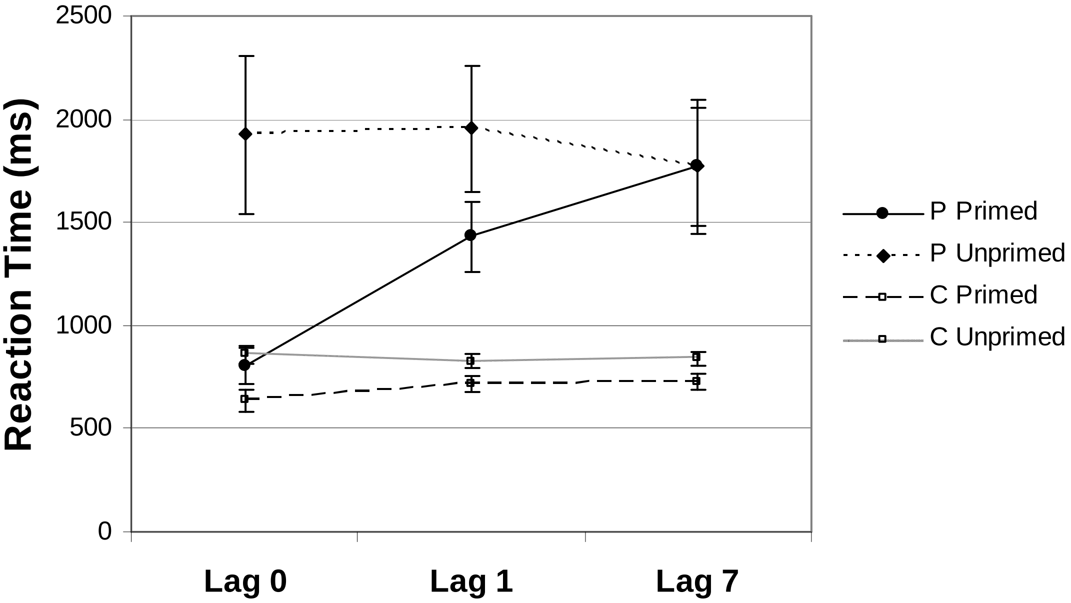


Figure 5.1: Reaction times for patients (P) and controls (C) according to priming and lag (error bars represent standard error)

---

[14] E.g., incorrect circumlocutions, "you cook on them" for SINK; picture parts, "shirt" for MAN; phonological, "sky" for SKIS; visual "pen" for LIPSTICK; or unrelated/perseverative, "stairs" for PLATE

In the ANOVA for patients' RTs, there were significant main effects of priming (*F*(1,4) = 9.670; *p* = .036) and lag (*F*(2,8) = 6.026; *p* = .025), and an interaction between priming and lag (*F*(1,4) = 14.733; *p* = .018), showing an effect of priming that decayed swiftly with increasing lag (see Figure 5.1). Planned comparisons revealed that for patients there were significant differences in RT at Lag 0 (*t*(4) = 3.552), *p* = .012) and Lag 1 (*t*(4) = 3.396; *p* = .014), but not at Lag 7. In the ANOVA for controls there were main effects of priming (*F*(1,4) = 47.905; *p* = .002) and lag (*F*(2,8) = 6.765; *p* = .019), and an interaction between priming and lag (*F*(2,8) = 11.871; *p* = .004) which appears to be driven by a larger priming effect at lag 0. Planned comparisons revealed that there were significant differences in controls' RT between primed and unprimed items (see Figure 5.1) at Lag 0 (*t*(4) = 5.470; *p* = .003), Lag 1 (*t*(4) = 9.204; *p* = .001) and Lag 7 (*t*(4) = 6.815; *p* = .001), a consistent effect of prior presentation regardless of number of intervening items.

Accuracy

The accuracy results revealed a 3-way interaction between priming, lag and group (*F*(1,11) = 4.654; *p* = .043) showing that though patients' accuracy reached control levels at lag 0, as can be seen in Figure 5.2, this priming advantage declined sharply with more intervening trials. There were also significant 2-way interactions between priming and group (*F*(1,8) = 12.656; *p* = .007), showing that the patients responded more to priming than controls regardless of lag, and lag and group (*F*(2,16) = 9.067; *p* = .002), showing that when priming conditions were collapsed, longer lags reduced patients' but not controls' accuracy. The main effect of group was significant, showing that patients' responses were significantly less accurate than controls' (.662 vs. .975, respectively).

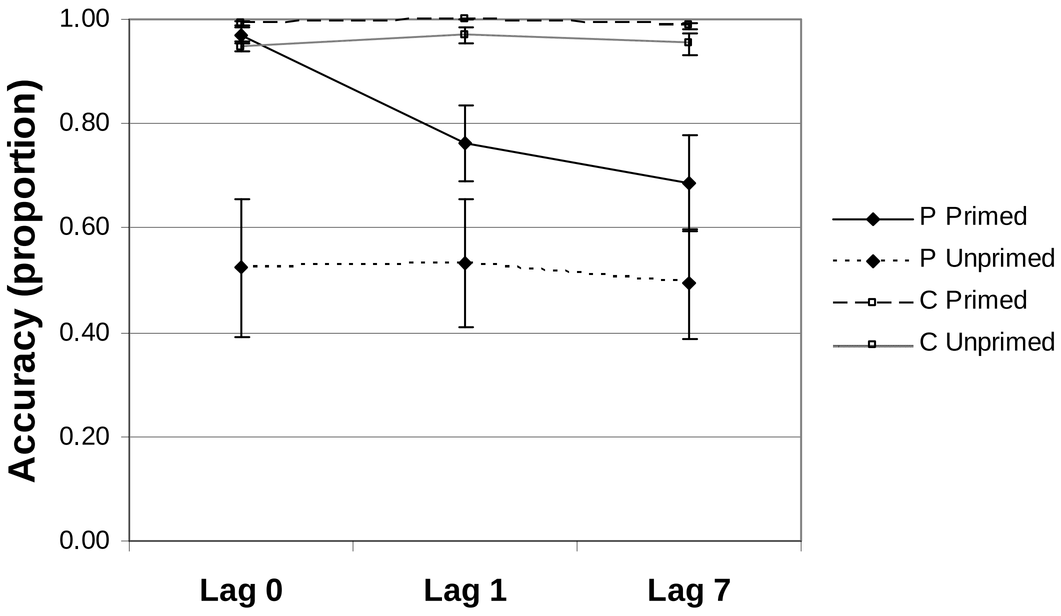


Figure 5.2: Accuracy for patients (P) and controls (C) according to priming and lag (error bars represent standard error)

In the group ANOVA for patients alone, there were significant main effects of priming (*F*(1,4) = 16.973; *p* = .015) and lag (*F*(2,8) = 9.107; *p* = .009), and an interaction between lag and priming (*F*(2,8) = 5.617; *p* = .030), driven by the larger priming effect at lag 0 (see Figure 5.2). Planned comparisons showed that there were significant benefits from priming at lag 0 (*t*(4) = 3.520; *p* = .012), lag 1 (*t*(4) = 3.933; *p* = .009) and lag 7 (*t*(4) = 4.302; *p* = .007). In the ANOVA for controls, there was a significant effect of priming (*F*(1,4) = 11.585; *p* = .027), but not of lag (*F*(2,8) = 2.250), and no interaction (*F*(2,8) = .344). Planned comparisons showed a significant difference in controls' accuracy between primed and unprimed items (see Figure 5.2) at Lag 0 (*t*(4) = 4.176; *p* = .007) and Lag 1 was marginally significant (*t*(4) = 2.107; *p* = .052), and Lag 7 approached significance (*t*(4) = 1.533; *p* = .100).

Semantic Errors[15]

For semantic errors, there was only a significant 2-way interaction between priming and group (*F*(1,8) = 11.303; *p* = .01), indicating that the priming effect was larger for patients than controls; see Figure 5.3 for performance of each group. The main effect of group was significant (*F*(1,8) = 9.729; *p* = .014), showing that patients produced significantly more semantic errors than controls (.167 vs. .018 respectively).

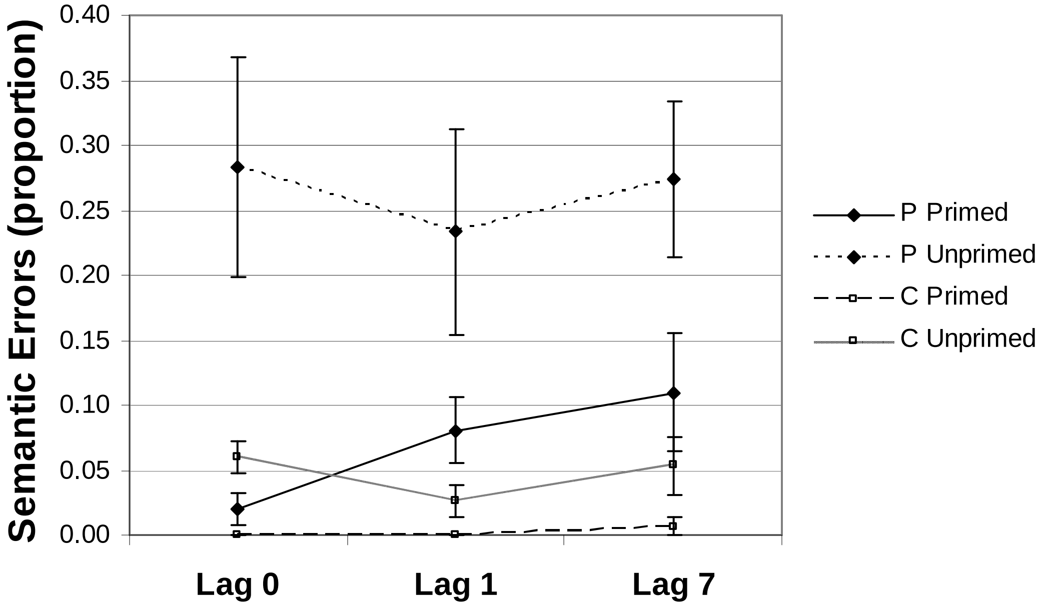


Figure 5.3: Semantic error rates as a proportion of all trials for patients (P) and controls (C) according to priming and lag (error bars represent standard error)

In the patients' ANOVA for semantic errors there was a significant main effect of priming (*F*(1,4) = 15.366; *p* = .017); planned comparisons revealed that patients showed significantly lower semantic error rates with primed than unprimed items (see Figure 5.3) at Lag 0 (t(4) = 3.089; *p* = .019), Lag 1 (t(4) = 2.580; *p* = .032) and Lag 7 (*t*(4) = 10.130; *p* = .001). In the controls' ANOVA on semantic errors, there was a significant main effect of priming (*F*(1,4) = 11.497; *p* = .028), and the main effect of lag approached significance (*F*(2,8) = 3.273; *p* = .092). Planned comparisons showed that semantic error rates to primed targets were significantly lower than with unprimed items

---

[15] There were no significant differences in omission rates or other errors, either in the overall comparison or individual ANOVAs for each group.

(see Figure 5.3) at Lag 0 (*t*(4) = 3.730; *p* = .010) and Lag 1 (*t*(4) = 2.161; *p* = .049), but lag 7 did not quite show a significant difference (*t*(4) = 1.484; *p* = .106).

DISCUSSION

Overall, the most striking aspect of the present results is that priming at the shortest lag brought patient performance up to normal control levels. Patients' RTs at lag 0 with primed items (808 ms) were very much in line with the control participants' unprimed naming RTs (859 ms). However, patient RTs with primed targets increased steeply with extra intervening items (lag 1 = 1433 ms; lag 7 = 1770 ms); though still showing a significant priming effect at lag 1, primed and unprimed latency were identical by lag 7. Patients' unprimed latencies remain relatively stable (lag 0 = 1924 ms; lag 1 = 1953 ms; lag 7 = 1770 ms), showing that the differences at each lag result from a reduction in repetition priming (RP). Patients' accuracy with no intervening items (97% correct) was within the range of controls (primed accuracy = 99.3%; unprimed = 94.7%). Although remaining significant across all lags, for patients the benefit from priming declined with more intervening items (lag 1 = 76.3%; lag 7 = 68.7%), whereas controls' performance appears to remain more stable with both primed and unprimed items (see Figure 5.2). As with both RT and accuracy, lag 0 reduces patients' semantic error rate to within the range of controls (patients primed semantic errors = 2%; controls primed = 0%; controls unprimed = 6%). Patients again show a decline in performance with increasing lag (lag 1 = 8%; lag 7 = 11%), although primed semantic error rates remained significantly lower than unprimed (lag 0 = 28.3%; lag 1 = 23.3%; lag 7 = 27.3%).

As can be seen from this summary, the detrimental effect of increasing lag is mirrored in all variables for the patients, compared to controls' performance which remains relatively undifferentiated across this series of short lags. It appears that in this SA patient group the large benefit from immediate repetition is quickly disrupted by the presence of intervening trials, although this decline is more pronounced when considering latency than accuracy and error rates, as the latter continue to show significant benefits even at lag 7. This decreasing RP effect with increasing lag resembles effects seen in other aphasic or semantically impaired groups. In Howard et al. (1985), stroke patients with various aphasia diagnoses showed an effect of RP on naming accuracy which declined to the level of unprimed performance after 30 items. In Howard et al. (2006) stroke aphasic patients with semantic impairment showed an effect of priming on naming accuracy at short but not long lags, compared with stroke aphasic patients without semantic impairment who benefited from priming at both short and long lags. SD patients have also been found to respond faster in a lexical decision task with short than long lags (Cummings et al. 2006), but only on ‘degraded’ words; known words showed an improvement at both short and long lags.

The current experiment was exploratory in nature and was not designed to determine the precise locus of RP effects. However, naming a pictured item can be broken down into several commonly accepted stages: object recognition/identification, linking initial visual processing to a semantic representation; mapping between semantics and phonology, activation of a phonological form; and production of that phonological form (Francis et al., 2008; Glaser, 1992; Humphreys et al., 1988; Morrison et al., 1992; Wheeldon & Monsell, 1992). In our task, the pictured items were always overtly named in the priming trials (with or without assistance from the tester), which necessarily primes all stages from object recognition to name production, as was our intent in order to maximise priming.

Different studies have offered various hypotheses on the locus of RP. In Howard et al. (1985) several priming tasks were used with stroke aphasic patients: auditory and written word to picture matching and a semantic judgement task consisting of answering a yes/no question about the characteristics of an item (e.g., “Does a cow eat grass?”). None of these tasks involved production of the item’s name by the patients, and the semantic judgement task made no connection between an item’s picture and its name, requiring only an internal access to the meaning. Both auditory WPM and the semantic judgement task produced a facilitatory effect on naming up to 41 items later (around 20 minutes). The authors concluded that because no overt production was required, these priming tasks improved subsequent naming performance by boosting target activations at the semantic level.

In their study of RP using spoken word to picture naming priming trials with stroke aphasic patients with and without semantic deficits, Howard et al. (2006) suggest that RP can also occur later in the word production process, for example during meaning to form mapping. They concluded that for those with semantic deficits, lemma access is primed over short lags; for those who can access lemmas well, they cite a longer lasting boost in meaning to form mapping. Wheeldon and Monsell (1992) used both word reading and naming to definition as their priming tasks with normal participants, and found a consistent and long-lasting priming effect on naming. The lack of facilitation when the priming trial elicited a homophone of the target ruled out boosting phonological activation alone; priming of object identification alone was also ruled out as their cross-modal priming tasks did not include pictures. Wheeldon and Monsell concluded that because all priming trials involve overt production of an item's name, their results could support an effect based on boosting semantic representations and/or meaning to form mapping.

It appears repetition priming does not rest purely on a phonological route but that there is also a semantic component such that the effect declines more quickly in patients with more severe semantic impairment (Howard et al. 2006) or on items which are more semantically degraded (Cummings et al. 2006). In the current experiment, it is clear that although the SA patients can still reap benefits in terms of accuracy after seven intervening items, although the benefit accruing to latency has diminished by this point. We suggest that in connectionist models of learning and speech production (de Zubicaray, McMahon, Eastburn, Pringle, & Lorenz, 2006; Foygel & Dell, 2000; Hinton & Shallice, 1991; McClelland & Rumelhart, 1987; Seidenberg & McClelland, 1989; Stark & McClelland, 2000) repetition priming causes change in the connection weights between semantic units, or between semantic and phonological units, raising the activation of the target. When that item is presented again soon afterwards, residual activation makes name selection more efficient. Our SA patient group benefited most from the target's raised activation with fewest items intervening between first and second presentation: we postulate that the semantic control system which manipulates task appropriate information is guided by the presentation of the prime. However, controlled selection is disrupted by the presence of intervening trials: with longer lags, impaired semantic control makes it harder to inhibit the raised activations of other more recent though irrelevant intervening items, leading to less efficient name selection and reduced priming. Continuing raised activation of the primed items can be detected in the significantly higher accuracy and lower semantic error rates even at lag 7, but impaired ability to inhibit activation of intervening items in this group is clear from the rise in RTs to the level of unprimed items by lag 7.

In the current experiment, pictures were named in both prime and target tasks, sometimes with no intervening trials. Howard et al. (1985) suggest that in immediate repetition a kind of phonological 'prompting' may be taking place, perhaps due to the information remaining in working memory. Wheeldon and Monsell (1992) further suggest that there could be an episodic memory trace, especially where priming and target tasks are identical. Neither of these effects can be ruled out by our data, indeed the heightened priming at lag 0 could indicate some retention of information by working memory, but we argue that continued effects on RT at lag 1 and on accuracy and error rates at lags 1 and 7 show true facilitation by priming. Future research could use different prime and target tasks in order to determine more precisely the nature of the repetition priming effect observed here amongst patients with SA, and whether such manipulations can provide more long-lasting benefits.

CHAPTER 6

SEMANTIC AND REPETITION PRIMING IN SEMANTIC APHASIA: DO WORD PRIMES HAVE AN EFFECT?

ABSTRACT

Background: We present a repetition and semantic priming experiment with a group of semantic aphasic (SA) stroke patients using a case-series approach. The study was designed to extend the repetition priming effects observed during picture-picture priming with SA patients and to assess the effect of semantic priming on patients with SA. This experiment was also an extension of previous work with SA patients using correct and misleading phonological cues.

Aims: We assessed whether word primes can produce repetition priming effects in this patient group. We also aimed to refine the possible locus of priming effects by the inclusion of semantic priming trials, which do not prime either input or output target production.

Methods and Procedures: The procedure was carried out with five patients with aphasia following stroke that had all failed verbal and picture versions of tests of semantic association, revealing difficulties with manipulation of semantic information. Five age- and education-matched controls also took part. Pictures to be named (n=150) were presented individually on a computer screen in three sessions at least a week apart. One trial comprised *prime word – filler picture – target picture.* All targets were presented in each session with one of the following prime types: identity (repeated), semantic or unrelated. Each target item appeared once with each prime type across the three sessions, preceded by the same filler picture each time: prime words appeared only once across the entire test.

Outcomes and Results: Repetition priming with word primes facilitated picture naming in this SA patient group in latency, accuracy and error rates, though their performance remained significantly below that of controls. Semantic primes produced a significant benefit to accuracy in session 3, but there were no significant effects of semantic primes on latency or semantic error rates.

Conclusions: For patients with semantic control impairments, repetition priming with word primes, as with picture primes, enhanced naming performance. The outcome of semantic priming trials suggested that priming increased target activation at the level of semantic representations, indicating that semantic priming with familiar targets could have a role in anomia therapy. Models of speech production that include cascading or feedback of information can account for the priming effects observed.

INTRODUCTION

Priming is a paradigm often found to produce performance benefits with prior presentation of a related item. The relationship can be one of identity (i.e. straight repetition) or semantic similarity (categorical and/or associative). There is a large experimental literature on both kinds of priming across a variety of tasks, such as lexical decision, reading aloud and picture naming (1988; Chertkow, Bub, & Seidenberg, 1989; Fischler, 1977; Howard et al., 2006; McEvoy, 1988; Meyer & Schvaneveldt, 1971; Tree & Hirsh, 2003; Vitkovitch et al., 2001; Wheeldon & Monsell, 1994).

In normal picture naming both inhibitory and facilitatory effects on target naming have been demonstrated with semantic primes. Early papers using the term 'semantic priming' tend more towards reports of facilitation (Bajo, 1988; Meyer & Schvaneveldt, 1971), but the effects of associate and co-ordinate relationships were not necessarily separated (Lucas, 2000). Fischler (1977) did tease out separate effects of co-ordinate and associate primes: in a lexical decision task, word pairs could be highly associated (e.g., CAT-DOG; in fact these items are both categorically and associatively related), or merely semantically similar without association (e.g., NURSE-WIFE). Faster performances were observed with targets following both types of prime relative to unrelated primes; Fischler concluded that processing of a word can be facilitated by prior encoding of a semantically similar item. In his meta-analysis of semantic priming in normal participants, Lucas (2000) found a majority of studies which showed facilitation when co-ordinate primes were used.

However, more recent papers present evidence that semantic priming with categorically related items has an inhibitory effect, also known as a semantic interference effect (SIE). In Wheeldon and Monsell (1994), healthy participants showed a negative priming effect on picture naming (e.g., SHARK) when preceded by naming a semantic co-ordinate to definition (e.g., WHALE). Tree and Hirsh (2003) performed naming tasks with young (18-25) and older (66-87) healthy participants and found inhibition of naming in both age groups following a categorically but not associatively related prime. Vitkovitch, Cooper-Pye and Leadbetter (2006) found semantic interference in normal participants when related words or pictures are named three trials before target pictures. Humphreys, Lloyd-Jones and Fias (1995) found semantic interference from related primes on word and picture naming with normal participants, as long as words and pictures were intermingled.

Repetition and semantic priming have often been carried out with aphasic and semantically impaired patients, both as a form of therapy to improve naming and as a way to explore semantic deficits. It is a useful technique for semantically impaired patients, because unlike many other tests of semantic knowledge, it does not require overt searching through memory stores but relies on more automatic processing. It can therefore help to distinguish between damage to the core representations and disordered manipulation of semantic information (Moss & Tyler, 1995).

Chertkow et al. (1989) found positive effects of co-ordinate priming in a lexical decision task with AD patients. They even observing hyperpriming, or proportionally greater priming effects than controls with the same stimuli, particularly on items which were “degraded” in off-line tests. These items had longer RTs in initial tests, hence appeared to allow more scope for priming to have an effect. Baum (1997) also found facilitation from semantic priming in a lexical decision task with both fluent and nonfluent aphasic patients. Semantic priming with co-ordinate relationships between prime and target was shown to have facilitative effects on a lexical decision task in patients with Alzheimer’s disease and normal control participants in terms of accuracy and RT, but these effects were lacking in semantic dementia (SD) patients (Nakamura, Nakanishi, Hamanaka, Nakaaki, & Yoshida, 2000). However Glosser, Friedman, Grugan, Lee and Grossman (1998) found no semantic priming effects in AD patients in a word reading task with co-ordinate primes.

Several papers report semantic effects in the contextual priming paradigm, which consists of naming a single picture from array indicated by the tester. Martin, Fink, Laine and Ayala (2004) and Renvall, Laine and Martin (2005) showed immediate interference in semantically impaired aphasic patients when naming from semantically related arrays in the form of ‘contextual’ naming errors, naming other items visible in the array. However, the patients subsequently showed short term improvements in naming (5 minutes post CP procedure), and Renvall, Laine and Martin (2007) further demonstrated that naming was significantly above baseline level for a semantically impaired patient 6 weeks after treatment. They argue that interactive models of word retrieval (e.g., Dell et al., 1997) account for the priming of semantically related targets through spreading activation among shared semantic features.

Differences between types of patients may account for some variable effects of semantic priming in patients with semantic impairments. The lack of priming effects in SD (Nakamura et al., 2000) accords with other accounts of semantic memory deterioration in this condition: if details of semantic representation are lost, then the activation from a related prime cannot spread to the target. Nakamura et al (2000) argue that semantic priming effects pertain in AD because it is the retrieval of semantic information that is impaired as opposed to the background representations. However, they qualify their results by reporting that their AD patients are at the mild end of the spectrum and effects may be different when the disease is more advanced. Contrasting with Nakamura et al. (2000), Glosser et al. (1998) argue that the lack of semantic interference in their AD group indicates that AD is a core semantic impairment.

The type of prime used also has bearing on the direction of semantic priming effects in both healthy and semantically impaired participants. Firstly, there is a clear difference between associative and co-ordinate primes, with associative priming usually showing a facilitatory effect and co-ordinates often producing interference. Prime-target pairs for ‘semantic priming’ in Meyer and Schvaneveldt (1971) were taken from association norms, producing facilitation; Lucas (2000) also notes a larger effect size or “associative boost” in studies where items are both categorically and associatively related. The picture-word interference (PWI) paradigm presents convergent evidence here; co-ordinate distractors have frequently been shown to produce SIEs (Alario et al., 2000; Caramazza & Costa, 2000, 2001; Costa et al., 2005; de Zubaricay et al., 2001; Glaser & Glaser, 1989; Levelt et al., 1999; Wilshire et al., 2007), whereas associatively related distractors are usually facilitatory (Alario et al., 2000; Costa et al., 2005; La Heij et al., 1990; Lupker, 1988).

There is much debate in the literature about the mechanisms of associate and co-ordinate semantic priming. Associates are usually item-specific, for example “nuts” is an associate of SQUIRREL but not of MOUSE; hence spreading activation from an associate would tend to boost the activation of a specific member of a category, facilitating target naming as reflected in the studies named above. Contrastingly co-ordinates from the same category usually represent a competitor to the target, leading to semantic interference. One account raised by both priming and picture-word interference studies is as follows: a semantic word prime or distractor (e.g., "boat") raises the activation of that item, potentially including phonological, semantic and/or lexical representations; when the target (e.g., TRAIN) appears, processing it necessarily raises some overlapping semantic information. Remaining activation from the prior presentation of the co-ordinate "boat" is boosted again, making the prime a strong competitor when naming the target. Some extra time is required to overcome this competitor and name the target correctly, leading to longer latency compared to trials with an unrelated prime, i.e., there is semantic interference (Alario et al., 2000; Levelt et al., 1999; Roelofs, 1992). At longer SOAs in the PWI paradigm (> +200ms), this SIE can diminish to the point where there is no difference from an unrelated prime or distractor (Alario et al., 2000). Lateral inhibition has also been suggested as a mechanism to account for an SIE from a semantic prime (Berg & Schade, 1992). In this case activation of the prime would depress that of near semantic neighbours including the target, making it harder to access the target on a subsequent trial. However, these are controversial issues about which opinion is still divided.

A third factor with bearing on the direction of semantic priming effects relates to experimental task. In the studies mentioned above, recognition tasks such as lexical decision are more often linked to facilitation, regardless of prime type: many of the studies in Lucas' meta-analysis (2000) use various types of lexical decision (masked, paired and continuous), and show facilitation even with co-ordinate primes. On the other hand, production tasks such as naming are more often associated with inhibition by semantic primes (Bak & Hodges, 2003; Wheeldon & Monsell, 1994). It could be that during a recognition task like lexical decision, the spreading activation (or reactivation of shared features) from a semantically related item (e.g., CAT) boosts the activation of the target (e.g., DOG), leading to faster decision times; however, when production of the name is required, the increased activation of the prime obscures or outweighs the activation of the target, leading to inhibition (Vitkovitch & Humphreys, 1991). Categorisation rather than naming of targets has also been seen to lead to facilitation from semantic primes (Glaser and Dungelhoff, 1984); a similar account to that for lexical decision could also be applied in this case.

Previous uses of semantic priming in therapy for other aphasic patients have shown benefits, but semantic priming has not yet been attempted with semantic aphasic (SA) patients. Semantic priming will be examined here as an extension to the phoneme miscueing manipulations presented in Soni et al. (2009) and Soni, Lambon Ralph and Woollams (in press). These studies found that co-ordinate miscues significantly reduced picture naming accuracy relative to correct cues (Soni et al., 2009; Soni et al., in press), and a marginally significant difference was seen between neutral and co-ordinate cues. Associate miscues were less successful at deflecting target naming (Soni et al., in press); there was a significant difference in error rates between correct and associative miscues, but not between neutral and associative miscues. These miscueing effects suggest that semantic priming might cause inhibition in this particular patient group. Several theories proposed in the literature could account for potential inhibitory effects. One possibility is that the activation of the prime depresses the activation of the target during the selection procedure (de Zubicaray & McMahon, 2009; Vitkovitch et al., 2001). An alternative account is competitive selection, where the prime's activation is raised relative to the target's (Thompson-Schill & Botvinick, 2006).

Repetition priming showed positive effects for this patient group, tempered by the effect of increasing lag Soni, Lambon Ralph and Woollams (submitted). However, these facilitatory effects in picture-picture repetition priming left open the question as to whether the facilitation was coming from referent identification, semantic selection, or phonological selection in the picture naming process, because all three processes were primed by the nature of the task. One way to assess the locus of the facilitation observed in picture naming is to see if it generalises to word primes, as this avoids making a connection between the phonological form and the visual representation of the target. If the repetition priming effect generalises to word primes, the locus of priming is constrained: it cannot be due to facilitation of object recognition. There are still several ways in which the priming effect of words could be explained. One is that priming could stem from a boost to phonological activation of a particular set of phonemes that persists over time. It is also possible that mapping between semantics and phonology is strengthened for a particular item, or that production of the phonological form boosts the activation of a semantic representation so that selection amongst alternatives is more efficient.

Using semantic primes distinguishes between these alternatives, helping to establish the locus of the priming effect. If semantic primes are effective at changing performance on target trials, they will rule out both input and output facilitation as the name of the target is not pronounced during a semantic priming trial. Thus a semantic prime can only influence the activation and production of the target by affecting selection at the semantic level.

METHOD

Participants

Five SA patients were recruited from stroke clubs or referred by speech and language services in Greater Manchester, UK. They were a subset of those reported in other work on this patient group (Jefferies, Baker et al., 2007; Jefferies, Patterson, & Lambon Ralph, 2006; Jefferies et al., 2008; Soni et al., 2009). Patients were enrolled if they failed both word and picture versions of semantic association tests such as the Camel and Cactus Test (CCT, Bozeat et al., 2000) and/or the Pyramids and Palm Trees Test (PPT, Howard & Patterson, 1992). Each patient had a chronic impairment from a CVA at least a year previous to the current study. Four were diagnosed with transcortical sensory aphasia (TSA), with poor comprehension, fluent speech and good repetition. Patient BB had less fluent speech and poorer repetition in addition to impaired comprehension. Table 6.1 includes biographical details, aphasia type and some lesion details.

Control participants

A set of control participants was also tested with the same materials, matched individually to each patient by age and years of education (n=5). They were selected from a departmental database of available healthy participants in South Manchester: all had English as a first language, normal or corrected to normal vision and no adverse neurological history.

Patient	Age	Sex	Educ leaving age	Years since CVA	Frontal damage	Temporo parietal damage	Aphasia diagnosis
HN	77	M	15	2	✗	✓	Anomic/ TSA
PG[1]	63	M	18	8	✓	W	TSA
SC	80	M	16	8	✗	✓	Anomic/ TSA
BB[b]	59	F	16	6	✓	✓	Mixed transcortical
ME	40	F	16	9	✗	✓	TSA

Table 6.1: SA patients' biographical details, lesions and patterns of co-occurrence

Patients are arranged in order of naming scores in the 64 item battery (Bozeat et al., 2000)
w = damage confined to white matter immediately underlying cortex.
[1] No scan available. Description of lesion: L frontal and capsular

Background neuropsychology and semantic testing

Patients were tested on forward and backwards digit span (Wechsler, 1997), the Visual Object and Space Perception (VOSP) battery (Warrington & James, 1991), and the Coloured Progressive Matrices test of non-verbal reasoning (Raven, 1962). Executive skill and attention were tested with the Wisconsin Card Sorting test (Milner, 1963; Stuss et al., 2000), the Brixton Spatial Rule Attainment task (Burgess & Shallice, 1997), and Elevator Counting (with and without distraction) from the Test of Everyday Attention (Robertson et al., 1993). Phonological skill was assessed using word repetition from PALPA (Kay et al., 1992): 4/5 showed strong performance (> 91%); the remaining patient (HN) repeated over 80% correctly. Semantic skills were tested using a number of assessments. For example, tests of semantic association included the Pyramids and Palm Trees (PPT, Howard & Patterson, 1992) and Camel and Cactus (CCT, Bozeat et al., 2000), where participants have to decide which of two (PPT) or four (CCT) items is most associated with a target, e.g. pyramid with a pine tree or a palm tree. Both PPT and CCT were assessed with word and picture versions. CCT forms part of a 64-item battery that also tested spoken picture naming and spoken word to picture matching on the same items. Other semantic tests comprised synonym judgement (Jefferies et al., 2009), category fluency (animals, birds, fruit, household items, tools and vehicles) and letter fluency (letters F, A and S). As is immediately apparent from Table 6.2, all patients showed significant impairments across all tests tapping semantic knowledge.

Table 6.2: Background neuropsychological assessment of SA patients

Task/test	Max	Normal cut-off$^{\alpha}$	HN	PG	SC	BB	ME	mean
Background Neuropsychology:								
VOSP dot counting	10	8	8	**5**	10	10	**3**	**7.2**
VOSP position discrimination	20	18	19	20	**17**	18	**15**	**17.8**
VOSP number location	10	7	9	9	10	8	**2**	**7.6**
VOSP cube analysis	10	6	**4**	10	9	**2**	**4**	**5.8**
Raven’s coloured matrices (percentiles)			20	50	50	50	**<5**	35.0
WCST (number of categories)	6	1^{β}	6	**0**	6	1	**0**	2.6
Brixton spatial anticipation (correct)	54	28	28	**26**	**25**	**23**	**11**	**22.6**
TEA counting without distraction	7	6	7	**0**	7	**4**	7	**5.0**
TEA counting with distraction	10	3	9	3	**1**	**0**	9	4.4
Digit span forwards	-	5	6	6	6	5	6	5.8
Digit span backwards	-	2	2	2	2	**0**	3	**1.8**
Semantic Tests:								
PALPA word repetition	80	80	**69**	**73**	**78**	**77**	80	**75.4**
Picture PPT	52	48.4	**35**	**42**	50	**41**	**29**	**39.4**
Word PPT	52	48.9	**44**	**43**	51	**35**	**39**	**42.4**
Synonym judgement	96	90.1	**70**	**69**	**71**	**63**	**81**	**70.8**
Letter fluency	-	21.8	**19**	**2**	24	**0**	**14**	**9.56**
Category fluency	-	62.7	63	**4**	**17**	**13**	**25**	**24.4**
64 Item Picture Naming	64	59.1	**50**	**46**	**28**	**10**	**5**	**27.8**
64 Item Spoken Word-picture Matching	64	62.7	**50**	**58**	**59**	**54**	**50**	**54.4**
64 Item Picture CCT	64	52.7	54	**44**	**46**	**38**	**13**	**39.0**
64 Item Word CCT	64	56.6	**54**	**40**	**56**	**30**	**34**	**42.8**

Patients are arranged in order of naming scores in the 64 item battery.
$^{\alpha}$ For semantic tests, this represents the control mean – 2SD.
$^{\beta}$ Cut-off for 50-74 year olds (regardless of educational level).
All impaired scores are shown in bold.
NT = Not taken.

Stimuli

One hundred and fifty black and white line drawings of common natural and man-made objects from Soni et al.'s (Soni et al., submitted) repetition priming experiment were used (Snodgrass & Vanderwart, 1980; Szekely et al., 2003). The stimuli were then divided into three lists (one for each priming condition) matched on name agreement (mean = 0.98; SD = 0.03, from the International Picture Naming Project (IPNP): Szekely et al., 2003), reaction time (mean = 881 ms; SD = 138 ms, from IPNP: Szekely et al., 2003), number of syllables (mean = 1.54; SD = 0.73, from IPNP: Szekely et al., 2003), number of phonemes (mean = 3.98; SD = 1.42, from IPNP: Szekely et al., 2003), frequency (mean = 3.20; SD = 1.39, from CELEX lexical database: Baayen et al., 1995), AoA (overall mean = 2.07; SD = 0.94, from the MacArthur Communicative Development Inventory (CDI): Fenson et al., 1994) and visual complexity (mean = 16607 kilobytes (KB); SD = 7992 KB, from IPNP: Szekely et al., 2003). Words were selected so that each test item had a semantically related co-ordinate (e.g., *bull* for COW) and an unrelated prime (e.g., *peach* for COW) as well as a repeated prime (e.g., *cow* for COW): only co-ordinates of the target were selected as semantic primes due to their stronger and less ambiguous effects in previous work (Soni et al., 2009; Soni et al., in press). The items which were used in Chapter 3 to provide semantic cues for target stimuli in the current experiment were used as semantic primes here; as this stimulus set was larger, additional semantic primes were selected according to what were considered to be highly salient co-ordinates of the targets. Unrelated primes were selected after stimulus order had been set in order to avoid any semantic relationship with either the target or adjacent filler pictures or trials. Due to the large number of items in the test, it was not possible to match primes in the same way that targets were matched, so semantic and unrelated prime words were not matched to targets or each other. See Appendix A for target items, filler pictures and semantic and unrelated prime words; norms for all target items (Lists 1 – 3) are provided in Appendices B1, B2 and B3, and matching between lists in Appendix C.

Each trial had the structure [prime word – filler picture – target picture], and hence were equivalent to "Lag 1" priming in Soni et al.'s study (Soni et al., submitted), at which there was still a significant benefit in terms of accuracy. The inclusion of one intervening trial between prime and probe was adopted as it meant that the impact of priming could be assessed independently of the simple repetition of the prime that could occur at Lag 0. One hundred and fifty filler pictures were selected from the same sources as the target items, but were mutually exclusive with the group of target pictures. The same filler picture always preceded each target, but prime words were only used once in the entire test, so that the only semantic associations were those required by the experimental manipulation.

Procedure

The experiment was presented using E-Prime (Schneider et al., 2002) on a laptop, with participants sitting around 80cm from the screen. Testing occurred over three sessions at a minimum of one week apart and was carried out in the patients' homes. For one patient who found it particularly arduous, the complete test was spread over 5 sessions, all at least a week apart. Each patient saw each target with each prime type across the whole test, and order of test versions was counterbalanced across the group. Each of the three test sessions consisted of 150 probe or target items with a filler picture and either a repeated prime (50 trials), a semantic prime (50 trials) or an unrelated prime (50 trials); the entire test thus comprised 450 trials. Trials appeared in a pseudorandom order, and the order of trials was varied at each test session, so prime type was not predictable, and as far as possible 'unplanned' semantic associations between adjacent trials were avoided.

Instructions were given that words and pictures would appear on the screen to be named. If the item was a word, the tester read it aloud. Four out of five patients (all except PG) had trouble reading, so they produced the prime words by auditory repetition rather than reading it on the screen. The requirement of the test was for correct production of the prime, regardless of input modality. A correct production was elicited before moving on to the next item, if necessary by the tester repeating the word. The majority of trials were correctly produced at first attempt, but were not in every case, which was sometimes due to poor hearing. At the onset of each picture an audio beep was played for 300ms, to serve as a marker for subsequent RT measurement. The picture appeared on screen for a maximum of 5 seconds after which the screen went white; as soon as a response was given the next picture was initiated by the tester with a button press. If no response had been given, then the patient would be prompted for an answer; if no response was made, or an error was produced, the correct name was given before the next trial was initiated. Responses were marked on a printed scoresheet, and also recorded test sessions on a Sony IC digital recorder for later use in measuring reaction times. Accuracy of targets, error rate and type were measured; RTs were also measured using Wavepad Sound Editor software (NCH, Swiftsound, : www.nch.com.au/wavepad).

RESULTS

Although repetition and semantic primes were mixed in the procedure of the experiment, the results for each will be considered separately for clarity. Dependent variables were analysed using a fully repeated measures ANOVA with within-subjects factors of priming (2 levels; related and unrelated prime), session (3 levels; sessions 1, 2 and 3), and the between-subjects factor group (2 levels; patients and controls). Further repeated measures ANOVAs are reported for each group individually and planned comparisons are provided where necessary to explore significant interactions. Although repetition effects were predicted to be facilitatory, the direction of semantic priming effects was not predicted with certainty, hence for consistency all t-tests will be reported as 2-tailed. Only reaction times for correct trials were considered. Errors were defined as semantic[16], omission[17], or other[18].

REPETITION PRIMING

Reaction Times

For the ANOVA on RTs there was a significant 2-way interaction between session and group ($F(2,16) = 5.371$; $p = .016$) due to greater improvement across session by patients than controls; neither the priming by group interaction ($F(1,8) = .096$) nor the session by priming by group interaction ($F(2,16) = 1.718$) were significant. See Figure 6.1 for performance of each group with primed and unprimed items. The patients' ANOVA showed a significant effect of session on RT ($F(2,8) = 5.920$; $p = .026$), but no effect of priming ($F(1,4) = .302$); the interaction between priming and session was not significant either ($F(2,8) = 1.738$). As can be seen in Figure 6.1, the trend is towards improvement (faster RTs) at each session, somewhat more for primed than unprimed targets. In the ANOVA for controls, there was a marginally significant beneficial effect of priming on RTs ($F(1,4) = 6.410$; $p = .065$), and also of session ($F(2,8) = 3.702$; $p = .073$), but the priming by session interaction was not significant ($F(2,8) = 1.615$).

---

[16] E.g., co-ordinate, "kite" for BALLOON; associate, "cup" for SPOON; superordinate, "animal" for TIGER; or correct circumlocutions, "you light them" for CANDLE.

[17] No complete word answer, or "don't know".

[18] E.g., incorrect circumlocutions, "you cook on them" for SINK; picture parts, "shirt" for MAN; phonological, "sky" for SKIS; visual "pen" for LIPSTICK; or unrelated/perseverative, "stairs" for PLATE.

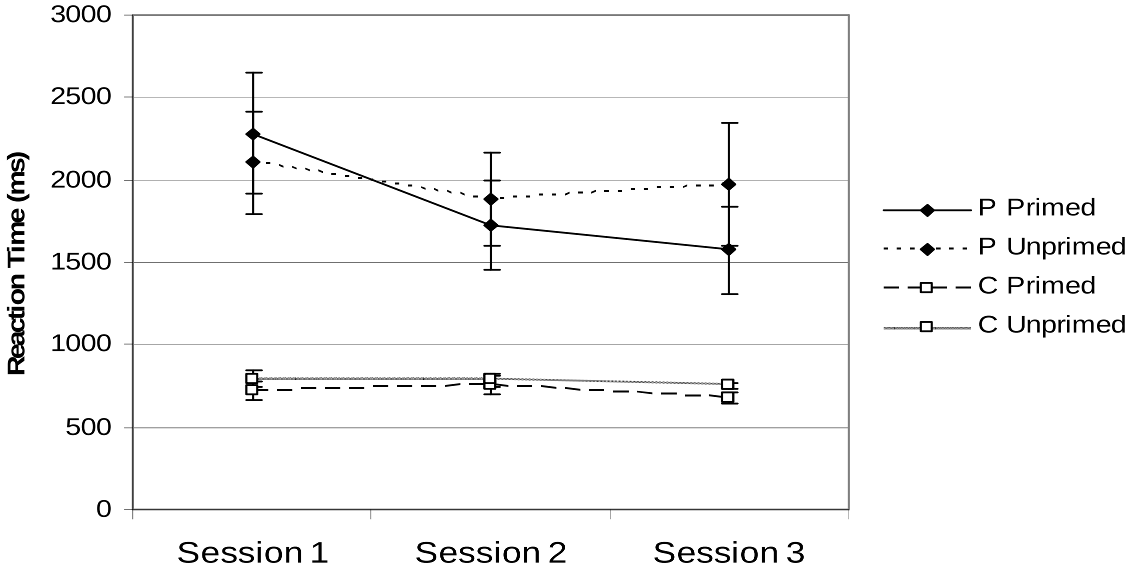


Figure 6.1: Reaction times (repetition priming) for patients (P) and controls (C) according to priming and session (error bars represent standard error of the mean)

Accuracy

In the overall ANOVA for accuracy there was a significant 2-way interaction between priming and group ($F(1,8) = 13.164$; $p = .007$) due to a much larger priming effect on patients than controls; neither the session by group interaction ($F(2,16) = .054$) nor the session by priming by group interaction ($F(2,16) = .033$) were significant. See Figure 6.2 for performance of each group with primed and unprimed items. In the group ANOVA for patients there was a significant effect on accuracy from priming ($F(1,4) = 15.097$; $p = .018$); both the main effect of session ($F(2,8) < 1$) and the priming by session interaction were not significant ($F(2,8) < 1$). In the controls ANOVA neither of the main effects of priming ($F(1,4) = 2.032$) and session ($F(2,8) = 2.053$) were significant, nor the interaction ($F(2,8) = 1.615$).

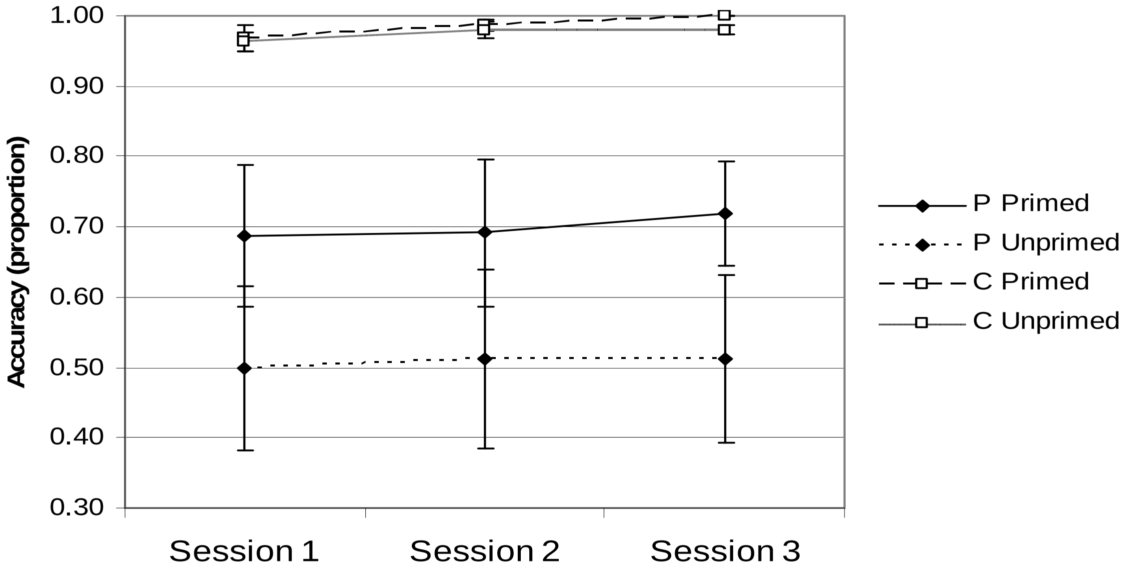


Figure 6.2: Accuracy (repetition priming) for patients (P) and controls (C) according to priming and session (error bars represent standard error of the mean)

Semantic Errors

In the overall ANOVA for semantic errors there was a significant 2-way interaction between priming and group (*F*(1,8) = 9.361; *p* = .016) due to priming having a greater benefit for patients than controls. The 3-way interaction between priming, session and group was marginally significant (*F*(2,16) = 3.474; *p* = .056), indicating a different effect of priming for each group at each session; the 2-way interaction between session and group was not significant (*F*(2,16) = 2.287). See Figure 6.3 for semantic error rates of both groups. The patients' ANOVA revealed a significant effect of priming (*F*(1,4) = 11.415; *p* = .028) but not session (*F*(2,8) = 1.480); the priming by session interaction was also significant (*F*(2,8) = 6.435; *p* = .022), showing that priming had a different effect for the group at each session. T-tests revealed that patients showed a significantly lower semantic error rates for primed targets in session 3 (*t*(4) = 4.763; *p* = .009), and in sessions 1 (*t*(4) = 2.092; *p* = .105) and 2 (*t*(4) = 1.687; *p* = .167) the difference approached significance. As can be seen in Figure 6.3, the priming by session interaction is accounted for an increase across session for the unprimed targets. The controls' ANOVA showed no effects of priming (*F*(1,4) = .769; *p* = .430) or session (*F*(2,8) = 1.348; *p* = .313), and no interaction (*F*(2,8) = 1.437; *p* = .293).

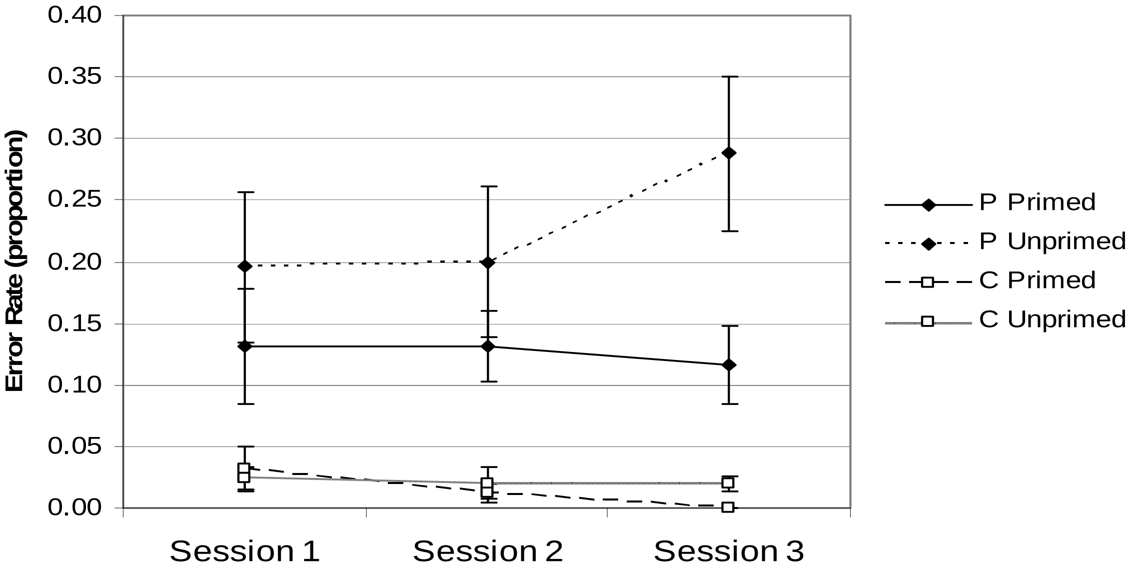


Figure 6.3: Semantic error rates (repetition priming) for patients (P) and controls (C) according to priming and session (error bars represent standard error of the mean)

Omissions

The overall ANOVA for omissions, presented in Figure 6.4, revealed significant 2-way interactions between priming and group (*F*(1,8) = 5.476; *p* = .047), reflecting larger priming effects for the patients, and session and group (*F*(2,16) = 4.216; *p* = .034), reflecting a session effect that was confined to patients. The 3-way interaction between session, priming and group was not significant (*F*(2,16) = 1.014). The patients' ANOVA showed a marginally significant effect of priming (*F*(1,4) = 5.799; *p* = .074) and of session (*F*(2,8) = 4.377; *p* = .052), but no interaction (*F*(2,8) = 1.425; *p* = .296). Due to the lack of interaction, overall omission rates (collapsed across priming) were compared from session to session: planned comparisons showed that there was a marginally significant drop in omissions between sessions 2 and 3 was (*t*(4) = 2.664; *p* = .056) and the difference between sessions 1 and 3 approached significance (*t*(4) = 1.737; *p* = .157): there was no significant change between sessions 1 and 2 (t(4) = 1.260). Controls produced almost no omissions; their ANOVA showed no significant effects of priming (*F*(1,4) = 2.667) or session (*F*(2,8) = 2.667), and no interaction (*F*(2,8) = 2.667).

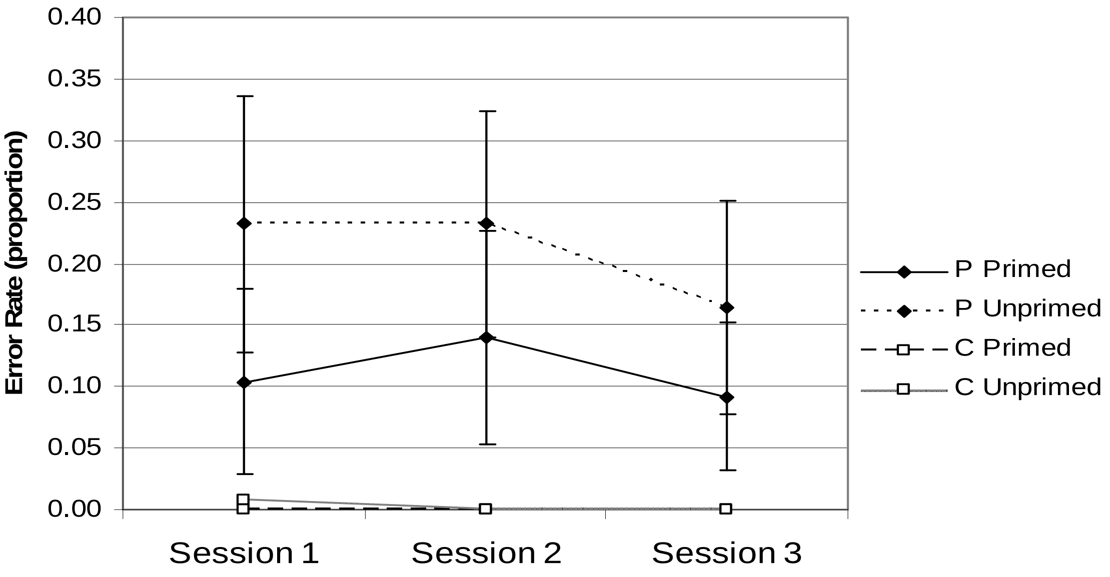


Figure 6.4: Omission rates (repetition priming) for patients (P) and controls (C) according to priming and session (error bars represent standard error of the mean)

In summary, patients showed minimal evidence of priming in reaction times, although they did become faster across testing sessions. Accuracy showed clear priming effects for patients that were not apparent in controls. Semantic error rates revealed a significant priming effect for the patients only in the third session, and interestingly this was as a result of an increase in semantic errors to the unprimed items. Omissions showed a priming effect in the patients and were also reduced in the final session. Taken together, these results indicate a beneficial effect of Lag 1 priming word-picture repetition priming in SA patients, particularly in accuracy, replicating and extending the results of Soni et al. (Soni et al., submitted).

SEMANTIC PRIMING

Reaction Times

For the ANOVA on RTs there were no significant 2-way interactions either in priming by group (*F*(1,8) = .191) or session by group (*F*(2,16) = 1.671); the 3-way interaction between priming, session and group also failed to reach significance (*F*(2,16) = .259). See Figure 6.5 for performance of each group in each condition. The patient ANOVA showed no significant effects of priming (*F*(1,4) = .391) or session (*F*(2,8) = 1.462) on

RT, and no interaction (*F*(2,8) = .165). The controls' ANOVA showed a significant effect of session (*F*(2,8) = 4.806; *p* = .043), but no effect of priming (*F*(1,4) = 3.429) and no interaction (*F*(2,8) < 1).

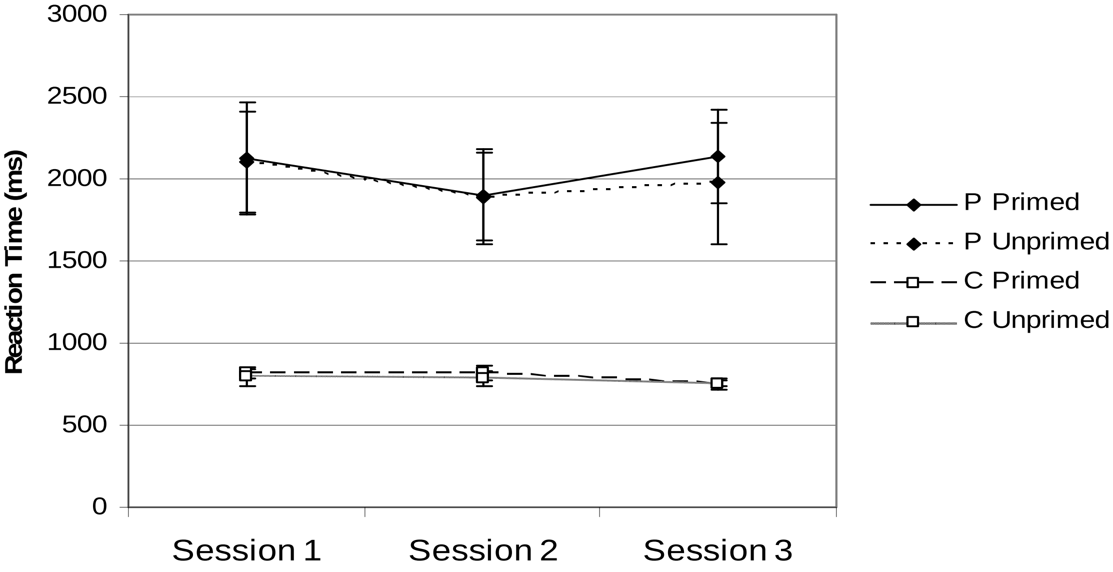


Figure 6.5: Reaction times (semantic priming) for patients (P) and controls (C) according to priming and session (error bars represent standard error of the mean)

Accuracy

In the overall ANOVA for accuracy there were no significant 2-way interactions, either between priming and group (*F*(1,8) < 1) or between session and group (*F*(2,16) = 1.671); the 3-way interaction priming by session by group also failed to reach significance (*F*(2,16) < 1). See Figure 6.5 for performance of each group with primed and unprimed items. The patients' ANOVA showed no effects of priming (*F*(1,4) < 1) or session (*F*(2,8) = 2.696), and no interaction (*F*(2,8) = 1.755); however, t-tests revealed that patients showed a significant positive effect of priming in session 3 (*t*(4) = 4.082; *p* = .015), but not in sessions 1 (*t*(4) < 1) or 2 (*t*(4) < 1). As can be seen in Figure 6.6, patients became more accurate with semantic primes as sessions went on, accuracy remaining flat with unrelated primes. Controls showed no effects in their individual ANOVA of priming (*F*(1,4) = 1.532) or session (*F*(2,8) = .809), and no interaction (*F*(2,8) < 1).

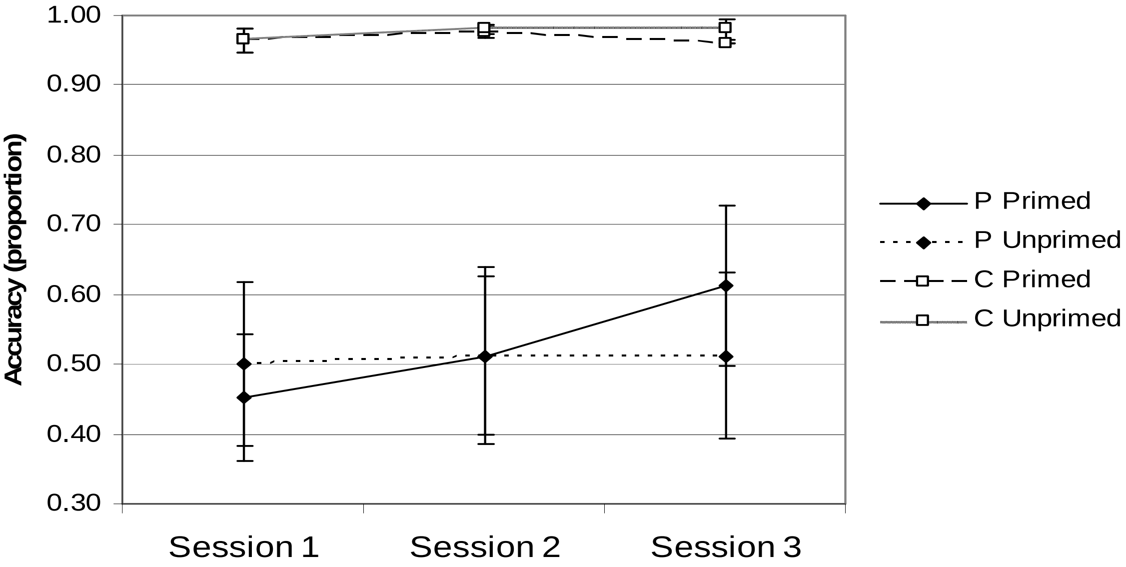


Figure 6.6: Accuracy (semantic priming) for patients (P) and controls (C) according to priming and session (error bars represent standard error of the mean)

Semantic Errors

In the overall group comparison for the DV semantic errors, both 2-way interactions proved non-significant; priming by group (*F*(1,8) < 1), session by group (*F*(2,16) = .174). The 3-way priming by session by group interaction was significant (*F*(2,16) = 8.000; *p* = .004), showing that priming has a different effect on each group at each session; see Figure 6.7 for performances of both groups. The patients' ANOVA shows no effect of priming (*F*(1,4) = 1.133) or session (*F*(2,8) = 1.139) on semantic error levels, but the priming by session interaction was significant (*F*(2,8) = 5.241; *p* = .035). Planned comparisons show that patients show no significant priming effects at session 1 (*t*(4) < 1), 2 (*t*(4) < 1), but in session 3 the effect of priming comes closer to significance (*t*(4) = 1.649; *p* = .174): the priming by session interaction reflects the increase in the beneficial impact of related primes in the final session. In the controls' ANOVA there were no effects of priming (*F*(1,4) = 1.882) or session (*F*(2,8) = 1.574), and no interaction (*F*(2,8) < 1).

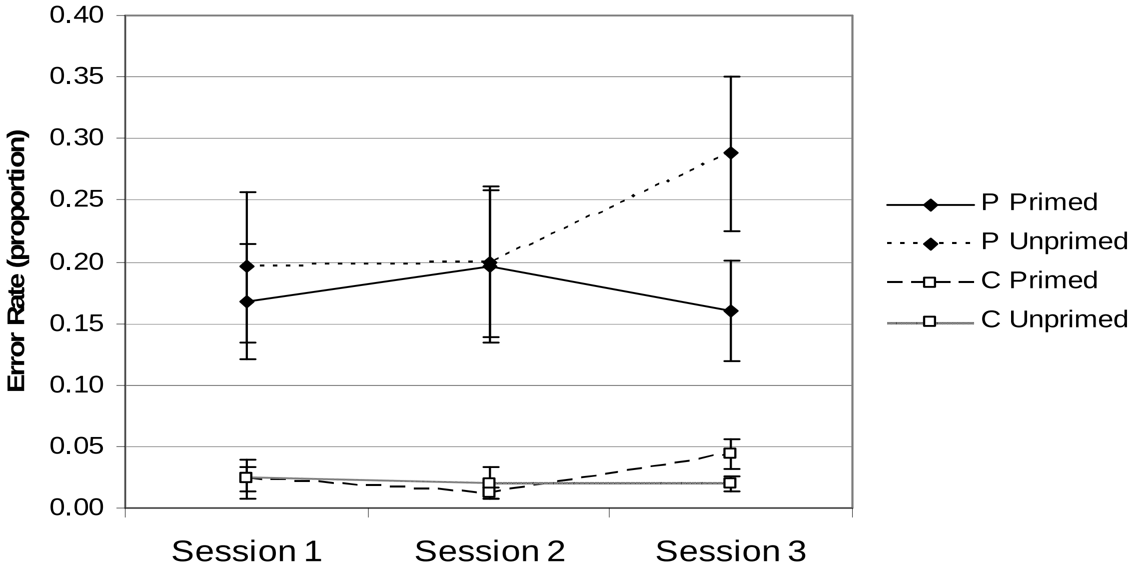


Figure 6.7: Semantic error rates (semantic priming) for patients (P) and controls (C) according to priming and session (error bars represent standard error of the mean)

Omissions

In the overall comparison there was a significant 2-way interaction between session and group (*F*(2,16) = 4.251; *p* = .033); controls produced almost no omissions whereas patients showed different omission levels at each session. There was no interaction between priming and group (*F*(1,8) = .196); the 3-way priming by session by group interaction also failed to reach significance (*F*(2,16) = 1.163). See Figure 6.8 for omission rates in each group. The patients' ANOVA showed no effect of priming (*F*(1,4) = .283) on omission rates, but there was a significant effect of session (*F*(2,8) = 4.660; *p* = .046). The interaction between priming and session was not significant (*F*(2,8) = .922). As can be seen in Figure 6.8, the patients showed a progressive decrease in omission errors across sessions. Controls produced almost no omissions to semantic primes, so neither the main effects of priming (*F*(1,4) = 2.667) and session (*F*(2,8) = 2.667) nor the interaction (*F*(2,8) = 2.667) were significant.

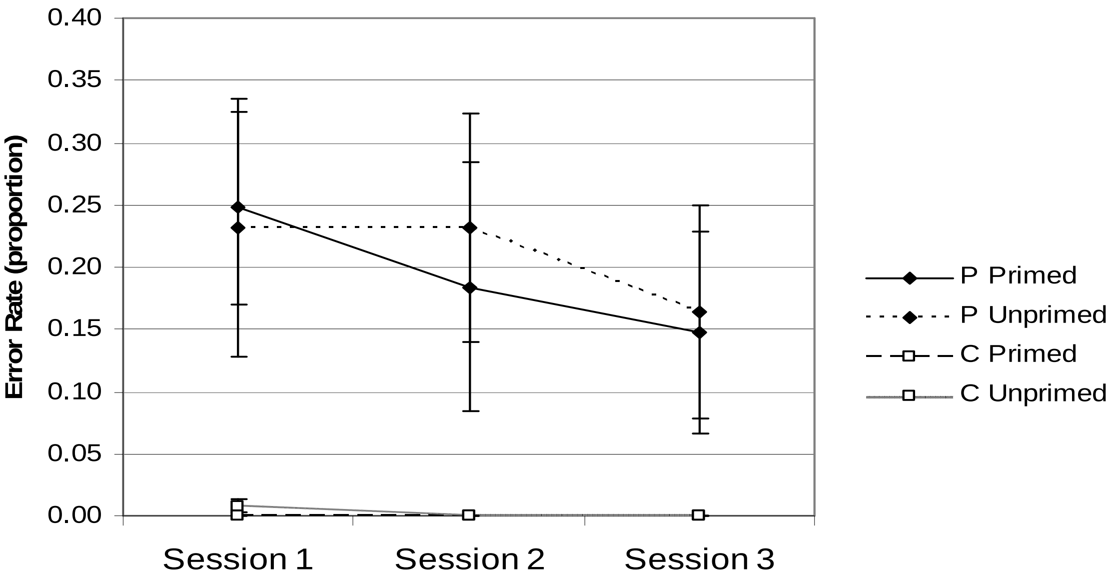


Figure 6.8: Omission rates (semantic priming) for patients (P) and controls (C) according to priming and session (error bars represent standard error of the mean)

In summary, reaction times and semantic error rates showed no benefit from semantic primes, and no session effect. However, patient accuracy improved across sessions for primed items, changing from a detrimental effect of semantic priming in session 1 to a significant benefit by session 3. Omission error rates were again significantly reduced across sessions, but failed to show a reliable priming effect.

DISCUSSION

The current repetition priming experiment demonstrated a beneficial effect of identity priming in accuracy and semantic errors, confirming effects seen with picture-picture repetition priming in Soni et al. (submitted). The extension of the effect to include word primes reveals that it is not merely improved visual recognition of the target that causes improvement. Although performance enhancement could be caused by the prime boosting phonological activation, our repetition priming data could also be explained by strengthened mapping between semantics and phonology or enhanced semantic selection.

There are several differences between the data from repetition and semantic priming here that bear further exploration. In contrast to the session effect on latency from repetition, there was no session effect on RTs from semantic primes. We argue that the repetition of all targets in each session gradually improves access to the referent (long term priming). This means that the repetition primes become more effective across sessions – the primes refer to exactly the same referent as the target, so access via word primes improves with every presentation of prime and target. No such latency benefit accrues to the semantic primes because they correspond to a different referent from the target.

A second query is raised by the difference between the benefits to accuracy across all sessions from identity primes, in contrast to an effect only in session 3 from semantic primes. It could be that the semantic access of the patients was too approximate to show benefit from the semantic primes in the early sessions. By the final session, patients would have had two previous target presentations with opportunity for name production and feedback. It is also possible that both semantic primes and failed naming attempts help to sharpen the semantic representations of targets as the sessions go on, allowing the presentation of a co-ordinate to actually benefit naming by session 3. In Laine and Martin's (1996) contextual priming experiment, anomic aphasic patient IL also showed improvement in accuracy with increasing sessions in semantically related arrays but not in phonological or unrelated arrays. The authors ascribed this effect to strengthened lexical retrieval due to repeated naming attempts, with spreading activation from related items serving to boost production of targets.

A third issue is the significant effect of repetition priming on omissions in contrast to a lack of effect from semantic primes. We argue that if a patient's naming attempt is sufficiently far from the target to produce an omission error, then the partial relation offered by a semantic prime may not be that dissimilar to an unrelated prime, hence the lack of priming effects. An identical prime, however, might boost the activation of both target and related concepts such that a response of some kind is produced. The significant effect of session on omissions in semantic priming trials showed a reduction in omissions that reflected increasing accuracy as sessions go on.

These linked trends showing the facilitatory effect of semantic priming over several sessions in this experiment run contrary to previously detailed interference effects from semantic primes (Alario et al., 2000; Levelt et al., 1999; Roelofs, 1992). However, we argue that this facilitation could reflect a refined focus on the correct target produced by longer-term repetition priming or learning, made possible through repeated sessions.

Our experiment design meant that each target picture was presented at each session, though with a different prime: this meant that in session 3, patients encountered target pictures for the third time, having had two opportunities for either correct naming or feedback on an error. Although the sessions were carried out a minimum of a week apart and significant repetition priming effects have elsewhere been shown to decay quite quickly in semantically impaired patients (Cumming et al., 2006; Howard et al., 2006), it seems reasonable that repeated presentation may have a beneficial effect over the longer term. After all, this is the premise upon which much anomia therapy is based (Conroy, Sage, & Lambon Ralph, 2009; Howard et al., 1985; Martin et al., 2004; Martin & Laine, 2000; Nickels, 2002a; Wisenburn & Mahoney, 2009). This hypothesis is supported by the increasing accuracy across session in both repetition and semantic priming conditions, and by the shorter latencies in both patients and controls in later repetition priming sessions.

Although the effects of semantic priming were not as strong or consistent as those from identity priming, we would expect this to be the case. The overlap between semantic primes and targets is partial, and in meaning only, whereas identity primes overlap perfectly with targets in both meaning and phonology. However, we did observe a significant benefit to accuracy from semantic primes in session 3, continuing an upward trend begun in session 1. This contrasts with accuracy levels on unprimed trials that remain stable across sessions. It appears that it is not just the fact of seeing the target three times that is effective for our control-impaired patient group, but seeing the target three times in the presence of a semantically informative prompt, either an identity prime or a semantic co-ordinate. We hypothesise that the semantic input of the primes constrained selection possibilities, so that the patients' impaired semantic control was better able to home in on the correct target in later sessions.

Theoretical implications of word priming in picture naming

In these experiments, we have seen that repetition priming using word primes had a powerful beneficial effect on latency, accuracy and error rates in subsequent picture naming. In addition, although weaker in effect, semantic word primes caused a significant benefit to accuracy in session 3. We argue that models of speech production that incorporate cascading of information and interaction between semantic and phonological processing can parsimoniously account for these effects (e.g., Dell et al., 1997). On a repetition priming trial, the production of the name activates a phonological form: activation then feeds back to the semantic representation, facilitating its production on the target naming trial. This explanation could encompass direct priming of phonological units, mapping between semantics and phonology, and the possibility of a boost to semantic activation that assists target selection.

The inclusion of the semantic priming experiment alongside the repetition priming helps to narrow down the possibilities for the locus of priming effects. We observed that semantic word primes were effective in enhancing accuracy in a picture naming task in session 3. This cannot be accounted for by priming the mapping between semantic and phonological output, or boosting the spoken production of the target word: naming CHISEL two trials before naming SCREWDRIVER does not activate the phoneme string /skru:draɪvʌ/, nor does it prime any connection between the semantic representation of SCREWDRIVER and its associated form. The most parsimonious explanation for semantic priming effects is that phonological activation from producing the prime CHISEL feeds back to the semantic features shared by both representations, which then boost the activation of the semantic representation of the target SCREWDRIVER, allowing it to reach the threshold for production more efficiently than an unrelated prime.

The current experiment also informs the debate on the level of semantic input in auditory repetition. Our paradigm relies on auditory repetition to produce priming effects, but some studies argue that this task has no semantic input (Hanley & Kay, 1997; Hanley, Kay, & Edwards, 2002). This contrasts with other studies which argue that imageability (high > low imageability words) and concreteness (concrete > abstract words) effects on repetition reflect a semantic contribution to repetition (Valdois et al., 1995). Lexicality effects (words > nonwords) have also been observed during auditory repetition (Franklin, Buerk, & Howard, 2002; Franklin, Howard, & Patterson, 1994). If words are repeated better than nonwords, there is some extra factor over and above phonological activation which enables efficient production of that item. What words have that nonwords do not is meaning, suggesting that there is a semantic component to auditory repetition. In our data we observed significant priming effects from both repetition and semantic priming, which we argue confirms that the semantic system is activated by repeating auditorily presented words.

CONCLUSIONS

Our demonstration of repetition priming effects with word primes confirmed that the repetition priming seen in picture-picture priming (Soni et al., submitted) was not due to merely priming referent identification. The effect of semantic priming on accuracy also ruled out that priming effects were due to prior production of the target’s phonological form. These data have implications for therapy in SA. Clearly repetition facilitates naming in this patient group, but it also appears that priming with co-ordinates can be effective on items that have become familiar.

CHAPTER 7

DISCUSSION CHAPTER

For most humans, the act of producing speech is very little thought of in daily life. We open our mouths, and most of the time our thoughts come out in the way we would wish. Under conditions of fatigue, the process – and its potential for error – becomes more visible, but for people with aphasia, producing correct, task appropriate speech or sometimes any verbal output is a constant challenge. Whether we notice it or not, speech production is a highly complex operation, normally carried out so swiftly (two to three words per second) that it appears to match the speed of our thinking.

In order to discover more of how speech production happens in both healthy participants and semantically impaired aphasic patients, it was necessary to focus the investigation in this thesis on a small part of the process using tightly controlled methodology. The five data chapters used variations on the single item picture naming task to examine how semantic knowledge and controlled manipulation of that information contribute to speech production. Although the behaviour studied was spoken output, this was used to reveal the nature of the process from semantic access through to phonological activation, with motor activation and actual shaping of speech sounds falling beyond the scope of study. This Discussion chapter will revisit each of the three Research Themes raised in the Introduction, citing relevant examples from the data chapters and wider literature, drawing conclusions and exploring related issues that were raised by the body of work. Finally, a section on potential future research will be followed by a short overall conclusion.

1. Interactivity between semantics and phonology during speech production, and what can occur when naming fails.

Initially this section will examine how data from the five experimental chapters addressed the issue of interactivity between semantics and phonology in speech production, testing our empirical findings against the framework of some of the major models in the literature. The subsequent section will examine the nature of semantic representations, the basic ‘raw material’ of the process, on which new insights were gained during the course of the experiments. The concluding section of Research Theme 1 briefly visits the debate between localised and distributed semantic representations.

Evidence in our data for interactivity between semantic and phonological processing

Research Theme 1 raised the debate about the nature of processing within various models of speech production presented in the literature. Much evidence has been presented on either side of the discrete/interactive debate (e.g., Dell & O'Seaghdha, 1992; Dell et al., 1997; Foygel & Dell, 2000; Levelt et al., 1999; Roelofs, 1997). However, our data offer many instances which militate against a strictly discrete, feedforward model in which semantic processing is completed before phonological processing begins, particularly in the two cueing/miscueing papers, Chapter 2 (Soni et al., 2009) and Chapter 3 (Soni et al., in press).

Observed effects such as the significantly raised accuracy and lowered semantic error rates produced by correct cues relative to neutral in both normals and patients (Soni et al., 2009; Soni et al., in press) can be accounted for by models which include either cascading of activation from semantics to phonology or feedback of information from phonological to semantic processing. In a model which allows cascading of activation, the picture of TIGER would stimulate the representations of large cats, including the target: several of these representations (e.g., LION, TIGER, CHEETAH, LEOPARD) might then be passed down to phonological processing. At this point the raised activation of the simultaneously presented correct cue phoneme /t/ would boost the activation of TIGER, allowing it to reach the threshold for production ahead of its competitors. If activation were also able to feed back between processing layers, the presentation of a correct phoneme (e.g., /t/) simultaneously with a target picture (e.g., TIGER) would allow a boost of activation to feed back to the semantic representation, again facilitating its production relative to a picture with an incongruous cue. However, this positive cueing effect can also be accommodated in a solely feedforward model such as WEAVER++, presented in Levelt et al. (1999). The picture would stimulate semantic processing, which might finalise on the correct representation (TIGER), passing it down alone to phonological processing. The simultaneous presentation of /t/ will have boosted the activation of this phoneme within the phonological level: this could then allow the correct target very efficient transit through phonological processing, leading to facilitated performance compared to trials where an incongruous phoneme was presented.

In contrast, miscueing effects observed in our data such as the significant detriments to RT in healthy participants, and reduced accuracy and raised semantic errors in both groups (Soni et al., 2009; Soni et al., in press) can only be explained by models which allow cascading and/or feedback of information. If we again take the example of TIGER, in a co-ordinate miscueing trial this picture would be presented with the phoneme /l/ for LION. If cascading is in operation, several activated 'big cat' representations would be passed down from semantics: on reaching phonological processing, if /l/ is available to boost the activation of LION, it may be able to reach production threshold faster than the correct target which has no such boost from a relevant phoneme. In a feedback model, the phonological activation produced by the phoneme /l/ could feed back up to semantic processing and boost the representation of LION, again allowing it to reach the threshold ahead of the target which is not augmented in this way.

Significant miscueing effects cannot be accounted for in a purely feedforward model. If semantic processing settles on a single response which is then passed down to phonology for formal assembly, there is no opportunity for a misleading but semantically relevant phoneme to influence the selection process. Any incorrect phoneme should have a similar (lack of) effect, but this was not what we observed in our data. In Chapter 4 (Soni et al., in press), the data distinguished between random incorrect phoneme cues and semantically relevant phonology, and still produced significant miscueing effects on latency, accuracy and semantic error rates. Further, different types of semantically related miscue had measurably separable effects: co-ordinate cues (e.g., /sh/ for SHOWER with BATH) produced lower accuracy rates than neutral phonemes in patients and normal participants, and both co-ordinate and associate cues (e.g., /w / for WATER with BATH) were effective at lengthening RTs relative to neutral in the tempo paradigm.

The production of exact cued errors (Soni et al., in press) is a more precise instance of the argument for cascaded or interactive models. The co-ordinates occurred in significantly greater numbers than their baseline levels in the neutral phoneme condition in both the patients and the tempo normal participants, while the associate cued errors were numerically greater for both groups and significantly so for tempo normals. These specific errors must be caused by either cascading or feedback of information: the miscue phoneme raises activation of the cued error over and above any other competitor or the target. If activation proceeds forward from semantics to phonology and only a single item passes to the next stage, there is no locus where specific errors could be provoked by a particular phoneme. There should be no differential effects between miscues, as all incorrect phonology should be irrelevant once a selection has been made at the semantic level.

A short note must also be included on omissions in the neutral phoneme condition, seen in the associative cueing paper (Chapter 4, Soni et al., in press). Patients showed a significant positive cueing effect between neutral phonemes and correct cues on omission rates, even producing numerically (though not significantly) more omissions to neutral phonemes than to co-ordinate cues. This suggests that uninformative phonology leads to ‘empty’ semantic space, namely a failure to respond. Along with the effects of semantically meaningful miscues, these data support the argument that phonology has an influence on selection at the semantic level, even though the result is an omission.

Although this Discussion has focussed on two-stage interactive models (Dell & O'Seaghdha, 1992; Dell et al., 1997; Foygel & Dell, 2000), our data can equally well be accommodated in parallel distributed processing or PDP models where interaction between semantics and phonology is an intrinsic part of processing (Lambon Ralph et al., 2002; Lambon Ralph et al., 2000; McClelland & Rumelhart, 1985; Plaut & Kello, 1999; Plaut et al., 1996). In such models, semantics and phonology interact throughout the process of response selection, collectively settling on a distributed pattern of activation corresponding to a particular item. Although parallel processing is postulated, a slightly earlier window for semantic processing accommodates observed empirical effects in the time course of lexical access (Dell & O'Seaghdha, 1992; Garrett, 1975, 1980; Levelt, 1992; Levelt et al., 1999; Nickels, 2002b; Peterson & Savoy, 1998; Rapp & Goldrick, 2000; Roelofs, 1997). In a PDP model, the activation caused by presentation of a cue phoneme (e.g., /l/ or /t/ with TIGER) would be able to link up to the level of component semantic features, and influence the pattern of activation relating to appropriate ‘big cat’ representations. The activation of representations associated with the activated phoneme (either the target or a competitor) would be enhanced relative to other semantically but not phonologically related items. This would lead to a semantically appropriate item with a boost from phonology reaching the production threshold ahead of competitors, facilitating faster, more accurate production. In some instances this would lead to a specific cued error (e.g., LION) instead of the target.

The investigation of priming with both identity and co-ordinate primes also helped reveal part of the process of speech production. In Chapter 5 (Soni et al., submitted) we saw that prior presentation of an identical stimulus significantly benefitted target naming in terms of latency, accuracy and errors, though the effect was diminished by the presence of more intervening items. In Chapter 6 the repetition priming effect was also observed when word primes were used, excluding enhanced visual identification as an account for the priming effect. Semantic priming in Chapter 6 also showed that prior presentation of a semantic co-ordinate, despite initially somewhat hindering target naming, facilitated accuracy once items had become familiar (in session 3), suggesting a possible therapeutic use of semantic priming with SA patients in combination with repetition. The activation of the co-ordinate during a priming trial appeared to spread to related concepts including the target, and in session 3 this priming effect became apparent during the subsequent target naming trial when performance was enhanced relative to unrelated primes. Although the repetition priming effects seen in Chapters 5 and 6 allowed the interpretation that priming had an effect at the semantic level, semantic priming was important in helping to specify the locus of the priming effect during speech production. Input and output phonology of the target were not primed by production of a co-ordinate, leaving only the semantic level for an influence to occur. This aligns with evidence from the cueing/miscuing experiments by suggesting that certain experimental manipulations can be used to influence the process of speech production at the level of semantic selection.

The nature of semantic representations

As well as the new evidence on the stage by stage process of speech production, consideration of our experiments in the frame of Research Theme 1 also offered new insight on the nature of semantic representations. One of the main findings in Chapter 4 (Soni et al., in press) was that both associative and categorical relationships form part of the semantic representations of concrete objects in both healthy and semantically impaired participants. This contradicts the argument that associative relationships underpin only abstract words, while concrete objects are represented solely by categorical information (Crutch et al., 2009; Crutch et al., 2006; Crutch & Warrington, 2005), and shows that different elements of representations can be accessed independently. However, the stronger effects of co-ordinate relative to associative miscues on latency (healthy participants only), accuracy, and semantic errors (both groups) suggest that categorical information has more weight or leverage than associative knowledge in the semantic representations of concrete objects. The semantic priming experiment presented in Chapter 6 also supported the argument that co-ordinate information is an integral part of the semantic representations of concrete objects by showing a positive effect of co-ordinate primes on target accuracy once targets had become familiar (in session 3).

The presence of associative semantic errors in SA naming (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Soni et al., in press) corroborates the finding that associate relationships also form part of the representations of concrete objects (Soni et al., in press). If a patient answers “nuts” when presented with SQUIRREL, not only have they accessed the correct semantic representation, but it follows that associative information is clearly part of the representation of SQUIRREL. These errors are rare in normal participants, though they can be induced by techniques such as tempo naming, either occurring through the pressured nature of the naming task (Hodgson & Lambon Ralph, 2008), or by deliberate cueing in conjunction with tempo naming (Soni et al., in press). The success of single phoneme cues in inducing specific associate errors above their baseline incidence in the neutral phoneme condition is further evidence of an associative element in the semantic representations of concrete objects in both semantically impaired and healthy participants.

Chapter 2 on action and object naming also provided insight into the nature of semantic representations. The ‘grammatical class’ effects that were observed were somewhat malleable, for example objects were named more accurately by patients when imageability was confounded (objects had higher mean imageability than actions), but this effect was abolished when imageability was controlled. The tempo naming element of this study produced an interesting similarity to SA naming in that healthy participants showed an object advantage in accuracy only at a speeded tempo, when executive resources were stretched, but not at the baseline speed. These data suggest that grammatical class has less bearing on naming performance than semantic variables such as imageability. Imageability is a factor which affects the richness of semantic representations: objects are typically more imageable than actions, leading to frequent reports of grammatical class effects where imageability is not controlled (Caramazza & Hillis, 1991; Hillis & Caramazza, 1995; Hillis et al., 2004; Miceli et al., 1988). The data presented in Chapter 2 supports other studies which show that often grammatical class effects can be better framed as imageability effects (Bird, Howard et al., 2000; Bird et al., 2003).

Higher imageability appears to make an item more readily available in the speech production process than one of lower imageability, all other factors being equal. As was observed in Chapter 2, this led to faster latencies for objects in tempo naming, and more accurate object responses with fewer semantic errors for healthy participants and SA patients. Due to the primacy of imageability rather than grammatical class effects, our data support the view that actions and objects are not processed separately by modular systems, but rather that they are subject to a unitary speech production system in which variable levels of semantic properties affect the speed and efficiency of processing, regardless of stimulus class. This lends support to theories such as the extended sensory-functional model presented in Bird, Howard and Franklin (2000), which argues that action representations are more reliant on functional features, while object representations are underpinned primarily by sensory features, although the input for each group contains some of each feature type, with different ‘grammatical classes’ merely representing clusters of similar items on a continuum. The imageability effects in our data support this view; differences in the make up of action and object semantic representations are based on differing proportions of similar underlying features rather than grammatical markers per se.

Are representations localised or distributed?

To conclude the exploration of speech production models and the nature of semantic representations, we briefly look at one of the chief debates in this field of the literature: do semantic representations exist in localised or distributed form? Many two-stage models, both feedforward and interactive, share the view that there is a stage in semantic processing where background semantic concepts, stemming either from ‘nondecompositional’ single units (Levelt et al., 1999; Roelofs, 1993) or a combination of semantic features (Dell et al., 1997; Foygel & Dell, 2000), form a localised unit termed a lemma or lexical node. In models encompassing localised representations, a network of related lexical items or semantic features could include both categorically and associatively related items. Spreading activation between related concepts in combination with cascading or feedback of information could then account for cueing effects with co-ordinate and associate miscues (Chapters 3 and 4), or the benefit to accuracy from semantic primes (session 3, Chapter 6).

The alternative in PDP models is that ‘items’ are made up of distributed patterns of activation across a bank of potentially active features (e.g., Harm & Seidenberg, 2004; Rogers et al., 2004; Small, Hart, Nguyen, & Cordon, 1995; Woollams et al., 2009). Categorical similarities between items are readily captured by virtue of sharing some component features, with ‘category effects’ built up from statistical regularities in the input rather than imposed structure. The data presented in this thesis cannot discount either localist or distributed representations, but we argue that PDP models can also provide a ready explanation of the role of associative knowledge in the representations of concrete objects. If a representation is distributed anyway, it requires no stretch of parameters to include both categorically and associatively related information. Both types of relationship would be present in the bank of potential features, as sometimes the same feature would be in an associative and sometimes a co-ordinate relationship, depending on the target item. Highly interactive PDP models relying on component semantic features therefore offer a parsimonious account of the effects of both co-ordinate and associate miscues. Although speculative, a distributed model for semantic representations with multiple possible combinations might also lend itself to the looser, less hierarchical nature of action naming.

2. Semantic control in speech production: its function and associated anatomical structures, and the effect of semantic control deficits in SA.

Research Theme 2 begins by revisiting the hypothesis of a frontoparietal network which could underpin semantic control, and introducing the idea of potential subtle divisions between frontal and more posterior functions within that system. It goes on to compare semantic control deficits with conditions where semantic knowledge is degraded as opposed to the manipulation of semantic material. Data from this thesis will then be presented to exemplify the effects of semantic control deficits on speech production in patients with SA. Finally a short section will demonstrate how semantic control extends beyond the verbal domain into the manipulation of everyday objects.

Semantic control in language and its anatomical bases

Despite its key role, there has been relatively little focus on semantic control within speech production in comparison to the volume of studies on models of the process from semantic to phonological activation. Once the initial activation of semantics has taken place, it is the semantic control system that selects the correct element of a detailed semantic representation, bringing it to the fore for production. Many studies have shown activation in left hemisphere prefrontal regions in controlled semantic processing tasks such as selection between competing alternatives (2006; Thompson-Schill et al., 1997) or retrieval of information where cues are weak (Badre & Wagner, 2004; Wagner et al., 2001). Semantically appropriate verb generation from associated objects was shown to be impaired when there is focal damage to the left inferior frontal gyrus or LIFG (Thompson-Schill et al., 1998), demonstrating that activation in these regions is not merely correlated with semantic control tasks, but causally related.

However, other work has implicated more posterior left hemisphere regions in addition to the prefrontal cortex in controlled semantic processing. Noppeney, Phillips and Price (2004) used a task akin to CCT (Bozeat et al., 2000), where healthy participants were shown triads of words and asked to select the most similar of two items to the probe word at the top. Using PET and fMRI methodology, they demonstrated that both temporal and frontal areas showed changes in activation associated with an alteration in the semantic relations of stimuli. They concluded that semantic executive processes may be distributed throughout the semantic system, including both frontal and more posterior regions in the left hemisphere. Other studies cite a similar network of connected regions which may coactivate according to task demands, for example left frontal and temporal regions when controlled semantic processing is required, or alternatively left frontal and parietal regions when more phonological elements are included in the task (Gold & Buckner, 2002; Gough et al., 2005). In neuropsychological studies, as will be seen in more detail in our own data below, both prefrontal and temporoparietal regions are associated with failures in controlled semantic processing such as the inability to inhibit miscued items during picture naming (Noonan et al., 2010; Soni et al., 2009; Soni et al., in press).

More recently, as well as citing the presence of a frontoparietal semantic control network, some studies have begun to tease apart possible subtle differences in the contributions of frontal and more posterior regions in controlled semantic processing.

Jefferies et al. (2007) found marginally smaller refractory effects (poorer performance following repeated exposure to a stimulus) in two patients with temporoparietal damage but no prefrontal damage, in comparison to patients with both temporoparietal and prefrontal lesions. Campanella, Mondani, Skrap and Shallice (2009) also found minimal refractory effects in a group of left hemisphere temporal lobe tumour patients who otherwise showed signs of disordered semantic access (inconsistent responding on particular items but no effects of item frequency).

In a detailed study of SA patients with either pure temporoparietal (T-P) or temporoparietal plus prefrontal cortex (+PFC) lesions, Noonan, Jefferies and Lambon Ralph (submitted) found several subtle differences between the two groups despite similar strong effects of phonemic cueing and little effect of stimulus frequency, indicating relatively preserved semantic representations. Executive dysfunction and item inconsistency indicated impaired semantic control in both T-P and +PFC groups, but these tendencies varied in degree. Both groups showed impaired performance in tests of executive function such as WCST (Milner, 1963; Stuss et al., 2000), the Brixton Spatial Rule Attainment task (Burgess & Shallice, 1997), and Elevator Counting (with and without distraction) from the Test of Everyday Attention (Robertson et al., 1993), but the +PFC group were more impaired than those with only T-P lesions. Both groups showed item inconsistency between but not within tasks, but the T-P only group were more consistent between tasks than the +PFC group. In picture naming (64 item battery, Bozeat et al., 2000), the T-P only group produced fewer associate semantic errors than the +PFC group. However, despite these differences, the T-P and PFC group were more similar to each other and distinct from a group of SD patients with temporal pole atrophy, whose deficits indicated impairments of representations rather than access (Noonan et al., submitted).

Comparison of control and representational deficits

In order to fully demonstrate the effect of deficits of semantic control, it is necessary to compare SA patients with other patients whose central semantic deficit stems from impaired representations rather than manipulation of semantic knowledge, namely semantic dementia or SD. Some effects typically seen in patients with SA but almost never in SD illustrate this difference neatly: for example, when an associate error such as “nuts” for SQUIRREL is produced by a patient with SA, it can be seen that the semantic representation for SQUIRREL still exists, although access to it might be erratic.

In Noonan et al. (submitted), several other differences were observed between the SD group and the SA groups[19] such as strong effects of frequency in SD but not SA, although similar accuracy levels on 64 item battery (Bozeat et al., 2000) showed relatively equal magnitude of impairment for all three groups.

In executive tests such as WCST (Milner, 1963; Stuss et al., 2000), the Brixton Spatial Rule Attainment task (Burgess & Shallice, 1997), and Elevator Counting (with and without distraction) from the Test of Everyday Attention (Robertson et al., 1993), the SA groups were impaired but the SD group showed relatively preserved performance, showing that poor executive function was not a factor in the semantic deficit of the SD patients. Unlike the SA groups, SD patients were remarkably consistent with particular items both within and between tests; SA patients also benefitted from correct phonemic cues while SD patients did not. These two effects both indicate that once a semantic representation has degraded in SD, guiding semantic control by methods such as phonemic cueing will not help to access it.

In the Camel and Cactus Test or CCT within the 64 item battery (Bozeat et al., 2000), the ease of determining the relevant semantic relationship and rejecting distractors (determined by control ratings) was a bigger factor in SA than SD performance. As relationships between probes and targets became easier to distinguish and distractors easier to reject, both SA groups grew more successful at this task, while SD performance varied less with these factors. This shows that as semantic control demand grew less, the SA patients were better able to perform the task while in SD the semantic control demand had less effect on performance. Finally, SA performance benefitted from the presence of more semantic constraint in a task, while the reverse was true for SD. In picture naming, where the picture itself rules out many potential responses, SA patients performed better than SD patients; however in category fluency, where as many items as possible must be named within a certain category (e.g., animals), the lack of semantic constraint benefitted the SD patients leading to better performance on category fluency than picture naming, while with SA patients the reverse was true. All these distinctions help to show that the semantic impairments are qualitatively different in SA and SD: in SA the background information is relatively preserved, but the ability to

---

[19] As the T-P and +PFC groups showed similar effects to each other but distinct from the SD group, they will be referred to in this section under the single title ‘SA groups’.

manipulate it is impaired, whereas in SD the core representations have become degraded.

Examples of semantic control deficits in SA patients: data from this thesis

The comparison of SA and SD patients described above helps to define what is meant by a semantic control deficit. Patient data from each of the studies presented in this thesis help to support our hypothesis that semantic control, alongside core semantic knowledge, is central to the process of speech production. During the design of the study in Chapter 2, it was hypothesised that naming different grammatical classes (objects and actions) might utilise different levels of semantic control, perhaps leading to the appearance of class effects which have been noted in the literature (Caramazza & Hillis, 1991; Hillis & Caramazza, 1995; Hillis et al., 2004; Miceli et al., 1988). These differences might be particularly pronounced in patient groups such as SA where semantic control is impaired. However, although grammatical class effects were observed, it appeared that they were based on different levels of imageability between classes rather than class per se. In the imageability confounded set, a significant object advantage for accuracy was observed in both patients and normals at the fast tempo with action and object stimuli matched on frequency, AoA, familiarity, name agreement and visual complexity, with only imageability being significantly different between grammatical classes. In the imageability controlled set (where imageability was matched between action and object pictures), this object advantage was abolished. Our data therefore supported other work which ascribed grammatical class effects to imageability (Bird, Howard et al., 2000; Bird et al., 2003).

We hypothesise that higher imageability allowed swifter, more accurate naming than lower imageability because it makes semantic representations richer or more detailed: it could allow the semantic control system to exercise more ‘traction’ on a particular item, through the greater detail in the semantic representation. It appears that high imageability is key in making items closer to the threshold for production than lower imageability in stimuli which are matched in other ways, regardless of grammatical class. Confirming this analysis, strong imageability effects have also been seen in a similar group of SA patients in comprehension tasks (Hoffman et al., 2010); abstract words, which are inherently lower in imageability, were comprehended less well than higher imageability concrete words unless the abstract words were presented with a sentence context cue which constrained possible referents.

In the cueing and miscueing experiments in Chapters 3 (Soni et al., 2009) and 4 (Soni et al., in press), we saw the part played by semantic control in speech production in the effects of different cues on naming success. In Chapter 3, patients responded significantly more accurately when correct cues were compared with neutral beeps. A similar picture was seen in Chapter 4 when comparing correct to neutral phonemes, showing that correct cues had an effect when compared with either non-speech sounds or incongruous phonology. It appears that semantic control systems were able to use correct cues as a guide to reaching appropriate semantic representations: boosting phonological activation of the initial phoneme allowed more efficient selection of the correct target.

On the miscueing side, in Chapter 3 (Soni et al., 2009), patients responded less accurately to co-ordinate phonemes than neutral beeps. In Chapter 4 (Soni et al., in press), the negative cueing effect on semantic error rates of co-ordinate cues relative to neutral phonemes approached significance, as did that of associate miscues. Again, effects were seen whether comparing miscues to non-speech sounds (beeps) or misleading but semantically uninformative phonology (neutral phonemes). The semantically relevant miscue phonemes appeared to boost the activation of a particular competitor, as can be seen from the raised incidence of exact cued errors as a proportion of trials, significant in the case of co-ordinate cues: even in the associate comparison which was non-significant for patients, more than twice as many cued errors occurred in the associate cue condition than in the neutral. When the cued error was not selected, the informative miscues still destabilised the naming process enough to produce a higher error rate: again, it seems that cue phonemes guided semantic control systems, in this case away from target selection. It is interesting to note that in the more successful (in terms of error generation) co-ordinate cue condition in Chapter 4, patients named the miscued item in more than a quarter of their errors, showing that auditory cues can guide semantic control towards a specific semantically related item even when it does not match visual input. It could be said that in Chapters 3 and 4 (Soni et al., 2009; Soni et al., in press), miscued naming is rather like a dual task for patients with semantic control deficits: a visual image has to be identified and named (a process already impaired), and simultaneously a conflicting auditory message boosting a competitor must be inhibited.

Given the facilitative effects on target naming of presenting a single initial phoneme from the target (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Soni et al., 2009; Soni et al., in press), the next step in Chapter 5 was to use repetition priming, where the whole item is presented in a priming trial in order to affect subsequent target naming. The hypothesis was that if a single phoneme was beneficial, the whole item should also facilitate naming in SA patients. In order to test semantic control more sensitively, reaction times were measured as well as accuracy and error types in the patients: a long RT can show where a response was particularly effortful even if the outcome was ultimately successful, where a measure of accuracy alone would be blind to such difficulty.

It was clear from the lag manipulation in the picture-picture repetition priming study in Chapter 5 (Soni et al., submitted) that the benefits bestowed by repeated stimuli could not be maintained when semantic control was impaired. As predicted, the effects in RT (significant priming effects at lag 0 and lag 1 which decayed by lag 7) proved more sensitive than either accuracy or semantic error rates (significant priming effects for both at all three lags, though primed performance did still deteriorate significantly with increasing lag). We hypothesise that the patients' poor semantic control meant that the activation from intervening items was able to mask or deplete the activation of the target, causing longer naming times and lower accuracy with increasing lag. Control participants matched on age and educational level showed very high accuracy and low error rates at this range of short lags, with significant or near significant differences between primed and unprimed items at lags 0, 1 and 7. The lack of lag effects showed that in a normally functioning control system, the rise in target activation caused by repeated presentations was longer lasting and better able to withstand the activations caused by naming intervening items. However, as with the patients, latency showed more sensitivity as a measure of controlled processing. The main effects of priming and lag on latency were both significant, as was the interaction: at lag 0, there was a greater effect of priming than at the other two lags.

The study of repetition and semantic priming in Chapter 6 used word primes rather than pictures, with a single filler picture between prime and target. Findings extended repetition effects from the picture-picture priming seen in Chapter 5 to include significant bonuses for patients in higher accuracy and lower semantic errors collapsed across session and a significant benefit of priming on latency in session 3. These data showed that repetition priming effects still obtained when no visual representation of the target was presented in the priming trial: words (in the main presented auditorily and repeated) were able to boost activation of targets such that when pictures were subsequently presented, enhanced controlled processing led to better performance with primed items. The significant session effect on RT showed that patients improved their performance in the longer term (sessions were at least a week apart), suggesting that repetition priming might be of benefit to semantically impaired patients over a much longer time period than has hitherto been observed (Cumming et al., 2006; Howard et al., 2006).

In Chapter 6, age and education matched control participants showed no significant repetition priming effects on accuracy or semantic errors from word primes, which could reflect ceiling effects in control performance: their picture naming was so accurate that any benefit from prior exposure to stimuli could not improve it. However, latency proved to be more sensitive, showing a marginally significant benefit from priming on RT when collapsed across session. This showed that as with the SA patients, prior presentation of an item’s name was able to speed up subsequent naming of the picture. Again, it is likely that the boost in activation caused by the prime enabled more efficient controlled processing of an item more on the target naming trial.

Although it might be inferred from co-ordinate and associate miscueing effects in Chapters 3 and 4 (Soni et al., 2009; Soni et al., in press) that semantic priming should have a detrimental effect on target naming, semantic priming with co-ordinate word primes in Chapter 6 produced a mixed picture with few significant effects of priming in either direction. The exception was the effect on patients’ accuracy, which showed a crossover from a small but non-significant inhibitory effect in session 1 to a significant benefit from semantic primes by session 3, while unprimed accuracy remained flat across sessions. The discrepancy between semantic effects in cueing (Chapters 3 and 4) and priming (Chapter 6) warrants some consideration. We argue that there are two potential factors which may account for this difference in direction of priming effects on accuracy: one relates to the test structure of the priming experiment, which could have resulted in repetition priming; the second argument relates to different underlying mechanisms which may be operating in cueing and priming trials.

As with the session effect of repetition priming on latency, the longer term benefit from semantic primes could be construed as long term repetition priming. The facilitation from semantic primes only became apparent by session 3 of the test, suggesting that this effect took some time and/or prior experience to generate. The experimental design meant that each item was seen in each priming condition; hence in session 3 items were being seen for the third time, though in combination with a prime which had not been seen before. By session 3, access to each item could have improved to such an extent that semantic primes could be used as a route to activate the target: the semantic control system had three occasions to link the name and visual representation of each picture, either producing the correct target or receiving feedback on an error. These opportunities could have been used to fill in details of a semantic representation, or perhaps to strengthen the connection with associated phonology. It is possible that through experience (in other words, learning), the semantic control system becomes able to channel any shared semantic activation from co-ordinates towards production of targets, resulting in facilitation. This is contrasted by the flat accuracy levels with unrelated primes across each session, showing that it is not just giving targets three times that facilitates naming, but giving targets three times in the presence of semantically useful information (correct or co-ordinate word primes).

This argument suggests, though speculatively, that although mainly operating at a relatively automatic, unconscious level, semantic control may at some level form a continuum with more conscious strategies employed by participants, particularly over repeated sessions where learning is involved. As suggested in the Introductory Chapter, the semantic control system could enhance effects that may be more automatic, for example heightening residual activation such as that left by prior exposure in a priming trial, thus honing performance in a subsequent priming trial. This enhancement of existing ‘automatic’ effects could also maximise lateral inhibition of close semantic neighbours, although in this experiment the longer term use of semantic primes resulted not in semantic interference but in increased accuracy. To account for this facilitation, we argue that in any trial, spreading activation from semantic word primes would raise the activation of closely related picture targets; over the course of the three experimental sessions, the semantic control system could have learned to enhance the target’s activation and inhibit the prime’s activation when that prime is a co-ordinate of the target. This could be where semantic control shades from the more automatic end of semantic processing to a slightly more strategic, learned response.

A second account of the different outcomes with semantic primes and cues rests on the internal trial structure in each experiment. On a cueing trial, there is a single opportunity for naming in each trial: one target is to be named, with the distracting but relatively subconscious cue phonemes presented in an attempt to destabilise that individual naming instance. The cue phoneme was presented very briefly (300 ms duration), and even where repeated to some patients, represents only very partial information: this paradigm resulted in inhibition of target naming accuracy. This can be contrasted with a semantic priming trial, where a co-ordinate word must be read or repeated, followed by naming a filler picture and then naming the target picture: prime and target are both named in full, in separate instances. This presents greater opportunity for slightly more conscious decision, perhaps allowing dismissal of the prompt offered by the prime as being unsuitable, or a mismatch to the target, particularly on session 3 when experience has been gained. However, the semantic control system could utilise the activation shared by both prime and target, allowing facilitation of accurate target naming compared to the absence of any shared activation from an unrelated prime. Perhaps the partial information offered by the cue is actually harder to inhibit than a fully specified semantic prime, working on a more automatic level at the same time as the target is being named: the semantic control system has less opportunity to inhibit mismatching information, thus allowing semantic interference from miscues.

As in repetition priming with word primes, controls' naming with co-ordinate word primes in Chapter 6 was so accurate as to show no significant effects of semantic priming. They did however show a significant benefit to RT from additional sessions. Like the patients, this could also reflect longer term repetition priming, with access to the target picture's name enhanced by repeated presentations, regardless of prime type. These repeated presentations allowed semantic control to operate ever more efficiently, reducing target naming times.

Across all these experiments, SA patients' scores on tests of executive function correlate with naming performance. Poorer executive control is associated with a greater susceptibility to interference by extraneous material, either from miscues (Chapters 3 and 4) or greater interval between prime and target (Chapter 5). Additionally, in Chapter 2 we saw that items like concrete objects which have high imageability (and therefore a reduced requirement for controlled processing) were named more successfully than lower imageability objects such as actions which were matched on other relevant variables. These factors suggest strongly that the semantic deficit in SA originates from impaired manipulation of semantic material rather than depleted semantic knowledge. This theoretical conclusion has some practical therapeutic implications. For example, repetition priming was shown to benefit SA patients, but their semantic control deficits meant that its effect was quickly dissipated by intervening items. If repetition therapy was offered to SA patients, this finding could be incorporated into test materials, maximising the benefit of repetition priming by using a short lag between prime and target.

Semantic control beyond language

The experiments carried out in this thesis showed that the semantic control system can be guided either to facilitate or hinder correct naming, but most importantly that the control system is open to experimental manipulation. However, it is not just in speech production that semantic control is necessary: other spheres of behaviour require controlled, regulated use of stored semantic knowledge, such as the effective use of everyday objects. Corbett, Jefferies and Lambon Ralph (2009) showed that patients with SA demonstrated deregulated cognition in a test of naturalistic object use (Naturalistic Action Test or NAT, Schwartz, Segal, Veramonti, Ferraro, & Buxbaum, 2002) compared to control participants. Manipulation of common tools and kitchen implements showed fragmented action sequences, particularly in dual task situations or when semantically related distractor objects were presented. These deficits were qualitatively similar to deficits in the verbal domain: Corbett et al. (2009) concluded that difficulties with both language and actions might share a common origin, namely impaired semantic control. The way that semantic control might link to the wider executive control domain forms the basis for Research Theme 3.

3. The effect of tempo naming on semantic control and the relationship of semantic control to a wider executive network.

In the Introduction, Research Theme 3 raised the use of the tempo paradigm partly as a stand alone procedure to increase error rates in normal participants, but chiefly as a method of causing semantic disturbance analogous to that seen in our SA patients. The first section of Theme 3 will explore the behavioural effects of the tempo task in Chapters 2 – 4, and to hypothesise about their underlying causes. The next section will compare tempo naming to other dual task paradigms, leading onto the final section reviewing some of the research on more general executive control mechanisms, assessing how semantic control might fit into this system.

Behavioural effects of tempo naming and possible underlying causes

The performance of control participants in Chapter 5 (picture-picture repetition priming, Soni et al., submitted) and Chapter 6 (repetition and semantic priming with word primes) showed that the semantic control system in healthy people generally operates so efficiently that, as with most aspects of producing speech, for much of the time we are completely unaware of its operations. The tempo naming paradigm is invaluable in that it allows us to witness the process of semantic control within normal speech production. In Chapters 2 – 4, the effects of tempo naming show that the semantic control system in healthy participants is open to influence by experimental means.

In Chapter 2, the tempo naming element of the grammatical class study showed that when normal participants were subject to an experimentally induced semantic control ‘deficit’, they named higher imageability objects faster and with fewer semantic errors than the lower imageability action set. There was no interaction with tempo, showing a straightforward imageability effect at each speed. However, on the accuracy measure the healthy participants showed a closer approximation of the behaviour of SA patients. The interaction between grammatical class and tempo approached significance, with healthy participants (like the SA patients) showing a significant object advantage in accuracy, but only during the more pressured fast tempo, not at baseline. This demonstrates that it is only when the semantic control demands are particularly high that the object naming advantage in accuracy becomes apparent. In this comparison, action and object stimuli were matched on the main psycholinguistic variables, with only imageability being significantly different between the two groups. We therefore argue that a semantic control deficit induced by fast tempo naming makes the system particularly sensitive to variables such as imageability for accurate naming.

The cued tempo naming paradigm also showed how semantic control in healthy participants could be guided by cue phonemes. For example, in Chapter 4 (Soni et al., in press), significantly longer latencies were observed to both co-ordinate and associate cues than neutral cues. As RTs were only measured on correct trials, this shows that participants took more time and effort to reach the correct response in the presence of semantically informative but misleading information which was boosting competitors rather than targets. Inhibition of extraneous material is seen as a core task of controlled processing (Collette, Van der Linden et al., 2005; Miyake et al., 2000), and it could be that the longer latencies compared to neutral phonemes reflect the time taken for such inhibition. These effects could result from the extra demands of the tempo task on controlled processing, making the overt task of naming a picture in the presence of a miscue more effortful. It is also noteworthy that no significant positive cueing effects on latency were observed between neutral and correct cues: although misleading phonology was present, it did not directly boost the activation of other related items; hence no time-consuming inhibition of competitors was required. It could also be that the constraints of the tempo task left no room for further speeding up, despite processing benefits incurred by correct cues.

Significant differences were observed in higher accuracy and lower semantic error rates between co-ordinate and neutral cues in healthy participants (Hodgson & Lambon Ralph, 2008; Soni et al., 2009; Soni et al., in press), showing that co-ordinate cues were able to effectively guide controlled selection away from target responses. Looking at the effects of associate miscues, in Chapter 4 (Soni et al., in press) it appeared from the numerical but not significant differences between associate and neutral cues that although associate phonemes were able to extend the time it took to reach a correct response, their effect was not strong enough to deflect the system into making errors. However, when considering exact cued errors the associate miscue effect reappeared: both co-ordinate and associate cues were significantly better at generating particular erroneous responses than their naturally occurring levels in the neutral phoneme condition. The low rate but significant effect for associate cued errors showed that even when the natural bias towards a certain response type was small, miscues were effective. In the co-ordinate condition, normal participants named the miscued item in nearly half of their errors. These cued error rates showed that semantic control systems in healthy participants were able to use phonology effectively as a guide towards a specific response, even when that phonology was incorrect.

Tempo naming as a dual task

Although showing some similarities to other speeded naming tasks such as deadline naming (Vitkovitch & Humphreys, 1991; Vitkovitch et al., 1993), we argue that tempo naming requires not just speed but precision during response timing. In concurrence with Hodgson and Lambon Ralph (2008), we hypothesise that this monitoring of response initiation led to the outcomes explored above such as differential cueing effects (Chapters 3 and 4, Soni et al., 2009; Soni et al., in press) and the tempo dependent effect on accuracy in different grammatical classes (Chapter 2). Tempo naming is a demanding task recruiting semantic control resources which would otherwise be dedicated to swift, accurate response selection. In effect, tempo naming is a dual task, with similar effects to other dual task studies seen in the literature. Tasks such as simple audio and visual monitoring or mental figure rotation are performed less effectively when carried out in conjunction than when carried out alone (Collette, Olivier et al., 2005; Newman et al., 2007).

Many dual task studies conduct functional brain imaging to contrast the areas of cortex which are activated by single and combined tasks, as well as monitoring behavioural output. For example, Collette et al. (2005) reported a study comparing a baseline discrimination task of pressing a key after either a visual cue (centrally presented cross) or an audio cue (a mid-pitched tone) with both visual and auditory discrimination tasks singly and presented as a dual task. Individually, each task involved pressing one of two buttons, for a high or low tone compared to the mid-pitched tone, or for the visual task, depending on whether a cross appeared in the top or bottom of the screen. Singly, the visual task was associated with activation in the right angular gyrus (BA 39), the right middle occipital gyrus (BA 19), the right superior parietal gyrus (BA 7), and the right fusiform gyrus (BA 20). The auditory task was associated with activations in the right superior temporal gyrus (BA 22) and bilateral inferior occipital gyri (BA 18). There was no prefrontal involvement when either task was performed alone.

In the dual task, a tone (high or low pitch) and a cross (top or bottom of screen) were presented simultaneously, then a cue was given. If the cue was visual (centrally presented cross) the participant had to respond by pressing one of two buttons according to the position of the previous visual marker, but if the cue was auditory (mid-pitch tone) the participant had to respond according to pitch of the previous tone. Subtracting out the activations from the single tasks, the dual task demonstrated left-sided activations in prefrontal regions (BA 9/46, BA 10/47 and BA 6), the left inferior parietal gyrus and intraparietal sulcus (BA 40) and the left cerebellum. The pattern of activation associated with this non-language dual task is reminiscent of the prefrontal and/or temporoparietal lesions in our SA group, whose semantic control deficits appear to be mimicked by healthy participants in the tempo task (Hodgson & Lambon Ralph, 2008; Soni et al., 2009; Soni et al., in press).

Semantic control within the wider executive network

The separate strands of tempo naming, dual task studies, imaging and neuropsychological research raise an important question in the literature: is semantic control part of a wider mechanism of executive control? General executive control operates in realms as diverse as the strategic deployment of attentional resources (Duncan, 2006; Peers et al., 2005), non-language dual task performance (Collette et al., 2006; Collette, Van der Linden et al., 2005; Miyake et al., 2000), and appropriate social behaviour (Baddeley, Della Sala, Papagno, & Spinnler, 1997). Examples from several studies which explore controlled processing tasks will now be given, followed by a section bringing together the arguments which relate semantic and more general mechanisms of control, both in terms of brain regions and types of processing.

Investigating the deployment of attention as part of a generalised executive control system, Peers, Ludwig, Rorden, Cusack, Bonfiglioli, Bundesen, Driver, Antoun and Duncan (2005) explored attentional deficits in a mixed group of patients with frontal and parietal lesions. Tasks included the identification of letter targets in a visual array where non-targets had to be ignored, requiring selective attention based on task relevance. Few differences were found between patients with frontal and parietal lesions. Peers et al. (2005) suggested that some areas of both parietal and frontal cortices have properties like adaptability of response in the face of task demands: they concluded that a frontoparietal network of areas underpins activities such as strategic weighting of attention according to task requirements. Duncan (2006) described convergent evidence from human behaviour, functional imaging and single cell recordings from monkeys which suggested that a fronto-parietal network of brain regions is recruited for many different tasks and carries out adaptable, task based ‘attentional selection’. He argued that neurons in this network are able to respond flexibly, adapting to incoming information and task demands.

Looking initially at regions of cortical activation, the above examples concur in highlighting the same range of frontal and temporoparietal regions, implicated in both language processing (Berthier, 2001; Noppeney et al., 2004) and core executive functions such as inhibition, shifting and updating (Collette et al., 2006; Collette, Van der Linden et al., 2005). This combination of brain regions calls to mind the frontal and/or temporoparietal areas of damage in our SA patient group. There is convergent evidence that little behavioural difference can be detected between frontal and temporoparietal lesion sites in groups which share outward behavioural traits, for example in transcortical sensory aphasia or TSA (Berthier, 2001) and in attention impairments induced by brain damage (Peers et al., 2005). A similar range of frontal and parietal regions are implicated in dual task studies (Collette, Olivier et al., 2005; Newman et al., 2007), which we argue involve the same division of processing resources as the tempo task. Although some new work has been produced tracing subtle differences between patients with left hemisphere temporoparietal lesions and patients who also have left hemisphere prefrontal lesions (Noonan et al., submitted), these two groups still had more in common with each other (impaired semantic control) compared to SD patients with temporal pole atrophy and degraded semantic representations. Our data from the SA patients show difficulties with semantic processing requiring a high degree of ‘executive’ control, supporting Noppeney et al.’s (2004) conclusion that controlled processing of language is subserved by frontal and temporal regions.

Turning to behavioural effects of impaired general executive functions, the difficulties with selective attention found in the frontal and parietal lesion patients described by Peers et al. (2005) recall the impaired inhibition of irrelevant material during tasks such as miscued naming shown both by SA patients and healthy participants under tempo naming conditions (Hodgson & Lambon Ralph, 2008; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009; Soni et al., in press). Furthermore, the flexible, task adaptive properties of the attentional network described by Duncan (2006) are a good description of what is disordered by SA or the tempo task. Where semantic control is hindered or impaired, the system adapts poorly to task demands: difficulties occur in selecting task appropriate information or inhibiting irrelevant material, and tasks which might normally be constrained by internal control mechanisms become unusually influenced by external experimental manipulation.

As with the data on brain regions responsible for control mechanisms, functional similarities support the contention that semantic control might be part of the wider system of executive control. The data from several different research strands in the literature combine to suggest a fronto-parietal network of regions is responsible both for controlled processing in language and also wider systems of executive control.

However, there is not complete commonality between neural regions responsible for semantic and domain general control processes. The ventral aspect of the left IFG (BA 47) and the angular gyrus (BA 39) have been identified as particularly important in semantic control tasks (Noonan et al., 2010), while domain-general executive control tasks are associated more with activation in the left posterior IFG (BA 44, 45), the dorsolateral PFC (BA 46), the supramarginal gyrus (BA 40) and the superior parietal lobes (BA 7) bilaterally (Collette et al., 2006; Collette, Olivier et al., 2005; Duncan, 2006; Duncan & Owen, 2000).

In order to defuse the potential dichotomy raised by the separate but seemingly linked systems of semantic and more general executive control, it is necessary to introduce the idea of graded specialisation (Plaut, 2002). Although the connectionist model presented by Plaut (2002) was developed to account for effects observed in optic aphasia, he extended the application of graded specialisation more broadly to encompass the debate between theories of a single amodal semantic system or multiple subsystems based on different modalities of input (e.g., auditory, visual). Another way to frame this idea is “unity and diversity”, where a network of neural regions or a set of tasks associated with executive function may load differently on the same available resources (Collette, Van der Linden et al., 2005; Miyake et al., 2000). For example, in Collette et al.’s (2005) PET study, three core executive tasks of updating, shifting and inhibition are collectively shown to be associated with raised activations in the same frontal and parietal regions, but each of the three tasks activates those regions to varying levels. Looking instead at behavioural measures, Miyake et al. (2000) observed differential correlations between executive tests such as WCST (Stuss et al., 2000) or Tower of Hanoi and the same core executive functions of updating, shifting and inhibition. The hypotheses of graded specialisation or unity and diversity allow for the existence of an overarching system, for example general executive control, but within that broad scope there can be a role for more specialised subsystems, for example manipulation of semantic information during speech production or object use, in other words semantic control. They are not two independent entities, but different levels of the same system.

FUTURE DIRECTIONS OF RESEARCH

Several studies could arise using methods already carried out in this thesis (points 1-3), while another co-opts a new technique to further explore the theme of semantic control in speech production and its neural bases (point 4).

1) Can frontal vs. temporoparietal contributions to semantic control be teased apart in semantic aphasia?

Semantic aphasia (SA) is a relatively recently coined term that has developed to refer to a subgroup of stroke patients with impairments in the manipulation of semantic knowledge (Corbett, Jefferies, Ehsan et al., 2009; Corbett, Jefferies, & Lambon Ralph, 2009; Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009; Soni et al., in press, submitted). In the future it would be productive to expand the number of patients, selecting again by failure on both word and picture versions of a test of semantic association such as CCT (Bozeat et al., 2000) or PPT (Howard & Patterson, 1992). Some work on this area has already begun, finding subtle differences between SA patients with temporoparietal only and temporoparietal plus frontal lesions (Noonan et al., submitted). If the group were larger, it might be possible to select within it for frontal only and temporoparietal only lesions, plus a group whose lesions include both frontal and posterior areas. In this way a more rigorous test might be conducted on semantic control impairments shown by each group, and whether there is any fine grained or qualitative difference which can be ascribed to lesion site. This would help to explore the extent and function of different parts of the network which has been identified as responsible for semantic control.

2) Could repetition priming have a therapeutic effect in SA?

Following on from the significant benefit to latency and accuracy in SA patients from repetition priming with pictures (Chapter 5, Soni et al., submitted), it would be valid to conduct a larger, more therapeutically based study. In Chapter 6, we also saw an increasing benefit to latency with further sessions. As the time taken to produce an utterance is a critical factor in verbal communication, the benefits to latency from repetition priming, either with words or pictures, could have a significant impact on the quality of life of people with aphasia, in addition to more accurate word finding. Following on from the benefits of further sessions in Chapter 6, a number of therapeutic sessions could take place, perhaps varying in number for different groups of patients, for example one group with four and one with eight weekly sessions. Follow up naming tests could be conducted post-therapy to judge the longevity of the effect, for example two, four and six weeks from the last therapy session. As priming in semantically impaired patients has thus far only been demonstrated over much shorter periods (Cumming et al., 2006; Howard et al., 2006; Soni et al., submitted), this would have theoretical as well as therapeutic interest.

3) Does categorical knowledge have an influence on the naming of abstract items analogous to the influence of associated knowledge on naming concrete items?

The tempo task could be extended in its original form with word naming (Kello & Plaut, 2000) to further explore the effect of associative knowledge in naming concrete and abstract items, as suggested by Crutch and Warrington (2005, 2006, 2009) and qualified in Soni et al. (in press). By using words rather than pictures a much wider group of stimuli could be tested, including abstract items or concepts which are not readily picturable. For example, if an abstract target was JEALOUSY, a co-ordinate might be ENVY. This paradigm could be used to determine whether or to what extent co-ordinate information has a bearing on retrieval of abstract items, converse to the partial reliance of concrete objects on associative knowledge. This could add valuable insight to the nature of representational frameworks for both concrete and abstract items.

4) Can transcranial magnetic stimulation (TMS) be used to induce in healthy participants the same kind of cueing effects seen in SA patients?

TMS is a valuable tool in investigating the neural basis of language and other cognitive processes. Based on similar technology to magnetic resonance imaging (MRI), it uses a focal magnetic field applied to the scalp to affect processing in cortical tissue to a depth of around 2cm beneath the coil. This can cause a ‘virtual lesion’ (Walsh & Rushworth, 1999), a temporary disruption processing at a site chosen by the tester. TMS can also be applied in a repetitive paradigm (rTMS), where stimulation is given at a rate of one or more pulses per second for a few minutes, to maximise effects. This can sometimes be carried out ‘online’ during performance of the experimental task, or ‘offline’ prior to the experimental task: even offline TMS gives a window of effect lasting several minutes during which an experiment can be carried out.

The use of TMS clarifies not only which areas are active during performance of a task, but which are critically necessary. This assists with determining causation, which is not possible from imaging studies that can only give correlations between tasks and activations. TMS thus provides a bridge to lesion studies in neuropsychology, but TMS causes a temporary effect in an area specified by the tester in an otherwise healthy participant rather than a non-uniform lesion in a patient with unknown pre-morbid abilities. As such, it can provide a powerful, focussed investigative tool. The effects of TMS are noticeable particularly in latency, but can also be seen in accuracy of performance.

Specifically, TMS could be used with the different phonological cue types which were linked to ‘semantic aphasic’ type effects in normal participants under tempo naming conditions. Previously, rTMS has been used on the anterior temporal lobes to mimic effects seen in SD patients (Pobric, Jefferies, & Lambon Ralph, 2007). Taking the typical SA lesion sites (prefrontal, temporoparietal) as a guide, stimulation could be applied to those areas inferred to be involved in semantic control to see if the cue conditions are again successful in producing differential effects in accuracy or semantic errors, as in SA patients, or latency, as in the tempo paradigm. Distinctions between frontal and temporo-parietal aspects of the control system could be further explored in a similar way to the larger scale patient study outlined in point 1, and compared to a neutral site for semantic control such as the occipital cortex.

CONCLUSIONS

Consideration of the data from these experiments suggests some ‘higher order’ conclusions as well as the three specific research themes explored thoroughly above. Effects seen throughout this thesis must be combined with more general reasoning on how the brain could implement what we have termed semantic cognition, or the effective, task-oriented use of stored semantic knowledge.

We argue that our data support the notion of continua rather than independent modular systems, for example that proposed for grammatical classes (Bird, Howard et al., 2000; Bird et al., 2003; Gordon & Dell, 2003). A related debate within the literature concerns whether a unified processing account or divided, modular systems offer a more parsimonious explanation for language processing. We support theories such as the primary systems hypothesis (Lambon Ralph et al., 2002; Patterson & Lambon Ralph, 1999), which rely on the interactive operation of basic underlying systems like semantics, phonology and visual processing to account for effects as varied as past tense formation for regular and irregular verbs (Holland & Lambon Ralph, 2010; Joanisse & Seidenberg, 1999; Kello, Sibley, & Plaut, 2005; Woollams et al., 2009), letter by letter reading (Behrmann, Nelson, & Sekuler, 1998), deep dyslexia (Jefferies, Sage, & Lambon Ralph, 2007), surface dyslexia (Woollams, Lambon Ralph, Plaut, & Patterson, 2007), phonological dyslexia and dysgraphia (Crisp & Lambon Ralph, 2006; Rapcsak et al., 2009) and auditory repetition in patients with semantic and phonological impairments (Jefferies, Crisp, & Lambon Ralph, 2006).

A related issue is that of how far specific brain regions are dedicated to particular functions. Although some locations appear to specifically govern particular functions (e.g., Broca's area for fluent, grammatical speech output), more often language processing appears to rest on the co-operative output of several regions and the integrity of white matter tracts between them. The semantic control system is a good example here, as it seems to rely on the concerted processing of several areas (left hemisphere prefrontal, temporal and parietal regions) which are functionally linked but not neuroanatomically contiguous. Damage to any part of this network leads to reduced functionality in speech production (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2008; Noonan et al., 2010; Soni et al., 2009; Soni et al., in press). The data in this thesis is consistent with the conclusion that networks are key, not just for successful language processing, but for many cognitive systems.

The notion of graded specialisation allows that language and other functions can be carried out by processing systems and networks of brain areas which can subserve both general applications and more specialised, dedicated processes. This is linked to the notion of core underlying systems which are adaptable, as opposed to multi-divided systems and regions which are dedicated to very specific functions (Patterson & Plaut, 2009). This agrees with what we can garner both from evolution and the principle of cognitive economy: a system which may have developed for one particular purpose is put to better use when adapted to multiple related tasks, rather than developing modular systems to process similar material for different outputs. Humans are the ultimate adaptable animal.

REFERENCES

Aggujaro, S., Crepaldi, D., Pistarini, C., Taricco, M., & Luzzatti, C. (2006). Neuro-anatomical correlates of impaired retrieval of verbs and, nouns: Interaction of grammatical class, imageability and actionality. [Proceedings Paper]. *Journal of Neurolinguistics, 19*(3), 175-194.

Alario, F., Segui, J., & Ferrand, L. (2000). Semantic and associative priming in picture naming. *The Quarterly Journal of Experimental Psychology, 53a*(3), 741-764.

Andrews, M., Vigliocco, G., & Vinson, D. (2009). Integrating Experiential and Distributional Data to Learn Semantic Representations. *Psychological Review, 116*(3), 463-498.

Baayen, R., Piepenbrock, R., & Gulikers, L. (1995). The CELEX lexical database (Release 2). Philadelphia: University of Pennsylvania, Linguistic Data Consortium.

Baddeley, A., Della Sala, S., Papagno, C., & Spinnler, H. (1997). Dual task performance in dysexecutive and nondysexecutive patients with a frontal lesion. *Neuropsychology, 11*(2), 187-194.

Badre, D., Poldrack, R., Pare-Blagoev, E., Insler, R., & Wagner, A. (2005). Dissociable controlled retrieval and generalized selection mechanisms in ventrolateral prefrontal cortex. *Neuron, 47*(6), 907-918.

Badre, D., & Wagner, A. (2004). Selection, integration, and conflict monitoring: Assessing the nature and generality of prefrontal cognitive control mechanisms. *Neuron, 41*(3), 473-487.

Bajo, M. (1988). Semantic facilitation with pictures and words. [Article]. *Journal of Experimental Psychology-Learning Memory and Cognition, 14*(4), 579-589.

Bak, T., & Hodges, J. (1997). Noun-verb dissociation in three patients with motor neuron disease and aphasia. *Brain And Language, 60*(1), 38-41.

Bak, T., & Hodges, J. (2003). Kissing and dancing - a test to distinguish the lexical and conceptual contributions to noun/verb and action/object dissociation. Preliminary results in patients with frontotemporal dementia. *Journal Of Neurolinguistics, 16*(2-3), 169-181.

Baum, S. (1997). Phonological, semantic, and mediated priming in aphasia. [Article]. *Brain and Language, 60*(3), 347-359.

Bedny, M., & Thompson-Schill, S. (2006). Neuroanatomically separable effects of imageability and grammatical class during single word comprehension. *Brain and Language, 98*(2), 127-139.

Behrmann, M., Nelson, J., & Sekuler, E. (1998). Visual complexity in letter-by-letter reading: "Pure" alexia is not pure. [Article]. *Neuropsychologia, 36*(11), 1115-1132.

Berg, T., & Schade, U. (1992). The role of inhibition in a spreading-activation model of language production. I. The psycholinguistic perspective. *Journal of Psycholinguistic Research, 21*, 405-434.

Berlingeri, M., Crepaldi, D., Roberti, R., Scialfa, G., Luzzatti, C., & Paulesu, E. (2008). Nouns and verbs in the brain: Grammatical class and task specific effects as revealed by fMRI. [Proceedings Paper]. *Cognitive Neuropsychology, 25*(4), 528-558.

Berndt, R., Haendiges, A., Mitchum, C., & Sandson, J. (1997). Verb retrieval in aphasia: II. Relationship to sentence processing. *Brain and Language, 56*(1), 107-137.

Berthier, M. (2001). Unexpected brain-language relationships in aphasia: Evidence from transcortical sensory aphasia associated with frontal lobe lesions. [review/experimental]. *Aphasiology, 15*(2), 99-130.

Bird, H., Howard, D., & Franklin, S. (2000). Why is a verb like an inanimate object? Grammatical category and semantic category deficits. *Brain and Language, 72*(3), 246-309.

Bird, H., Howard, D., & Franklin, S. (2003). The importance of being imageable. *Journal of Neurolinguistics, 16*, 113-149.

Bird, H., Lambon Ralph, M., Patterson, K., & Hodges, J. (2000). The rise and fall of frequency and imageability: Noun and verb production in semantic dementia. *Brain and Language, 73*(1), 17-49.

Bozeat, S., Lambon Ralph, M., Graham, K., Patterson, K., Wilkin, H., Rowland, J., et al. (2003). A duck with four legs: Investigating the structure of conceptual knowledge using picture drawing in semantic dementia. *Cognitive Neuropsychology, 20*(1), 27-47.

Bozeat, S., Lambon Ralph, M., Patterson, K., & Hodges, J. (2000). Non-verbal semantic impairment in semantic dementia. *Neuropsychologia 38*(9), 1207-1215.

Burgess, P., & Shallice, T. (1997). *The Hayling and Brixton Tests*. Thurston, Suffolk: Thames Valley Test Company.

Campanella, F., Mondani, M., Skrap, M., & Shallice, T. (2009). Semantic access dysphasia resulting from left temporal lobe tumours. [Article]. *Brain, 132*, 87-102.

Cappa, S., & Perani, D. (2003). The neural correlates of noun and verb processing. *Journal of Neurolinguistics, 16*, 183-189.

Caramazza, A., & Costa, A. (2000). The semantic interference effect in the picture-word interference paradigm: does the response set matter? *Cognition, 75*(2), B51-B64.

Caramazza, A., & Costa, A. (2001). Set size and repetition in the picture-word interference paradigm: Implications for models of naming. *Cognition Vol 80(3) Jul 2001, 291-298*.

Caramazza, A., & Hillis, A. (1990). Where do semantic errors come from? *Cortex, 26*(1), 95-122.

Caramazza, A., & Hillis, A. (1991). Lexical organisation of nouns and verbs in the brain. *Nature, 349*, 788-790.

Chertkow, H., Bub, D., Deaudon, C., & Whitehead, V. (1997). On the status of object concepts in aphasia. *58*(2), 203-232.

Chertkow, H., Bub, D., & Seidenberg, M. (1989). Priming and semantic memory loss in Alzheimer's Disease. [Article]. *Brain and Language, 36*(3), 420-446.

Cloutman, L., Gottesman, R., Chaudhry, P., Davis, C., Kleinman, J., Pawlak, M., et al. (2009). Where (in the brain) do semantic errors come from? [Article]. *Cortex, 45*(5), 641-649.

Collette, F., Hogge, M., Salmon, E., & Van der Linden, M. (2006). Exploration of the neural substrates of executive functioning by functional neuroimaging. *Neuroscience, 139*(1), 209-221.

Collette, F., Olivier, L., Van der Linden, M., Laureys, S., Delfiore, G., Luxen, A., et al. (2005). Involvement of both prefrontal and inferior parietal cortex in dual-task performance. *Cognitive Brain Research, 24*(2), 237-251.

Collette, F., Van der Linden, M., Laureys, S., Delfiore, G., Degueldre, C., Luxen, A., et al. (2005). Exploring the unity and diversity of the neural substrates of executive functioning. *Human Brain Mapping, 25*(4), 409-423.

Collina, S., Marangolo, P., & Tabossi, P. (2001). The role of argument structure in the production of nouns and verbs. *Neuropsychologia, 39*, 1125-1137.

Collins, A., & Loftus, E. (1975). Spreading activation theory of semantic processing. P*sychological Review, 82*(6), 407-428.

Conroy, P., Sage, K., & Lambon Ralph, M. (2006). Towards theory-driven therapies for aphasic verb impairments: A review of current theory and practice. *Aphasiology, 20*(12), 1159-1185.

Conroy, P., Sage, K., & Lambon Ralph, M. (2009). Improved vocabulary production after naming therapy in aphasia: can gains in picture naming generalise to connected speech? [Article]. *International Journal of Language & Communication Disorders, 44*(6), 1036-1062.

Corbett, F., Jefferies, E., Ehsan, S., & Lambon Ralph, M. (2009). Different impairments of semantic cognition in semantic dementia and semantic aphasia: evidence from the non-verbal domain. [Article]. *Brain, 132*, 2593-2608.

Corbett, F., Jefferies, E., & Lambon Ralph, M. (2009). Exploring multimodal semantic control impairments in semantic aphasia: Evidence from naturalistic object use. [Article]. *Neuropsychologia, 47*(13), 2721-2731.

Corina, D., Gibson, E., Martin, R., Poliakov, A., Brinkley, J., & Ojemann, G. (2005). Dissociation of action and object naming: Evidence from cortical stimulation mapping. *Human Brain Mapping, 24*(1), 1-10.

Costa, A., Alario, F., & Caramazza, A. (2005). On the categorical nature of the semantic interference effect in the picture-word interference paradigm. *Psychonomic Bulletin and Review, 12*(1), 125-131.

Crepaldi, D., Aggujaro, S., Arduino, L., Zonca, G., Ghirardi, G., Inzaghi, M., et al. (2006). Noun-verb dissociation in aphasia: The role of imageability and functional locus of the lesion. [Article]. *Neuropsychologia, 44*(1), 73-89.

Crepaldi, D., Berlingeri, M., Paulesu, E., & Luzzatti, C. (2011). A place for nouns and a place for verbs? A critical review of neurocognitive data on grammatical-class effects. [; Research Support, Non-U.S. Gov't]. *Brain Lang, 116*(1), 33-49.

Crisp, J., & Lambon Ralph, M. (2006). Unlocking the nature of the phonological-deep dyslexia continuum: The keys to reading aloud are in phonology and semantics. [Article]. *Journal of Cognitive Neuroscience, 18*(3), 348-362.

Cristescu, T. C., Devlin, J. T., & Nobre, A. C. (2006). Orienting attention to semantic categories. *Neuroimage, 33*(4), 1178-1187.

Crutch, S., Connell, S., & Warrington, E. (2009). The different representational frameworks underpinning abstract and concrete knowledge: Evidence from odd-one-out judgements. [Article]. *Quarterly Journal of Experimental Psychology, 62*(7), 1377-1390.

Crutch, S., Ridha, B., & Warrington, E. (2006). The different frameworks underlying abstract and concrete knowledge: Evidence from a bilingual patient with a semantic refractory access dysphasia. *Neurocase, 12*(3), 151-163.

Crutch, S., & Warrington, E. (2005). Abstract and concrete concepts have structurally different representational frameworks. [Article]. *Brain, 128*, 615-627.

Cumming, T., Graham, K., & Patterson, K. (2006). Repetition priming and hyperpriming in semantic dementia. [Article]. *Brain and Language, 98*(2), 221-234.

Damasio, A., & Tranel, D. (1993). *Nouns and verbs are retrieved with differently distributed neural systems.* Paper presented at the Proc Natl Acad Sci USA.

Damian, M., & Martin, R. (1999). Interactivity of semantic and phonological factors in speech production. *Journal of Experimental Psychology: Learning, Memory & Cognition, 25*(2), 345-361.

Davis, C., Heidler-Gary, J., Gottesman, R., Crinion, J., Newhart, M., Moghekar, A., et al. (2010). Action versus animal naming fluency in subcortical dementia, frontal dementias, and Alzheimer's disease. [Article]. *Neurocase, 16*(3), 259-266.

de Zubaricay, G., Wilson, S., McMahon, K., & Muthiah, S. (2001). The semantic interference effect in the picture-word paradigm: An event related fMRI study emplying overt responses. *Human Brain Mapping, 14*, 218-227.

de Zubicaray, G., & McMahon, K. (2009). Auditory context effects in picture naming investigated with event-related fMRI. [Article]. *Cognitive Affective & Behavioral Neuroscience, 9*(3), 260-269.

de Zubicaray, G., McMahon, K., Eastburn, M., Pringle, A., & Lorenz, L. (2006). Classic identity negative priming involves accessing semantic representations in the left anterior temporal cortex. *Neuroimage, 33*(1), 383-390.

Dell, G. (1986). A spreading-activation theory of retrieval in sentence production. [Article]. *Psychological Review, 93*(3), 283-321.

Dell, G., & O'Seaghdha, P. (1991). Mediated and convergent lexical priming in language production - a comment. [Note]. *Psychological Review, 98*(4), 604-614.

Dell, G., & O'Seaghdha, P. (1992). Stages of lexical access in language production. *Cognition, 42*(1-3), 287-314.

Dell, G., & Reich, P. (1981). Stages in sentence production: An analysis of speech error data. *Journal of Verbal Learning and Verbal Behaviour, 20*, 611-629.

Dell, G., Schwartz, M., Martin, N., Saffran, E., & Gagnon, D. (1997). Lexical access in aphasic and nonaphasic speakers. *Psychological Review, 104*, 801-838.

Devlin, J., Matthews, P., & Rushworth, M. (2003). Semantic processing in the left inferior prefrontal cortex: A combined functional magnetic resonance imaging and transcranial magnetic stimulation study. *Journal Of Cognitive Neuroscience, 15*(1), 71-84.

Duncan, J. (2006). EPS Mid-Career Award 2004 - Brain mechanisms of attention. [Review]. *Quarterly Journal of Experimental Psychology, 59*(1), 2-27.

Duncan, J., & Owen, A. (2000). Common regions of the human frontal lobe recruited by diverse cognitive demands. [Review]. *Trends in Neurosciences, 23*(10), 475-483.

Ellis, A., & Lambon Ralph, M. (2000). Age of acquisition effects in adult lexical processing reflect loss of plasticity in maturing systems: Insights from connectionist networks. *Journal Of Experimental Psychology-Learning Memory And Cognition, 26*(5), 1103-1123.

Fenson, L., Dale, P., Reznick, J., Bates, E., Thal, D., & Pethick, S. (1994). Variability in early communicative development. [Article]. *Monographs of the Society for Research in Child Development, 59*(5), 1-189.

Fillingham, J., Sage, K., & Lambon Ralph, M. (2005). Further explorations and an overview of errorless and errorful therapy for aphasic word-finding difficulties: The number of naming attempts during therapy affects outcome. [Article]. *Aphasiology, 19*(7), 597-614.

Fischler, I. (1977). Semantic facilitation without association in a lexical decision task. [Article]. *Memory & Cognition, 5*(3), 335-339.

Foygel, D., & Dell, G. (2000). Models of impaired lexical access in speech production. [Article]. *Journal of Memory and Language, 43*(2), 182-216.

Francis, W., Corral, N., Jones, M., & Saenz, S. (2008). Decomposition of repetition priming components in picture naming. [Article]. *Journal of Experimental Psychology-General, 137*(3), 566-590.

Francis, W. N., & Kucera, H. (1982). *Frequency analysis of English usage: lexicon and grammar*. Boston: Houghton Mifflin.

Franklin, S., Buerk, F., & Howard, D. (2002). Generalised improvement in speech production for a subject with reproduction conduction aphasia. [Article]. *Aphasiology, 16*(10-11), 1087-1114.

Franklin, S., Howard, D., & Patterson, K. (1994). Abstract word meaning deafness. [Article]. *Cognitive Neuropsychology, 11*(1), 1-34.

Garrett, M. (1975). *The analysis of sentence production*. San Diego, CA: Academic Press.

Garrett, M. (1980). *Levels of processing in sentence production.* New York: Academic Press.

Glaser, W. (1992). Picture naming. [Review]. *Cognition, 42*(1-3), 61-105.

Glaser, W., & Dungelhoff, F.-J, (1984). The time course of picture-word interference. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 640-654.

Glaser, W., & Glaser, M. (1989). Context effect in Stroop-like word and picture processing. *Journal of Experimental Psychology-General, 118,* 13-42.

Gloor, P. (1997). *The temporal lobe and the limbic system*. Oxford: Oxford University Press.

Glosser, G., Friedman, R. B., Grugan, P. K., Lee, J. H., & Grossman, M. (1998). Lexical semantic and associative priming in Alzheimer's disease. [Article]. *Neuropsychology, 12*(2), 218-224.

Gold, B., & Buckner, R. (2002). Common prefrontal regions coactivate with dissociable posterior regions during controlled semantic and phonological tasks. *Neuron, 35*(4), 803-812.

Goodglass, H., & Kaplan, E. (1983). *The assessment of aphasia and related disorders* (2nd Edition ed.). Philadelphia: Lea & Febiger.

Gordon, J., & Dell, G. (2003). Learning to divide the labor: an account of deficits in light and heavy verb production. *Cognitive Science, 27*, 1-40.

Gough, P., Nobre, A., & Devlin, J. (2005). Dissociating linguistic processes in the left inferior frontal cortex with transcranial magnetic stimulation. *Journal Of Neuroscience, 25*(35), 8010-8016.

Hanley, J., & Kay, J. (1997). An effect of imageability on the production of phonological errors in auditory repetition. [Article]. *Cognitive Neuropsychology, 14*(8), 1065-1084.

Hanley, J., Kay, J., & Edwards, M. (2002). Imageability effects, phonological errors, and the relationship between auditory repetition and picture naming: Implications for models of auditory repetition. [Article]. *Cognitive Neuropsychology, 19*(3), 193-206.

Harley, T. (1984). A critique of top-down independent levels models of speech production:Evidence from non-plan-internal speech errors. *Cognitive Science, 8,* 191-219.

Harley, T. (1990). Phonological activation of semantic competitors during lexical access in speech production. *Language and Cognitive Processes, 8*, 291-209.

Harm, M., & Seidenberg, M. (2004). Computing the meanings of words in reading: Cooperative division of labor between visual and phonological processes. [Review]. *Psychological Review, 111*(3), 662-720.

Helmick, J., & Wipplinger, M. (1975). Effects of stimulus repetition on naming behaviour of an aphasic adult - clinical report. [Article]. *Journal of Communication Disorders, 8*(1), 23-29.

Hengst, J. A., Duff, M. C., & Dettmer, A. (2010). Rethinking repetition in therapy: Repeated engagement as the social ground of learning. [Proceedings Paper]. *Aphasiology, 24*(6-8), 887-901.

Hillis, A., & Caramazza, A. (1995). Representation of grammatical categories of words in the brain. *Journal of Cognitive Neuroscience, 7,* 396-407.

Hillis, A., Oh, S., & Ken, L. (2004). Deterioration of naming nouns versus verbs in primary progressive aphasia. *Annals of Neurology, 55,* 268-275.

Hinton, G. E., & Shallice, T. (1991). Lesioning an Attractor Network - Investigations of Acquired Dyslexia. *Psychological Review, 98*(1), 74-95.

Hodges, J., Graham, N., & Patterson, K. (1995). Charting the progression in semantic dementia: Implications for the organization of semantic memory. [Article]. *Memory, 3*(3-4), 463-495.

Hodgson, C. (1999). Object naming in the elderly: Some experiments and a model. Unpublished D.Phil. University of York.

Hodgson, C., & Ellis, A. (1998). Last in, first to go: Age of acquisition and naming in the elderly. *Brain and Language, 64*(1), 146-163.

Hodgson, C., & Lambon Ralph, M. (2008). Mimicking aphasic semantic naming errors in normal speech production: Evidence from a novel experimental paradigm. *Brain and Language, 104*(1), 89-101.

Hoffman, P., Jefferies, E., & Lambon Ralph, M. (2010). Ventrolateral Prefrontal Cortex Plays an Executive Regulation Role in Comprehension of Abstract Words: Convergent Neuropsychological and Repetitive TMS Evidence. [Article]. *Journal of Neuroscience, 30*(46), 15450-15456.

Holland, R., & Lambon Ralph, M. (2010). The Anterior Temporal Lobe Semantic Hub Is a Part of the Language Neural Network: Selective Disruption of Irregular Past Tense Verbs by rTMS. [Article]. *Cerebral Cortex, 20*(12), 2771-2775.

Holmes, S., Fitch, F., & Ellis, A. (2006). Age of acquisition affects object recognition and naming in patients with Alzheimer's disease. *Journal Of Clinical And Experimental Neuropsychology, 28*(6), 1010-1022.

Howard, D., & Gatehouse, C. (2006). Distinguishing semantic and lexical word retrieval deficits in people with aphasia. *Aphasiology, 20*(9-11), 921-950.

Howard, D., Hickin, J., Redmond, T., Clark, P., & Best, W. (2006). Re-visiting "semantic facilitation" of word retrieval for people with aphasia: Facilitation yes but semantic no. *Cortex, 42*(6), 946-962.

Howard, D., & Orchard-Lisle. (1984). On the origin of semantic errors in naming: Evidence from the case of a global aphasic. *Cognitive Neuropsychology, 1*, 163-190.

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

Howard, D., Patterson, K., Franklin, S., Orchard-Lisle, V., & Morton, J. (1985). The facilitation of picture naming in aphasia. [Article]. *Cognitive Neuropsychology, 2*(1), 49-80.

Humphreys, G., Lloyd-Jones, T., & Fias, W. (1995). Semantic interference effects on naming using a postcue procedure - tapping the links between semantics and phonology with pictures and words. *Journal Of Experimental Psychology-Learning Memory And Cognition, 21*(4), 961-980.

Humphreys, G., Riddoch, M., & Quinlan, P. (1988). Cascade Processes In Picture Identification. *Cognitive Neuropsychology, 5*(1), 67-103.

Janssen, N., Melinger, A., Mahon, B., Finkbeiner, M., & Caramazza, A. (2010). The word class effect in the picture-word interference paradigm. [Article]. *Quarterly Journal of Experimental Psychology, 63*(6), 1233-1246.

Jefferies, E., Baker, S., Doran, M., & Lambon Ralph, M. (2007). Refractory effects in stroke aphasia: A consequence of poor semantic control. *Neuropsychologia, 45*(5), 1065-1079.

Jefferies, E., Crisp, J., & Lambon Ralph, M. (2006). The impact of phonological or semantic impairment on delayed auditory repetition: Evidence from stroke aphasia and semantic dementia. [Article]. *Aphasiology, 20*(9-11), 963-992.

Jefferies, E., & Lambon Ralph, M. (2006). Semantic impairment in stroke aphasia versus semantic dementia: a case-series comparison. *Brain, 129*(8), 2132-2147.

Jefferies, E., Lambon Ralph, M., Jones, R., Bateman, D., & Patterson, K. (2004). Surface Dyslexia in Semantic Dementia: A Comparison of the Influence of Consistency and Regularity. *Neurocase, 10*(4), 290-299.

Jefferies, E., Patterson, K., Jones, R., & Lambon Ralph, M. (2009). Comprehension of Concrete and Abstract Words in Semantic Dementia. *Neuropsychology, 23*(4), 492-499.

Jefferies, E., Patterson, K., & Lambon Ralph, M. (2006). The natural history of late-stage "pure" semantic dementia. *12*(1), 1-14.

Jefferies, E., Patterson, K., & Lambon Ralph, M. (2008). Deficits of knowledge versus executive control in semantic cognition: Insights from cued naming. *Neuropsychologia, 46*, 649-658.

Jefferies, E., Sage, K., & Lambon Ralph, M. (2007). Do deep dyslexia, dysphasia and dysgraphia share a common phonological impairment? [Article]. *Neuropsychologia, 45*(7), 1553-1570.

Joanisse, M., & Seidenberg, M. (1999). Impairments in verb morphology after brain injury: A connectionist model. [Article]. *Proceedings of the National Academy of Sciences of the United States of America, 96*(13), 7592-7597.

Kay, J., Lesser, R., & Coltheart, M. (1992). *Psycholinguistic assessments of language processing in aphasia (PALPA)*. Hove, UK: Lawrence Erlbaum Associates.

Kello, C., & Plaut, D. (2000). Strategic control in word reading: Evidence from speeded responding in the tempo-naming task. *Journal of Experimental Psychology: Learning, Memory & Cognition, 26*(3), 719-750.

Kello, C., & Plaut, D. (2003). Strategic control over rate of processing in word reading: A computational investigation. *Journal of Memory and Language, 48*(1), 207-232.

Kello, C., Sibley, D., & Plaut, D. (2005). Dissociations in performance on novel versus irregular items: Single-route demonstrations with input gain in localist and distributed models. [Article]. *Cognitive Science, 29*(4), 627-654.

Kertesz, A. (1982). *The Western Aphasia Battery*. New York: Grune & Stratton.

Kertesz, A., & Poole, E. (2004). The aphasia quotient: The taxonomic approach to measurement of aphasic disability. *Canadian Journal of Neurological Sciences, 31*(2), 175-184.

La Heij, W., Dirkx, J., & Kramer, P. (1990). Categorical interference and associative priming in picture naming. *British Journal of Psychology, 81*, 511-525.

Lachman, R., & Lachman, J. (Eds.). (1980). *Picture naming: Retrieval and activation of long term memory*. Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc.

Laine, M., & Martin, N. (1996). Lexical retrieval deficit in picture naming: Implications for word production models. [Article]. *Brain and Language, 53*(3), 283-314.

Lambon Ralph, M. (1998). Distributed versus localist representations: Evidence from a study of item consistency in a case of classical anemia. [Article]. *Brain and Language, 64*(3), 339-360.

Lambon Ralph, M., McClelland, J., Patterson, K., Galton, C., & Hodges, J. (2001). No right to speak? The relationship between object naming and semantic impairment: Neuropsychological evidence and a computational model. *Journal of Cognitive Neuroscience, 13*(3), 341-356.

Lambon Ralph, M., Moriarty, L., & Sage, K. (2002). Anomia is simply a reflection of semantic and phonological impairments: Evidence from a case-series study. *Aphasiology, 16*(1-2), 56-82.

Lambon Ralph, M., & Patterson, K. (2008). Generalization and differentiation in semantic memory: Insights from semantic dementia. *Annals of the New York Academy of Science, 1124,* 61-76.

Lambon Ralph, M., Sage, K., & Roberts, J. (2000). Classical anomia: a neuropsychological perspective on speech production. *Neuropsychologia, 38*(2), 186-202.

Levelt, W. (1989). *Speaking: From intention to articulation*. Cambridge, MA: Massachusetts Institute of Technology.

Levelt, W. (1992). Accessing words in speech production - stages, processes and representations. [Article]. *Cognition, 42*(1-3), 1-22.

Levelt, W., Roelofs, A., & Meyer, A. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences Vol 22(1) Feb 1999, 1-75.*

Levelt, W., Schriefers, H., Vorberg, D., Meyer, A., Pechmann, T., & Havinga, J. (1991). The time course of lexical access in speech production - a study of picture naming. [Article]. *Psychological Review, 98*(1), 122-142.

Lucas, M. (2000). Semantic priming without association: A meta-analytic review. [Review]. *Psychonomic Bulletin & Review, 7*(4), 618-630.

Lupker, S. J. (1988). Picture Naming - an Investigation of the Nature of Categorical Priming. *Journal of Experimental Psychology-Learning Memory and Cognition, 14*(3), 444-455.

Luzzatti, C., Aggujaro, S., & Crepaldi, D. (2006). Verb-Noun double dissociation in aphasia: Theoretical and neuroanatomical foundations. [Article]. *Cortex, 42*(6), 875-883.

Luzzatti, C., Raggi, R., Zonca, G., Pistarini, C., Contardi, A., & Pinna, G. (2001). On the nature of selective impairment of verb and noun retrieval. *Cortex, 37,* 724-726.

Mahon, B., Costa, A., Peterson, R., Vargas, K., & Caramazza, A. (2007). Lexical selection is not by competition: A reinterpretation of semantic interference and facilitation effects in the picture-word interference paradigm. *Journal Of Experimental Psychology-Learning Memory And Cognition, 33*(3), 503-535.

Martin, A., & Chao, L. (2001). Semantic memory and the brain: Structure and processes. [Review]. *Current Opinion in Neurobiology, 11(2),* 194-201.

Martin, A., Ungerleider, L., & Haxby, J. (2000). *Category specificity and the brain: The sensory-motor model of semantic representations of objects*. Cambridge: MIT Press.

Martin, N., Dell, G., Saffran, E., & Schwartz, M. (1994). Origins of paraphasias in deep dysphasia - testing the consequences of a decay impairment to an interactive spreading activation model of lexical retrieval. [Article]. *Brain and Language, 47*(4), 609-660.

Martin, N., Fink, R., Laine, M., & Ayala, J. (2004). Immediate and short-term effects of contextual priming on word retrieval in aphasia. [Article]. *Aphasiology, 18*(10), 867-898.

Martin, N., & Laine, M. (2000). Effects of contextual priming on impaired word retrieval. [Article]. *Aphasiology, 14*(1), 53-70.

Martin, N., Weisberg, R., & Saffran, E. (1989). Variables influencing the occurrence of naming errors - implications for models of lexical retrieval. [Article]. *Journal of Memory and Language, 28*(4), 462-485.

Martin, R., & Cheng, T. (2006). Selection demands versus association strength in the verb generation task. *Psychonomic Bulletin and Review, 13*(3), 396-401.

Masterson, J., & Druks, J. (1998). Description of a set of 164 nouns and 102 verbs matched for printed word frequency, familiarity and age-of-acquisition. *Journal of Neurolinguistics, 11*(4), 331-354.

McClelland, J. (1978). On the time relations of cognitive processes: Theoretical explorations of systems of processes in cascade. [Article]. *Bulletin of the Psychonomic Society, 12*(4), 283.

McClelland, J., & Rumelhart, D. (1985). Distributed memory and the representation of general and specific information. [Article]. *Journal of Experimental Psychology-General, 114*(2), 159-188.

McClelland, J., & Rumelhart, D. (1987). *A distributed model of human learning and memory* (Vol. 2, Psychological and Biological Models). Cambridge, Massachusetts, USA

The Mit Press.

McEvoy, C. (1988). Automatic and strategic processes in picture naming. [Article]. *Journal of Experimental Psychology-Learning Memory and Cognition, 14*(4), 618-626.

Mechelli, A., Josephs, O., Lambon Ralph, M., McClelland, J., & Price, C. (2007). Dissociating stimulus-driven semantic and phonological effect during reading and naming. *Human Brain Mapping, 28*(3), 205-217.

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words - evidence of a dependence between retrieval operations. [Article]. *Journal of Experimental Psychology, 90*(2), 227-&.

Miceli, G., Silveri, M., Nocentini, U., & Caramazza, A. (1988). Patterns of dissociation in the comprehension and production of nouns and verbs. *Aphasiology, 2,* 351-358.

Miceli, G., Silveri, M., Villa, G., & Caramazza, A. (1984). On the basis for the agrammatic's difficulty in producing main verbs. *Cortex, 20*, 207-220.

Miller, G., & Felbaum, C. (1991). Semantic networks of English. *Cognition, 41,* 197-229.

Milner, B. (1963). Effects Of Different Brain Lesions On Card Sorting - Role Of Frontal Lobes. *Archives Of Neurology, 9*(1), 90-&.

Mitchell, D. B., & Brown, A. S. (1988). Persistent repetition in picture priming naming and its dissociation from recognition memory. [Article]. *Journal of Experimental Psychology-Learning Memory and Cognition, 14*(2), 213-222.

Miyake, A., Friedman, N., Emerson, M., Witzki, A., Howerter, A., & Wager, T. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. [Proceedings Paper]. *Cognitive Psychology, 41*(1), 49-100.

Morrison, C., Chappell, T., & Ellis, A. (1997). Age of acquisition norms for a large set of object names and their relation to adult estimates and other variables. [Article]. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 50*(3), 528-559.

Morrison, C., Ellis, A., & Quinlan, P. (1992). Age Of Acquisition, Not Word-Frequency, Affects Object Naming, Not Object Recognition. *Memory and Cognition, 20*(6), 705-714.

Moss, H., & Tyler, L. (1995). Investigating semantic memory impairments - the contribution of semantic priming. [Article]. *Memory, 3*(3-4), 359-395.

Nakamura, H., Nakanishi, M., Hamanaka, T., Nakaaki, S., & Yoshida, S. (2000). Semantic priming in patients with Alzheimer and semantic dementia. [Article]. *Cortex, 36*(2), 151-162.

Newman, S., Keller, T., & Just, M. (2007). Volitional control of attention and brain activation in dual task performance. *Human Brain Mapping, 28*(2), 109-117.

Nicholas, M., Obler, L., Albert, M., & Goodglass, H. (1985). Lexical retrieval in healthy aging. *Cortex, 21*, 595-606.

Nickels, L. (2002a). Improving word finding: Practice makes (closer to) perfect? [Article]. *Aphasiology, 16*(10-11), 1047-1060.

Nickels, L. (2002b). Theoretical and methodological issues in the cognitive neuropsychology of spoken word production. *Aphasiology, 16*(1-2), 3-19.

Noonan, K. (2010). *Conceptualising the void: Bridging the gap between semantic cognition and cognitive control.* . Unpublished Alternative format, University of Manchester, Manchester.

Noonan, K., Jefferies, E., Corbett, F., & Lambon Ralph, M. (2010). Elucidating the nature of deregulated semantic cognition in semantic aphasia: Evidence for the roles of prefrontal and temporoparietal cortices. *Journal of Cognitive Neuroscience, 22*, 1597-1613.

Noonan, K., Jefferies, E., & Lambon Ralph, M. (submitted). The dual neural bases of semantic regulation: A direct comparison of deficits to semantic cognition following temporoparietal, frontal or anterior temporal lesions.

Noppeney, U., Phillips, J., & Price, C. (2004). The neural areas that control the retrieval and selection of semantics. [Article]. *Neuropsychologia, 42*(9), 1269-1280.

Oppenheim, G., Dell, G., & Schwartz, M. (2010). The dark side of incremental learning: A model of cumulative semantic interference during lexical access in speech production. [Article]. *Cognition, 114*(2), 227-252.

Patterson, K., & Lambon Ralph, M. (1999). Selective disorders of reading? [Review]. *Current Opinion in Neurobiology, 9*(2), 235-239.

Patterson, K., & Plaut, D. (2009). "Shallow Draughts Intoxicate the Brain": Lessons from Cognitive Science for Cognitive Neuropsychology. [Article]. *Topics in Cognitive Science, 1*(1), 39-58.

Peers, P., Ludwig, C., Rorden, C., Cusack, R., Bonfiglioli, C., Bundesen, C., et al. (2005). Attentional functions of parietal and frontal cortex. *Cerebral Cortex, 15*(10), 1469-1484.

Perani, D., Cappa, S., Schnur, T., Tettamanti, M., Collina, S., Rosa, M., et al. (1999). The neural correlates of verb and noun processing: A PET study. *Brain, 122*(12), 2337-2344.

Peterson, R., & Savoy, P. (1998). Lexical selection and phonological encoding during language production. *Journal of Experimental Psychology: Learning, Memory & Cognition, 24*, 539-557.

Plaut, D. (2002). Graded modality-specific specialisation in semantics: A computational account of optic aphasia. [Review]. *Cognitive Neuropsychology, 19*(7), 603-639.

Plaut, D., & Kello, C. (1999). The emergence of phonology from the interplay of speech comprehension and production: A distributed connectionist approach. In B. MacWhinney (Ed.), *The Emergence of Language* (pp. 381-415). Mahweh, NJ: Erlbaum.

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

Plaut, D., & Shallice, T. (1993). Deep dyslexia - A case study of connectionist neuropsychology. *Cognitive Neuropsychology, 10*, 377-500.

Pobric, G., Jefferies, E., & Lambon Ralph, M. (2007). Anterior temporal lobes mediate semantic representation: Mimicking semantic dementia by using rTMS in normal participants. *104*(50), 20137-20141.

Quillian, M. (1967). Word concepts: A theory and simulation of some basic semantic capabilities. *Behavioural Science, 12*, 410-430.

Randall, B., & Tyler, L. (2003). The trouble with nouns and verbs. *Brain and Language, 87*(1), 53-54.

Rapcsak, S., Beeson, P., Henry, M., Leyden, A., Kim, E., Rising, K., et al. (2009). Phonological dyslexia and dysgraphia: Cognitive mechanisms and neural substrates. [Review]. *Cortex, 45*(5), 575-591.

Rapp, B., & Goldrick, M. (2000). Discreteness and interactivity in spoken word production. *Psychological Review, 107*, 460-499.

Raven, J. (1962). *Coloured progressive matrices sets A, AB, B*. London: HK Lewis.

Raymer, A. M., & Ellsworth, T. A. (2002). Response to contrasting verb retrieval treatments: A case study. [Article]. *Aphasiology, 16*(10-11), 1031-1045.

Renvall, K., Laine, M., Laakso, M., & Martin, N. (2003). Anomia treatment with contextual priming: A case study. [Article]. *Aphasiology, 17*(3), 305-328.

Renvall, K., Laine, M., & Martin, N. (2005). Contextual priming in semantic anomia: A case study. [Article]. *Brain and Language, 95*(2), 327-341.

Renvall, K., Laine, M., & Martin, N. (2007). Treatment of anomia with contextual priming: Exploration of a modified procedure with additional semantic and phonological tasks. [Article]. *Aphasiology, 21*(5), 499-527.

Rhee, J., Antiquena, P., & Grossman, M. (2001). Verb comprehension in frontotemporal degeneration: The role of grammatical, semantic and executive components. *Neurocase, 7*(2), 173-184.

Roach, A., Schwartz, M., Martin, N., Grewel, R., & Brecher, A. (1996). The Philadelphia Naming Test: Scoring and rationale. *Clinical Aphasiology, 24*, 121-134.

Robertson, I. H., Ward, T., & Ridgeway, V. (1993). Test of Everyday Attention - Preliminary Norms, Reliability, and Validity. *Journal of Clinical and Experimental Neuropsychology, 15*(3), 413-413.

Roelofs, A. (1993). Testing a non-decompositional theory of lemma retrieval in speaking - retrieval of verbs. *Cognition, 47*(1), 59-87.

Roelofs, A. (1997). The WEAVER model of word-form encoding in speech production. *Cognition, 64*(3), 249-284.

Rogers, T., Lambon Ralph, M., Garrard, P., Bozeat, S., McClelland, J., Hodges, J., et al. (2004). Structure and deterioration of semantic memory: A neuropsychological and computational investigation. *Psychological Review, 111*(1), 205-235.

Rumelhart, D., Hinton, G., & Williams, R. (Eds.). (1986). *Learning internal representations by error propagation* (Vol. 1). Cambridge, MA: MIT Press.

Saccuman, M., Cappa, S., Bates, E., Arevalo, A., Della Rosa, P., Danna, M., et al. (2006). The impact of semantic reference on word class: An fMRI study of action and object naming. [Review]. *Neuroimage, 32*(4), 1865-1878.

Saffran, E. M. (2000). The organization of semantic memory: In support of a distributed model. [Article]. *Brain and Language, 71*(1), 204-212.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime User's Guide*. Pittsburgh: Psychology Software Tools, Inc.

Schriefers, H., Meyer, A., & Levelt, W. (1990). Exploring the time course of lexical access in language production - picture-word interference studies. [Article]. *Journal of Memory and Language, 29*(1), 86-102.

Schwartz, M., Dell, G., Martin, N., Gahl, S., & Sobel, P. (2006). A case-series test of the interactive two-step model of lexical access: Evidence from picture naming. *Journal of Memory and Language, 54*(2), 228-264.

Schwartz, M., Segal, M., Veramonti, T., Ferraro, M., & Buxbaum, L. (2002). The Naturalistic Action Test: A standardised assessment for everyday action impairment. [Article]. *Neuropsychological Rehabilitation, 12*(4), 311-339.

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

Shapiro, K., Shelton, J., & Caramazza, A. (2000). Grammatical class in lexical production and morphological processing: Evidence from a case of fluent aphasia. *Cognitive Neuropsychology, 17*(8), 665-682.

Silveri, M. C., Perri, R., & Cappa, A. (2003). Grammatical class effects in brain-damaged patients: Functional locus of noun and verb deficit. *Brain and Language, 85*(1), 49-66.

Silveri, M. C., Salvigni, B. L., Cappa, A., Della Vedova, C., & Pulopolo, M. (2003). Impairment of verb processing in, frontal variant-frontotemporal dementia: A dysexecutive symptom. *Dementia And Geriatric Cognitive Disorders, 16*(4), 296-300.

Small, S., Hart, J., Nguyen, T., & Cordon, B. (1995). Distributed representations of semantic knowledge in the brain. [Article]. *Brain, 118*, 441-453.

Snodgrass, J., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6*(2), 174-215.

Snyder, H., Feigenson, K., & Thompson-Schill, S. (2007). Prefrontal cortical response to conflict during semantic and phonological tasks. *Journal Of Cognitive Neuroscience, 19*(5), 761-775.

Soni, M., Lambon Ralph, M., Noonan, K., Ehsan, S., Hodgson, C., & Woollams, A. (2009). "L" is for tiger: Effects of phonological (mis)cueing on picture naming in semantic aphasia. *Journal of Neurolinguistics, 22*(6), 538-547.

Soni, M., Lambon Ralph, M., & Woollams, A. (in press). "W" is for bath: Can associative errors be cued? *Journal of Neurolinguistics, In Press*.

Soni, M., Lambon Ralph, M., & Woollams, A. (submitted). Repetition priming of picture naming in semantic aphasia: The impact of intervening items. *Aphasiology, submitted*.

Stark, C., & McClelland, J. (2000). Repetition priming of words, pseudowords, and nonwords. [Article]. *Journal of Experimental Psychology-Learning Memory and Cognition, 26*(4), 945-972.

Stuss, D., Levine, B., Alexander, M., Hong, J., Palumbo, C., Hamer, L., et al. (2000). Wisconsin Card Sorting Test performance in patients with focal frontal and posterior brain damage: effects of lesion location and test structure on separable cognitive processes. *Neuropsychologia, 38*(4), 388-402.

Swiftsound. Wavepad (Version 4.03): NCH.

Szekely, A., D'Amico, S., Devescovi, A., Federmeier, K., Herron, D., Iyer, G., et al. (2003). Timed picture naming: Extended norms and validation against previous studies. *Behavior Research Methods Instruments & Computers, 35*(4), 621-633.

Thompson-Schill, S., Bedny, M., & Goldberg, R. (2005). The frontal lobes and the regulation of mental activity. *Current Opinion In Neurobiology, 15*(2), 219-224.

Thompson-Schill, S., & Botvinick, M. (2006). Resolving conflict: A response to Martin and Cheng. *Psychonomic Bulletin and Review, 13*(3), 402-408.

Thompson-Schill, S., D'Esposito, M., Aguirre, G., & Farah, M. (1997). Role of left inferior prefrontal cortex in retrieval of semantic knowledge: A reevaluation. *Proceedings of the National Academy of Science, 94*, 14792-14797.

Thompson-Schill, S., Swick, D., Farah, M., D'Esposito, M., Kan, I., & Knight, R. (1998). Verb generation in patients with focal frontal lesions: A neuropsychological test of neuroimaging findings. *Proceedings of the National Academy of Science, 95*, 15855-15860.

Tree, J. J., & Hirsh, K. W. (2003). Sometimes faster, sometimes slower: associative and competitor priming in picture naming with young and elderly participants. [Article]. *Journal of Neurolinguistics, 16*(6), 489-514.

Tyler, L., Bright, P., Fletcher, P., & Stamatakis, E. (2004). Neural processing of nouns and verbs: the role of inflectional morphology. *Neuropsychologia, 42*(4), 512-523.

Tyler, L., Russell, R., Fadili, J., & Moss, H. (2001). The neural representation of nouns and verbs: PET studies. *Brain, 124*(8), 1619-1634.

Valdois, S., Carbonnel, S., David, D., Rousset, S., & Pellat, J. (1995). Confrontation of PDP models and dual-route models through the analysis of a case of deep dysphasia. *Cognitive Neuropsychology, 12*(7), 681-724.

Vitkovitch, M., Cooper-Pye, E., & Leadbetter, A. (2006). Semantic priming over unrelated trials: Evidence for different effects in word and picture naming. [Proceedings Paper]. *Memory & Cognition, 34*(3), 715-725.

Vitkovitch, M., & Humphreys, G. (1991). Perseverant Responding In Speeded Naming Of Pictures - It's In The Links. *Journal of Experimental Psychology-Learning, Memory and Cognition, 17*(4), 664-680.

Vitkovitch, M., Humphreys, G., & Lloyd-Jones, T. (1993). On Naming A Giraffe A Zebra - Picture Naming Errors Across Different Object Categories. *Journal of Experimental Psychology-Learning, Memory and Cognition, 19*(2), 243-259.

Vitkovitch, M., Rutter, C., & Read, A. (2001). Inhibitory effects during object name retrieval: The effect of interval between prime and target on picture naming responses. *British Journal Of Psychology, 92*, 483-506.

Vitkovitch, M., & Tyrrell, L. (1995). Sources Of Disagreement In Object Naming. *Quarterly Journal of Experimental Psychology, 48*(4), 822-848.

Wagner, A., Pare-Blagoev, E., Clark, J., & Poldrack, R. (2001). Recovering meaning: Left prefrontal cortex guides controlled semantic retrieval. *Neuron, 31*(2), 329-338.

Warrington, E. (1975). Selective impairment of semantic memory. *Quarterly Journal of Experimental Psychology, 27*, 635-657.

Walsh, V., & Rushworth, M. (1999). A primer of magnetic stimulation as a tool for neuropsychology. [Article]. *Neuropsychologia, 37*(2), 125-135.

Warrington, E., & James, M. (1991). *Visual object and space perception*. London: Pearson Assessment.

Warrington, E., McKenna, P., & Orpwood, L. (1998). Single word comprehension: A concrete and abstract word synonym test. *Neuropsychological Rehabilitation, 8*(2), 143-154.

Wechsler, D. (1997). *The Wechsler adult intelligence scale* (3rd ed.). San Antonio, TX: Psychological Corporation.

Wheeldon, L., & Monsell, S. (1992). The locus of repetition priming in spoken word production. [Article]. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 44*(4), 723-761.

Wheeldon, L., & Monsell, S. (1994). Inhibition of spoken word production by priming a semantic competitor. [Article]. *Journal of Memory and Language, 33*(3), 332-356.

Wilshire, C., & Saffran, E. (2005). Contrasting the effects of phonological priming in aphasic word production. *Cognition, 95*, 31-71.

Wilshire, C. E., Keall, L. M., Stuart, E. J., & O'Donnell, D. J. (2007). Exploring the dynamics of aphasic word production using the picture-word interference task: A case study. *Neuropsychologia, 45*(5), 939-953.

Wisenburn, B., & Mahoney, K. (2009). A meta-analysis of word-finding treatments for aphasia. [Article]. *Aphasiology, 23*(11), 1338-1352.

Woollams, A., Cooper-Pye, E., Hodges, J., & Patterson, K. (2008). Anomia: A doubly typical signature of semantic dementia. *Neuropsychologia, 46*, 2503-2514.

Woollams, A., Joanisse, M., & Patterson, K. (2009). Past-tense generation from form versus meaning: Behavioural data and simulation evidence. [Article]. *Journal of Memory and Language*, *61*(1), 55-76.

Woollams, A., Lambon Ralph, M., Plaut, D., & Patterson, K. (2007). SD-squared: On the association between semantic dementia and surface dyslexia. [Review]. *Psychological Review*, *114*(2), 316-339.

Zingeser, L., & Berndt, R. (1990). Retrieval of nouns and verbs in agrammatism and anomia. *Brain and Language, 39*, 14-32.

APPENDICES

Appendix 2A 1: Imageability confounded list, object stimuli and norms

Item	Imageability	Frequency[20]	AoA	Visual Complexity	Familiarity	Name Agr't	Baseline Tempo
anchor	5.39	0	3.74	3.7	1.59	100	837
ball	6.5	1.63	1.37	2.58	4.24	95	943
bath	6.28	1.28	1.43	2.6	5.89	97.5	825
beard	6.03	1.04	2.65	2.98	2.83	100	975
bee	6.31	1.63	1.95	4.68	3.16	95	1017
book	6.19	2.88	1.76	3.15	6.41	100	675
bridge	6.11	1.91	2.61	5.28	3.53	97.5	979
candle	6.33	0.7	2.7	2	3.91	100	787
castle	6.28	1.07	2.68	3.8	2.26	100	929
cheese	5.97	0.78	1.86	3.05	6.19	100	669
cherry	6.11	0.3	2.76	1.68	2.08	100	905
church	5.86	2.08	2.57	3.73	3.27	100	801
cigar	6.25	0.3	3.78	4.13	1.71	100	1096
cigarette	6.5	1.58	3	2.35	4.53	100	891
drum	6.31	0.95	2.17	2.75	2.54	100	901
elephant	6.64	0.95	2.43	3.23	2.11	100	749
feather	5.86	0.6	2.57	4.85	2.58	92.5	1032
fish	6.42	1.71	1.85	3.93	3.43	100	691
frog	6.36	1.11	2.26	5.33	2.09	100	803
grapes	6.25	0	2.48	3.68	3.11	100	784
horse	6.5	1.6	1.89	3.08	2.81	100	822
ladder	6.08	1.08	2.43	3.1	3.86	100	767
money	5.81	2.75	2.37	5.88	6.38	95	909
pencil	6.36	0.7	2.13	2.03	6.14	100	648
piano	6.42	0	2.67	5.73	2.84	92.5	747
pig	6.22	0	2.05	3.7	2.57	100	838
pipe	5.83	1.45	3.24	3.9	2.54	100	967
pram	5.83	0.3	1.87	3.83	2.03	97.5	978
scissors	6.19	0.3	2.43	2.1	5.16	100	732
waiter	5.44	0.85	3.84	4.45	3.23	100	1166
MEAN	**6.15**	**1.05**	**2.45**	**3.58**	**3.50**	**98.75**	**862**
SD	**0.30**	**0.77**	**0.62**	**1.12**	**1.48**	**2.34**	**128**

---

[20] All references to the measure ‘frequency’ in this section refer to log lemma frequency as used by Francis and Kuçera (1982).

Appendix 2A 2: Imageability confounded list, action stimuli and norms

Item	Imageability	Frequency	AoA	Visual Complexity	Familiarity	Name Agr't	Baseline Tempo
bending	3.81	1.81	2.73	3.23	3.81	100	1369
bouncing	3.92	0.85	2.58	3.9	1.98	97.5	1006
combing	4.22	0	2.2	4	4.31	97.5	912
crying	3.58	1.11	1.53	3.58	4.52	95	742
digging	4.17	1.28	2.53	4.3	2.29	100	849
diving	4.5	0.3	3.7	4.38	2.76	97.5	808
dripping	3.47	0.3	3.13	2.38	3.1	100	1016
dropping	3.47	2	2.23	3.98	3.38	100	938
kneeling	4.14	0.6	2.62	3.83	3.88	100	938
knocking	4	1.66	2.55	4.08	3.86	97.5	804
melting	3.53	1.08	3.28	4.6	3.07	100	1236
pinching	3.92	0.95	2.43	3.7	2.67	97.5	924
posting	4.06	0.7	2.85	4.55	5.55	97.5	979
praying	4.42	0.3	2.57	4.55	3.43	92.5	815
pushing	3.86	1.67	1.88	3.93	4.19	97.5	1096
raking	3.5	0.3	3.53	3.5	5.12	100	1138
reading	4.69	2.75	2.25	4.33	6.5	100	1037
riding	4.25	1.2	2.45	4.73	3.98	100	974
ringing	3.58	1.6	2.83	2.65	5.64	97.5	1097
rocking	3.06	0	2.65	4.15	2.64	100	1377
sewing	4.28	0.78	3.23	4.48	2.76	95	1058
shooting	4.39	1.45	3.15	4.33	2.31	100	786
skipping	3.75	0.6	2.6	3.95	1.98	100	760
stroking	3.97	0	2.6	3.63	3.76	97.5	1172
tying	3.56	1.61	2.53	4.45	4	100	941
washing	4.56	1.6	1.69	4.15	6.36	100	884
waving	4.25	1.04	1.78	4.75	4.43	100	912
writing	4.89	2.86	2.33	3.68	6.43	100	1035
yawning	4.39	0	2.64	3.03	5.24	97.5	965
MEAN	**4.01**	**1.05**	**2.59**	**3.96**	**3.93**	**98.53**	**985**
SD	**0.43**	**0.78**	**0.51**	**0.59**	**1.33**	**1.95**	**164**

Appendix 2B 1: Imageability controlled list, object stimuli and norms

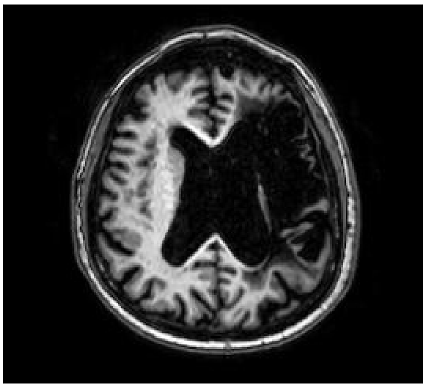
Item	Imageability	Frequency	AoA	Visual Complexity	Familiarity	Name Agr’t	Baseline tempo
brain	5.47	1.6	3.22	4.55	5.37	100	675
chain	5.47	1.26	3.19	3.68	2.98	100	619
conductor	4.36	0.95	4.09	4	2.69	95	827
devil	5.42	1.11	3.41	4.58	1.83	97.5	822
fruit	5.42	1.34	2.26	4.7	5.53	92.5	728
hammock	5.11	0	4.02	3.2	1.98	100	756
judge	4.25	1.82	4.41	4.6	2.09	97.5	909
king	5.36	1.7	2.48	5.23	2.11	100	691
knot	4.58	0	2.86	2.95	3.4	100	777
picnic	5.36	0.3	2.54	6.15	2.84	100	798
picture	4.83	2.34	1.76	5.15	5.03	95	882
pocket	5.36	1.34	2.23	3.68	4.83	100	680
saddle	5.14	0.3	3.38	3.63	2.28	100	872
shower	5.42	0.7	2.93	3.2	6.05	100	574
slide	4.78	1.43	2	2.88	2.7	97.5	643
stool	4.75	0.3	2.78	2.78	4.73	100	695
sword	5.44	0.7	3.04	2.25	1.81	100	623
ticket	5.47	1.79	3.04	3.18	5.49	100	1139
waitress	5.44	0.6	3.83	5.03	3	97.5	1203
whistle	4.86	0.48	2.54	2.65	2.56	100	727
MEAN	**5.11**	**1.00**	**3.00**	**3.90**	**3.47**	**98.63**	**782**
SD	**0.40**	**0.67**	**0.72**	**1.05**	**1.45**	**2.22**	**163**

Appendix 2B 2: Imageability controlled list, action stimuli and norms

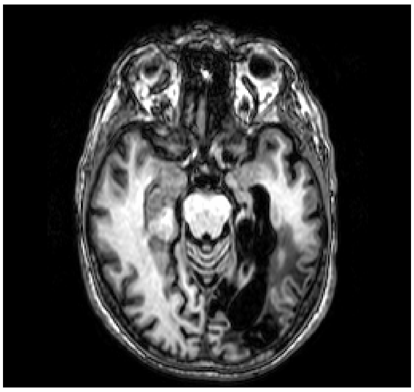
Item	Imageability	Frequency	AoA	Visual Complexity	Familiarity	Name Agr’t	Baseline tempo
bleeding	4.97	0.78	2.45	4	3.69	97.5	883
dancing	4.86	1.56	2.35	4.7	4.36	100	586
drinking	5.08	1.7	1.5	4	6.48	100	536
driving	5.14	2.06	2.83	4.88	5.64	97.5	600
fishing	4.89	0.85	3.35	5.6	2.05	97.5	750
flying	4.81	1.6	2.5	4.28	3.98	100	704
ironing	4.78	0	3.23	5.3	3.86	100	614
jumping	4.78	1.56	1.85	3.93	3.4	95	688
kicking	4.69	1.2	2.1	4.28	2.69	100	574
kissing	5.47	1.15	1.83	3.55	5.48	100	572
painting	4.92	1.46	2.1	3.83	3.52	97.5	603
raining	5.03	0.7	2.13	2.6	5.48	100	617
running	4.89	2.43	1.88	3.58	4.55	100	706
skating	4.61	0.48	3.23	3.5	2.1	97.5	784
skiing	4.92	1.34	4.03	3.88	2.05	100	631
smiling	5.44	1.04	1.43	3.45	6.19	95	759
smoking	5.31	1.42	3.1	4.38	4.71	100	724
snowing	5.42	0.3	2.18	4.35	3.26	100	640
swimming	5.17	1.48	2.43	4.33	4.21	100	562
walking	5.14	2.09	1.68	3.53	6.45	100	751
MEAN	**5.02**	**1.26**	**2.41**	**4.10**	**4.21**	**98.88**	**664**
SD	**0.25**	**0.62**	**0.69**	**0.69**	**1.42**	**1.72**	**91**

Appendix 3A: Structural scans for 5/7 patients in the present study showing lesion area (scans for JD and PG not available)

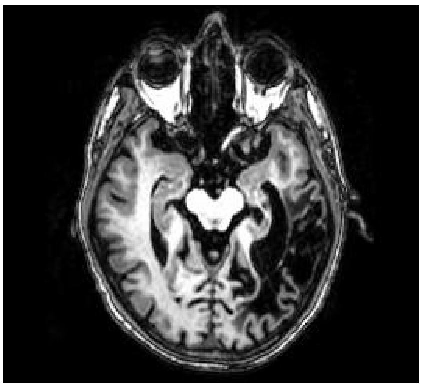
NY



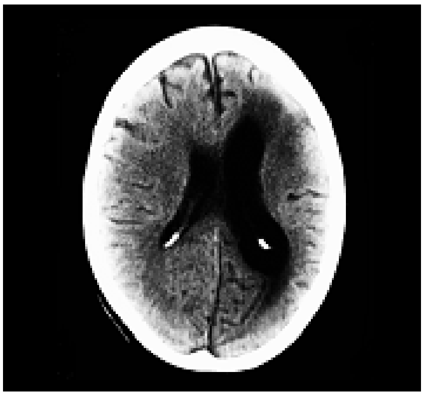
HN



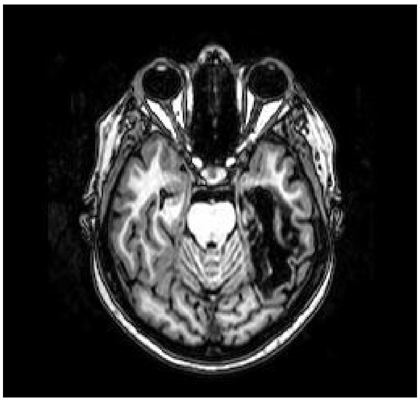
SC



BB*



ME



* BB = CT scan. Remaining patients = MRI.

Appendix 3B: Stimuli and cues from Hodgson and Lambon Ralph (2008) with mean accuracy for each cue condition from current patient data

Item	Correct cue	Miscue	% correct (neutral cue)	% correct (correct cue)	% correct (miscue)
apple	a	p	85.7	100.0	100.0
arm	a	l	100.0	57.1	42.9
bike	b	k	85.7	100.0	85.7
brush	b	k	100.0	71.4	71.4
bus	b	k	85.7	85.7	71.4
butterfly	b	m	57.1	71.4	57.1
car	k	b	85.7	85.7	71.4
cat	k	d	71.4	85.7	42.9
caterpillar	k	b	85.7	57.1	42.9
chair	ch	t	71.4	85.7	57.1
cloud	k	s	57.1	71.4	42.9
coat	k	h	85.7	71.4	42.9
comb	k	b	71.4	71.4	57.1
cow	k	b	100.0	71.4	71.4
cup	k	m	100.0	100.0	57.1
desk	d	ch	28.6	71.4	42.9
dog	d	k	71.4	85.7	85.7
door	d	w	85.7	100.0	85.7
dress	d	k	57.1	71.4	85.7
ear	ee	n	71.4	71.4	57.1
envelope	e	l	57.1	57.1	28.6
eye	i	n	71.4	100.0	85.7
finger	f	th	85.7	57.1	100.0
flower	f	r	57.1	85.7	57.1
foot	f	m	85.7	57.1	57.1
goat	g	sh	42.9	57.1	57.1
hand	h	f	100.0	85.7	85.7
hat	h	k	71.4	85.7	57.1
horse	h	d	85.7	100.0	57.1
jumper	j	k	71.4	71.4	71.4
knife	n	f	85.7	100.0	100.0
leg	l	a	57.1	100.0	85.7
lemon	l	o	57.1	100.0	57.1
lion	l	t	57.1	71.4	57.1
mitten	m	g	57.1	57.1	14.3
moon	m	s	57.1	71.4	71.4
mouse	m	k	85.7	42.9	71.4
needle	n	p	57.1	85.7	71.4
nose	n	ee	100.0	71.4	71.4
orange	o	l	42.9	71.4	71.4
pear	p	a	71.4	57.1	57.1
rabbit	r	h	85.7	85.7	100.0
screw	s	n	57.1	57.1	42.9
screwdriver	s	h	71.4	71.4	71.4
seal	s	w	57.1	57.1	28.6
sheep	sh	l	42.9	71.4	28.6
shirt	sh	t	57.1	85.7	57.1
skirt	s	d	42.9	57.1	0.0
snail	s	k	85.7	85.7	42.9
sock	s	sh	57.1	85.7	57.1
spider	s	f	57.1	85.7	42.9
spoon	s	f	85.7	100.0	100.0
sun	s	m	85.7	85.7	85.7
swan	s	d	71.4	85.7	57.1
table	t	ch	71.4	71.4	57.1
thumb	th	f	85.7	85.7	85.7
tiger	t	l	28.6	71.4	42.9
trumpet	t	h	57.1	71.4	71.4

TV	t	r	100.0	100.0	85.7
vase	v	j	71.4	71.4	57.1

Appendix 3C: Error classification used originally in (Hodgson & Lambon Ralph, 2008)

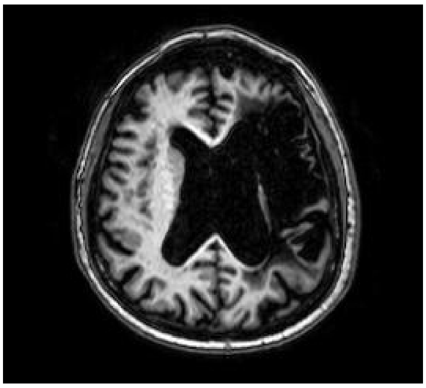
The same classification of three error types used by Hodgson and Lambon Ralph (2008) was also employed here: semantic errors, superordinate (e.g., ORANGE → ‘fruit’) or category co-ordinate (e.g. FOX → ‘dog’ or SNAIL → ‘snake’); omission (no response) errors; and other errors. The latter error category covered a variety of error categories for which normal participants make few such responses (i.e., naming part of the target (e.g., HAND → ‘finger’); visually but not semantically similar objects (e.g., ORANGE → ‘ball’); functionally or associatively related items (e.g., RABBIT → ‘carrot’); real words or nonwords phonologically but not semantically similar to the target[21]; a description or circumlocution (e.g., SCALES → ‘weighing thing’)).

---

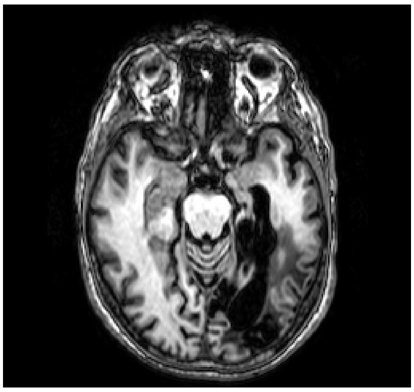
[21] Phonological similarity in this context means that target and response shared one or more phonemes in the same structural position (e.g., CONE → ‘phone’) or two or more phonemes in any position, e.g., FISH → ‘shaft’ (Dell et al., 1997).

Appendix 4A: Structural scans for 6/7 patients in the present study showing lesion area (scan for PG not available)

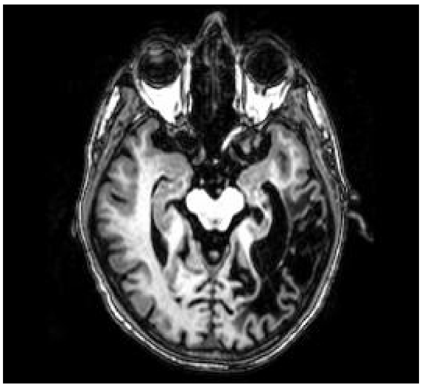
NY



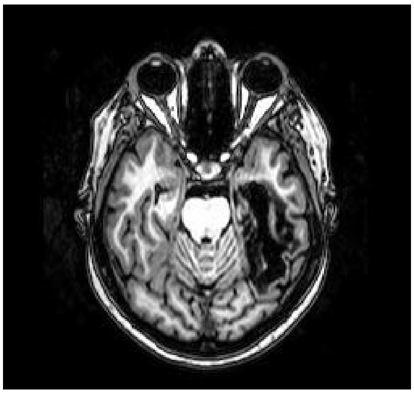
HN



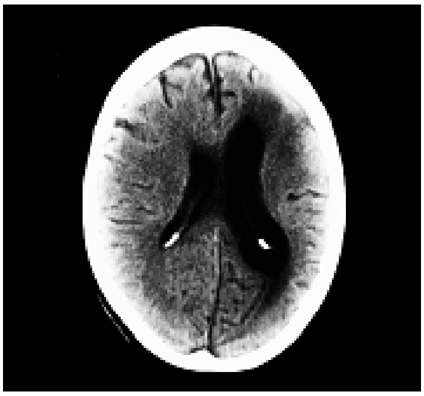
SC



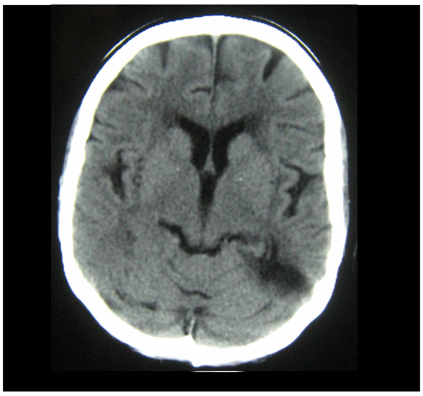
ME



BB



EW



Appendix 4B: Items and their co-ordinates and associates with cue phonemes

Item	Correct	Co-ordinate	Associate	Neutral
anchor	a	b (boat)	s (sea)	f
axe	a	s (saw)	t (tree)	r
bath	b	sh (shower)	w (water)	o
book	b	m (magazine)	r (reading)	ch
bowl	b	p (plate)	s (soup/cereal)	a
candle	k	l (lamp)	w (wax)	g
clock	k	w (watch)	t (time)	dj
comb	k	b (brush)	h (hair)	f
cow	k	sh (sheep)	m (milk)	w
cup	k	g (glass)	t (tea)	sh
desk	d	t (table)	w (work)	g
duck	d	s (swan)	p (pond)	ii
finger	f	h (hand)	r (ring)	w
flute	f	k (clarinet)	m (music)	dj
foot	f	l (leg)	sh (shoe)	ch
giraffe	dj	e (elephant)	t (tall)	b
glass	g	k (cup)	w (water)	e
glasses	g	k (contacts)	ei (eye)	w
glove	g	m (mitten)	h (hand)	r
goat	g	sh (sheep)	f (farm)	v
grapes	g	a (apples)	w (wine)	l
harp	h	v (violin)	m (music)	sh
helicopter	h	p (plane)	f (flying)	a
jumper	dj	t (t-shirt)	w (wool)	e
lips	l	ei (eyes)	k (kiss)	v
lobster	l	k (crab)	s (sea)	g
medal	m	t (trophy)	g (gold)	l
mermaid	m	f (fish)	s (sea)	ch
microwave	m	u (oven)	k (kitchen)	ei
mountain	m	h (hill)	s (snow)	dj
mouse	m	r (rat)	ch (cheese)	d
nun	n	p (priest)	ch (church)	t
nurse	n	d (doctor)	h (hospital)	l
orange	o	l (lemon)	dj (juice)	w
pig	p	k (cow)	m (mud)	dj
pond	p	l (lake)	f (fish/frog)	k
purse	p	w (wallet)	m (money)	f
ring	r	b (bracelet)	f (finger)	sh
saw	s	h (hammer)	w (wood)	v
sheep	sh	k (cow)	w (wool)	b
sock	s	sh (shoe)	f (foot)	o
swing	s	r (roundabout)	ch (child)	d
toaster	u	u (oven)	b (bread)	l
towel	t	f (flannel)	sh (shower)	g
trousers	t	s (skirt)	l (legs)	r
violin	v	g (guitar)	m (music)	sh
watch	w	b (bracelet)	t (time)	ii
whale	w	f (fish)	s (sea)	r

Appendix 4C: Norms for target items from Morrison et al. (1997)

Item	AoA (months)	Visual Complexity	Combined Log Freq	Name Agr't	Phonemes	RT
anchor	102.5	2.3	0.78	1	4	951
axe	62.5	1.85	0.00	1	3	1085
bath	23.4	3.1	1.65	0.95	3	966
book	22.1	2.45	2.43	1	3	656
bowl	38.5	1.65	1.43	1	3	831
candle	38.5	2.25	1.62	1	5	831
clock	22.1	2.6	0.7	1	4	772
comb	38.5	2	1.78	1	3	717
cow	23.4	3.85	1.92	1	2	1079
cup	25.1	2.05	2.12	0.96	3	852
desk	86.5	3.3	1.85	0.91	4	975
duck	22.1	3.05	2.1	0.82	3	958
finger	23.4	2.35	0.48	1	5	775
flute	92.5	4.15	1.73	0.95	4	1402
foot	38.5	1.85	2.00	0.96	3	758
giraffe	38.5	4.35	2.52	0.96	5	783
glass	44.5	1.95	1.36	0.96	4	845
glasses	23.4	2.6	1.52	0.86	6	758
glove	44.5	2.7	0.78	0.91	4	848
goat	56.5	2.8	1.56	0.96	3	972
grapes	56.5	3.35	1.81	1	5	849
harp	126.5	3.7	1.15	1	3	914
helicopter	23.4	4.2	1.08	0.82	9	793
jumper	38.5	2.85	0.48	0.77	5	1122
lips	50.5	1.55	1.79	0.68	4	696
lobster	86.5	4.25	1.73	0.91	6	1289
medal	86.5	2.1	0.85	0.95	4	1197
mermaid	50.5	4.35	0.30	1	5	*
microwave	68.5	3.6	0.48	0.95	8	*
mountain	62.5	2.3	0.95	0.9	6	921
mouse	23.4	3	1.45	0.82	3	961
nun	102.5	2.8	0.78	1	3	*
nurse	50.5	4.3	1.51	1	3	1039
orange	38.5	2.12	0.48	1	5	1098
pig	23.4	2.7	0.48	0.96	3	855
pond	44.5	4.05	1.18	1	4	*
purse	44.5	2.4	1.00	0.95	3	772
ring	50.5	2.55	1.83	0.95	3	785
saw	68.5	2.25	2.21	1	2	683
sheep	44.5	3.3	1.32	0.96	3	1269
sock	23.4	1.8	1.32	1	3	712
swing	50.5	2.72	1.49	0.95	4	942
toaster	50.5	3.5	0.30	1	5	862
towel	38.5	3.5	1.20	0.95	3	990
trousers	25.1	2.3	1.46	1	6	757
violin	62.5	3.75	0.3	1	6	1051
watch	38.5	2.95	1	1	4	780
whale	56.5	2.85	0.48	1	3	1050
MEAN	49.03	2.88	1.27	0.95	4.06	913
SD	23.802	0.806	0.628	0.070	1.451	174

* indicates that no latency data were available for these items.

Appendix 4D: Norms for matched list from Morrison et al. (1997)

Item	AoA (months)	Visual Complexity	Combined Log Freq	Name Agr’t	Phonemes	RT
arm	38.5	1.8	2.02	1	2	923
basket	38.5	3.85	1.28	0.96	6	832
bed	22.1	2.45	2.39	1	3	706
bottle	38.5	1.4	1.92	0.96	4	956
box	38.5	1.95	1.60	1	4	753
cake	23.4	2.8	1.34	1	3	789
camera	50.5	2.7	1.40	1	5	725
cannon	114.5	3.7	0.60	1	5	1159
caravan	56.5	3.2	0.90	1	7	*
castle	38.5	3.45	1.40	0.95	4	893
cat	23.4	2.6	2.02	1	3	766
caterpillar	44.5	3	0.48	0.91	8	*
cheese	44.5	2	1.46	1	3	843
coat	68.5	2.45	1.71	1	3	1010
cockerel	74.5	4.35	0.30	0.7	6	1175
elephant	23.4	4.12	1.11	1	7	837
flag	38.5	2	1.00	1	4	847
flower	22.1	2.8	1.45	1	4	754
fox	38.5	4.02	0.85	1	4	975
gun	44.5	2.75	1.81	0.85	3	709
hair	56.5	2.88	2.28	0.95	2	999
hat	23.4	2.15	1.04	0.96	3	684
judge	102.5	4.15	1.76	1	3	*
kangaroo	44.5	3.7	0.30	0.96	7	856
key	23.4	2.05	1.85	0.96	2	738
knife	23.4	1.95	0.95	0.96	3	816
monkey	25.1	3.2	0.95	0.86	5	794
nose	56.5	1.35	1.87	1	3	721
peach	102.5	2.55	0.60	0.82	3	1247
peacock	92.5	4.25	0.60	0.96	5	1010
peg	44.5	2.4	0.70	0.85	3	1589
penguin	38.5	2.6	0.70	0.91	7	897
pineapple	74.5	3.6	1.84	0.86	6	871
scarecrow	44.5	4.3	0.30	1	6	*
scissors	23.4	2.2	0.70	1	5	741
screwdriver	68.5	1.9	0.00	1	9	1179
ski	102.5	3.05	0.78	1	3	1039
snake	25.1	3.55	1.18	1	4	775
soldier	44.5	4	1.43	1	5	1170
spider	25.1	3.15	0.70	0.95	5	907
stool	50.5	2.35	1.08	1	4	973
telescope	92.5	2.1	0.85	1	8	1011
tent	44.5	2.95	1.58	1	4	744
torch	56.5	2.65	1.00	1	3	975
train	25.1	3.45	0.7	0.95	4	838
trumpet	56.5	3.15	0.78	0.96	7	1053
vase	62.5	3.4	0.70	1	3	1171
zebra	44.5	4.3	2.12	1	5	864
MEAN	49.08	2.93	1.18	0.96	4.48	916
SD	24.657	0.821	0.583	0.062	1.738	183

* indicates that no latency data were available for these items.

Appendix 4E: Results of t-tests comparing target and matched lists

Variable	Target Mean	Matched List Mean	t =	p =
AoA (months)	49.03	49.08	.015	.988
Visual Complexity	2.88	2.93	.423	.674
Log Frequency	1.27	1.17	1.057	.296
Name Agreement	0.95	0.96	.744	.461
Phonemes	4.06	4.48	1.671	.101
RT	913.66	916.23	.099	.922

Appendix 5A: List 1 items and associated stimulus properties

Item	Set	Name agr’t	RT	Syllables	Phonemes	Frequency	AoA	Visual complexity
anchor	A	1	951	2	4	1.946	3	14010
baby	B	0.94	729	2	4	5.557	1	18598
barrel	A	0.98	882	2	4	3.091	3	18478
beard	A	0.96	1033	1	4	3.258	3	30362
bed	A	1	706	1	3	5.136	1	13761
book	A	1	656	1	3	6.075	1	8619
boot	B	0.9	869	1	3	3.689	1	8857
bra	B	1	917	1	3	1.946	3	11410
broom	A	1	821	1	4	2.197	1	11261
button	B	1	917	2	4	3.296	1	5726
cannon	A	1	1159	2	5	1.946	3	17678
castle	B	1	893	2	4	3.332	3	22746
chair	A	1	732	1	2	4.92	1	11238
church	B	0.96	988	1	3	5.215	1	34595
comb	A	1	717	1	3	1.792	1	28324
cow	A	0.94	1079	1	2	3.714	1	17300
dinosaur	A	0.98	1012	3	6	1.792	3	12393
door	B	1	719	1	2	5.958	1	12638
egg	A	0.98	874	1	2	4.466	1	10440
fan	B	0.98	865	1	3	2.89	3	35152
finger	B	0.98	775	2	5	4.82	1	5370
flag	B	1	847	1	4	3.296	2	9461
fork	A	1	723	1	3	2.773	1	8818
genie	A	0.98	1214	2	4	0.693	3	18559
glasses	B	0.96	758	2	6	3.497	1	11525
goat	B	0.96	972	1	3	3.367	3	15302
grapes	A	0.9	849	1	5	0	2	23841
hammer	B	1	724	2	4	2.485	1	9533
hat	A	0.98	684	1	3	4.234	1	8732
hook	B	1	919	1	3	3.638	3	10144
house	A	0.98	745	1	3	6.409	1	18069
jar	B	0.9	979	1	2	2.996	2	7664
kangaroo	A	1	856	3	7	1.386	3	14555
kite	B	1	796	1	3	1.792	3	17880
lion	A	1	812	2	4	3.258	1	32267
mirror	B	1	873	2	4	3.912	3	11938
mushroom	A	1	746	2	6	2.639	3	8337
owl	B	1	837	1	2	2.079	1	15316
pencil	A	1	702	2	5	2.996	2	7899
pig	B	1	855	1	3	3.784	1	10411
piggybank	A	0.94	965	3	8	0	3	24489
pizza	A	1	973	2	4	1.099	1	40526
plate	A	0.94	1013	1	4	4.025	1	21533
queen	B	1	931	1	4	3.989	3	11277
road	A	0.92	925	1	3	5.521	3	26797
ruler	B	1	779	2	4	2.944	3	10785

screwdriver	B	1	1179	3	9	1.386	3	9051
shoe	A	1	737	1	2	4.382	1	14105
skis	A	0.95	1039	1	4	0	3	20764
sock	B	1	712	1	3	2.944	1	8316
strawberry	B	1	1052	3	8	1.946	2	16771
sword	B	0.92	1084	1	3	2.89	3	10243
telescope	B	0.98	1011	3	8	2.197	3	21547
tie	B	0.98	758	1	2	3.555	3	19103
tomato	A	0.98	962	3	6	2.708	3	8388
tree	B	1	796	1	3	5.257	1	26074
umbrella	A	1	738	3	7	2.708	3	15140
watch	B	1	780	1	3	3.714	1	14511
wheel	A	1	913	1	4	3.807	3	22753
window	B	1	822	2	5	5.303	1	26944
MEAN	**-**	**0.9812**	**872.57**	**1.550**	**4.017**	**3.211**	**1.983**	**16305.4**
SD		**0.03**	**133.33**	**0.72**	**1.66**	**1.50**	**0.97**	**8042.96**

Appendix 5B: Means for Sets A and B of List 2 with associated t-tests

Variable	Set A	Set B	t =	p =
Name agreement	0.9803	0.9820	.382	.745
RT	873.93	871.20	.100	.921
Syllables	1.6	1.5	.711	.483
Phonemes	4.13	3.90	.814	.422
Frequency	2.97	3.46	1.539	.135
AoA	2.00	1.96	.186	.854
Visual complexity	17647.9	14962.9	1.789	.084

Appendix 5C: List 2 items and associated stimulus properties

Items	Set	Name agr't	RT	Syllables	Phonemes	Frequency	AoA	Visual complexity
apple	A	1	810	2	3	3.434	1	8241
balloon	B	1	702	2	5	1.946	1	8015
basket	A	0.98	832	2	5	3.219	2	23651
bat	B	1	764	1	3	2.708	2	16687
bone	A	1	872	1	3	4.248	3	14370
bottle	B	0.9	956	2	4	4.762	1	6551
bowl	A	0.98	831	1	3	3.526	1	9408
bus	B	1	771	1	3	4.382	1	23164
cake	A	1	789	1	3	3.555	1	16237
candle	B	1	831	2	5	2.833	3	8385
car	A	1	751	1	2	5.872	1	9255
cat	B	0.96	766	1	3	4.22	1	9894
chain	A	1	943	1	3	3.892	3	12912
cheese	B	1	843	1	3	3.466	1	12988
cigarette	A	0.94	1016	3	7	4.277	3	7988
dog	A	1	702	1	3	4.754	1	12012
dragon	A	1	891	2	5	2.303	3	19272
ear	B	1	681	1	2	4.489	1	9033
feather	A	0.98	977	2	4	3.091	3	21626
fish	B	1	777	1	3	5.1	1	12019
flower	A	1	754	2	4	4.543	1	15082
foot	B	0.98	758	1	3	5.79	1	7638
frog	A	1	751	1	4	2.303	1	14773
ghost	B	1	849	1	4	3.466	3	23538
girl	A	0.92	861	1	3	6.084	1	15540
guitar	B	0.98	870	2	4	2.079	3	12032
hair	A	0.98	999	1	2	5.298	1	41463

harp	B	0.96	914	1	3	1.386	3	14170
horse	A	1	809	1	3	4.89	1	18397
iron	B	1	856	2	3	4.277	3	16843
ironing board	B	0.9	1105	4	8	0	3	12848
jacket	B	0.92	881	2	5	3.761	1	30351
key	A	1	738	1	2	4.466	1	7493
king	B	1	898	1	3	4.605	3	31165
lemon	A	0.96	911	2	5	2.773	3	8524
match	B	1	910	1	3	4.06	3	13078
mouse	A	0.92	961	1	3	2.944	1	13250
nail	B	1	1086	1	4	3.258	2	9585
orange	A	0.96	1098	2	5	3.045	1	10314
pear	B	1	949	1	2	1.946	3	18960
pen	A	1	753	1	3	3.296	1	9078
pineapple	B	0.98	871	3	6	1.386	3	20721
pumpkin	A	1	909	2	7	1.099	2	18960
pyramid	B	0.98	987	3	7	2.079	3	19838
rake	A	0.98	828	1	3	1.099	3	5156
rocket	A	0.9	854	2	5	2.708	3	18164
rope	A	1	810	1	3	3.761	3	34568
shark	B	0.96	1014	1	3	3.045	3	14311
sink	A	0.96	984	1	4	2.773	1	26560
skeleton	B	1	817	3	8	2.565	3	10724
skunk	A	0.98	1044	1	5	0	3	16683
spoon	B	1	777	1	4	2.773	1	7344
tiger	B	0.91	1072	2	4	2.565	1	45476
toaster	B	0.96	860	2	5	0.693	3	13290
toilet	A	1	825	2	5	3.367	3	22049
train	B	1	838	1	4	4.407	1	18361
unicorn	A	1	928	3	7	0.693	3	12749
well	B	0.96	991	1	3	1.792	3	12965
whistle	A	1	790	2	4	2.303	3	10521
witch	B	1	879	1	3	3.497	3	27723
MEAN	**-**	**0.9798**	**871.57**	**1.533**	**3.967**	**3.216**	**2.033**	**16033.2**
SD		**0.03**	**104.12**	**0.72**	**1.47**	**1.40**	**0.97**	**8311.20**

Appendix 5D: Means for Sets A and B of List 2 with associated t-tests

Variable	Set A	Set B	t =	p =
Name agr’t	0.9813	0.9783	.582	.565
RT	867.4	875.8	.455	.653
Syllables	1.5	1.6	.580	.566
Phonemes	3.93	4.00	.258	.798
Frequency	3.32	3.11	.797	.432
AoA	1.93	2.13	1.117	.273
Visual complexity	15809.9	16256.6	.304	.763

Appendix 5E: List 3 items and associated stimulus properties

Items	Set	Name agr’t	RT	Syllables	Phonemes	Frequency	AoA	Visual complexity
arrow	A	0.98	785	2	3	2.773	3	5990
ball	B	1	886	1	3	4.718	1	13345
banana	A	1	808	3	6	2.197	1	8767
belt	B	1	812	1	4	3.296	2	18762
bench	A	0.94	896	1	4	3.178	2	25379
box	B	1	753	1	4	4.635	1	18074
bread	A	0.98	773	1	4	4.317	1	10161

bridge	B	0.98	862	1	4	4.205	3	27543
camel	A	1	892	2	4	3.258	3	26026
camera	B	1	725	3	5	3.611	2	16408
carrot	A	1	806	2	5	2.197	1	13201
clock	B	0.98	772	1	4	3.689	1	25639
cross	A	1	793	1	4	3.135	3	9790
crown	B	0.94	945	1	4	3.219	3	23655
desk	A	1	975	1	4	4.522	3	17761
dolphin	B	0.98	894	2	6	1.386	3	9949
drawer	A	1	994	2	3	3.219	1	16141
dress	B	1	840	1	4	4.477	1	23619
elephant	A	0.98	837	3	7	3.219	1	24585
eye	B	0.98	700	1	1	6.261	1	9104
fence	A	0.98	819	1	4	3.434	3	17349
fly	B	0.9	1080	1	3	3.611	3	11935
globe	B	0.98	883	1	4	2.485	3	24454
glove	A	1	848	1	4	2.996	3	11509
hand	B	0.98	723	1	4	6.586	1	13345
helicopter	A	1	793	4	9	2.833	2	18241
hose	B	0.96	983	1	3	1.609	2	26130
igloo	B	1	963	2	4	0.693	3	9673
knife	B	1	816	1	3	3.807	2	8773
ladder	A	1	988	2	4	2.833	2	25701
lamp	A	0.92	835	1	4	3.584	1	13522
leaf	A	1	848	1	3	4.407	3	26600
lightbulb	A	0.92	737	2	7	0	3	10034
lipstick	A	1	803	2	7	2.079	3	6029
man	A	0.94	978	1	3	7.396	1	15791
map	A	1	847	1	3	3.714	3	41029
mask	B	0.98	852	1	4	3.045	3	13646
monkey	A	1	794	2	5	2.944	1	18988
moon	B	1	804	1	3	4.094	1	3730
mop	A	0.94	933	1	3	1.386	2	14393
mountain	B	0.94	921	2	6	4.443	3	13588
nose	A	1	721	1	3	4.407	1	4703
nurse	B	0.96	1039	1	3	3.912	2	19385
onion	A	0.94	1100	2	5	2.833	3	11645
piano	B	1	798	3	5	3.332	3	19570
pipe	A	0.98	866	1	3	3.466	3	7235
razor	B	0.94	1089	2	4	2.303	3	14404
ring	B	1	785	1	3	1.386	3	7652
robot	B	0.98	793	2	5	2.079	3	9502
roof	A	0.94	1094	1	3	4.043	2	13178
saddle	A	1	1019	2	4	2.398	3	10307
saw	A	1	863	1	2	0.693	3	11302
slide	B	1	1003	1	4	2.565	1	20613
snake	B	1	775	1	4	3.178	3	23761
sun	A	1	762	1	3	5.03	1	18102
table	B	0.98	852	2	4	5.464	1	12010
typewriter	B	1	778	3	7	2.485	3	28850
whale	B	0.96	1050	1	4	2.485	3	15429
wig	A	0.94	933	1	3	2.639	3	22371
zebra	B	1	864	2	5	1.099	2	36034
MEAN	**-**	**0.9800**	**869.67**	**1.500**	**4.117**	**3.255**	**2.183**	**16573.5**
SD		**0.03**	**103.77**	**0.72**	**1.37**	**1.39**	**0.89**	**7727.28**

Appendix 5F: Means for Sets A and B of List 3 with associated t-tests

Variable	Set A	Set B	t =	p =
Name agr’t	0.9793	0.9807	.256	.800
RT	871.3	868.0	.182	.857
Syllables	1.57	1.43	.944	.353
Phonemes	4.2	4.1	.576	.569
Frequency	3.17	3.34	.680	.502
AoA	2.17	2.2	.200	.843
Visual complexity	15861.0	17286.1	.980	.335

Appendix 5G: Means for Lists 1-3 with associated t-tests

Variable	List 1 mean	List 2 mean	List 3 mean	1-2 t	1-2 p	2-3 t	2-3 p	1-3 t	1-3 p
Name agr’t	0.9812	0.9798	0.98	.367	.715	.043	.966	.313	.755
RT	872.57	871.57	869.67	.058	.954	.141	.888	.168	.867
Syllables	1.550	1.533	1.500	.182	.856	.357	.723	.536	.594
Phonemes	4.017	3.967	4.117	.231	.818	.791	.432	.468	.642
Frequency	3.211	3.216	3.255	.027	.978	.217	.829	.229	.820
AoA	1.983	2.033	2.183	.399	.692	1.191	.239	1.602	.114
Visual complexity	16305	16033	16574	.262	.794	.504	.616	.258	.797

Appendix 6A: All target items, filler pictures, and semantic and unrelated prime words

Target Items	Filler Pictures	Semantic primes	Unrelated primes
anchor	ironing board	bell	cage
ball	spider web	yoyo	waitress
banana	shower	kiwi	hanger
barrel	lips	flask	peacock
basket	rolling pin	bag	neck
bat	shirt	bird	paint
beard	chimney	moustache	hoe
bed	fireman	couch	shawl
belt	seal	braces	farmer
bone	anvil	leg	diamond
book	wheel	magazine	tail
bottle	plaster	glass	grave
bowl	package	cup	glitter
box	submarine	trunk	pushchair
bra	worm	girdle	stove
bread	tennis racket	roll	soap
bridge	roller-skate	tunnel	pepper
broom	pirate	dustpan	school
bus	swan	tram	log
button	dentist	zip	branch
cake	duck	biscuit	radio
camel	tear	llama	stethoscope
camera	sandwich	video	purse
candle	thimble	lantern	peg
cannon	nest	catapult	garden
car	beetle	lorry	pan
carrot	safety pin	potato	beach
castle	spider	temple	football
chain	washing machine	rope	blanket
chair	unicycle	sofa	parachute

cheese	puzzle	butter	grasshopper
church	shell	mosque	badge
cigarette	baby	pipe	fridge
clock	fishing rod	watch	peanut
comb	palm tree	hairbrush	jelly
cow	lighthouse	bull	peach
cross	seahorse	altar	paper
crown	bear	tiara	plug
desk	ostrich	sideboard	cracker
dinosaur	rain	crocodile	nut
dog	cactus	wolf	rose
door	soldier	gate	marble
dragon	bucket	serpent	triangle
drawer	toothbrush	cupboard	salt
dress	tyre	skirt	barbecue
egg	teapot	seed	wagon
elephant	picture	hippo	bracelet
eye	fish tank	ear	slipper
fan	lobster	heater	blouse
feather	envelope	scales	pants
fence	boot	wall	cork
finger	scorpion	thumb	lightning
flag	celery	banner	ant
flower	curtains	leaf	wine
fly	lamp	wasp	accordion
foot	paperclip	hand	nun
frog	tractor	newt	skate
genie	lawnmower	fairy	desert
ghost	mirror	sprite	chest
girl	tap	boy	mixer
glasses	funnel	monocle	beaver
globe	seesaw	planet	balcony
glove	bride	mitten	digger
goat	arrow	sheep	clipboard
grapes	unicorn	cherries	music
guitar	paintbrush	violin	switch
hair	scissors	face	dime
hammer	priest	axe	ribbon
harp	toe	lyre	safe
hat	acorn	cap	moth
helicopter	heart	glider	pool
hook	octopus	bracket	rug
horse	icecream	mule	skateboard
hose	bomb	watering can	cot
house	turkey	flat	cabbage
igloo	walnut	tent	ocean
iron	pelican	hairdryer	corn
jacket	armadillo	coat	dish
jar	pencil	mug	battery
kangaroo	statue	koala	lock
key	giraffe	padlock	teeth
king	wheelbarrow	princess	shop
kite	hoof	frisbee	policeman
knife	present	fork	wing
ladder	motorcycle	stairs	coffin
lemon	wallet	orange	cane
lightbulb	chicken	torch	net
lion	suitcase	cheetah	popcorn
man	bicycle	woman	tape
map	highchair	atlas	van
mask	snail	wig	city
match	rocking chair	lighter	backpack

monkey	telephone	gorilla	copper
moon	TV	star	pond
mop	penguin	duster	sledge
mountain	lipstick	hill	yacht
mouse	roof	hamster	pot
mushroom	skeleton	courgette	sailor
nail	bench	screw	frigate
nose	turtle	mouth	pillar
nurse	fire	doctor	cookie
onion	hammock	garlic	astronaut
owl	saxophone	hawk	blackboard
pear	rainbow	apple	deer
pen	helmet	crayon	dice
piano	balloon	organ	shoulder
pig	tank	rhino	dresser
pineapple	towel	mango	antlers
pizza	arm	spaghetti	wood
plate	road	tray	gas
pumpkin	binoculars	melon	smoke
pyramid	banjo	sphinx	jumper
queen	jug	prince	burger
rake	ladybird	spade	diary
razor	fox	tweezers	bow
ring	watermelon	necklace	whip
robot	magnet	teddy	barn
rocket	cowboy	plane	vest
ruler	walrus	tape measure	tepee
saddle	crab	bridle	rock
saw	boat	drill	money
screwdriver	wheelchair	chisel	pillow
shark	ashtray	fish	trousers
shoe	rabbit	sandal	charcoal
sink	gun	bath	parrot
skis	drum	snowshoes	waffle
skunk	windmill	raccoon	parasol
slide	handcuffs	roundabout	tin
snake	clown	lizard	rose
sock	volcano	stockings	peas
spoon	cat	ladle	brick
strawberry	window	raspberry	top
sun	vase	cloud	toad
sword	letter	dagger	saucer
table	eagle	stool	pitchfork
telescope	waiter	microscope	alligator
tie	sewing machine	scarf	heel
tiger	medal	leopard	stereo
toaster	squirrel	microwave	knight
toilet	snowman	bidet	hay
tomato	piggybank	radish	moose
train	panda	coach	keyring
tree	hinge	bush	stamp
typewriter	butterfly	computer	porcupine
umbrella	swing	raincoat	knot
well	doll	fountain	hotdog
whale	mousetrap	dolphin	bolt
whistle	canoe	flute	paw
witch	trumpet	wizard	bin

Appendix 6B 1: List 1, target items with norms

Item	Name Agr’t	RT (ms)	Syllables	Phonemes	Frequency	AoA	Visual Complexity (KB)
anchor	1	951	2	4	1.946	3	14010
barrel	0.98	882	2	4	3.091	3	18478
beard	0.96	1033	1	4	3.258	3	30362
bed	1	706	1	3	5.136	1	13761
book	1	656	1	3	6.075	1	8619
bra	1	917	1	3	1.946	3	11410
broom	1	821	1	4	2.197	1	11261
button	1	917	2	4	3.296	1	5726
cannon	1	1159	2	5	1.946	3	17678
castle	1	893	2	4	3.332	3	22746
chair	1	732	1	2	4.92	1	11238
church	0.96	988	1	3	5.215	1	34595
comb	1	717	1	3	1.792	1	28324
cow	0.94	1079	1	2	3.714	1	17300
dinosaur	0.98	1012	3	6	1.792	3	12393
door	1	719	1	2	5.958	1	12638
egg	0.98	874	1	2	4.466	1	10440
fan	0.98	865	1	3	2.89	3	35152
finger	0.98	775	2	5	4.82	1	5370
flag	1	847	1	4	3.296	2	9461
genie	0.98	1214	2	4	0.693	3	18559
glasses	0.96	758	2	6	3.497	1	11525
goat	0.96	972	1	3	3.367	3	15302
grapes	0.9	849	1	5	0	2	23841
hammer	1	724	2	4	2.485	1	9533
hat	0.98	684	1	3	4.234	1	8732
hook	1	919	1	3	3.638	3	10144
house	0.98	745	1	3	6.409	1	18069
jar	0.9	979	1	2	2.996	2	7664
kangaroo	1	856	3	7	1.386	3	14555
kite	1	796	1	3	1.792	3	17880
lion	1	812	2	4	3.258	1	32267
mushroom	1	746	2	6	2.639	3	8337
owl	1	837	1	2	2.079	1	15316
pig	1	855	1	3	3.784	1	10411
pizza	1	973	2	4	1.099	1	40526
plate	0.94	1013	1	4	4.025	1	21533
queen	1	931	1	4	3.989	3	11277
ruler	1	779	2	4	2.944	3	10785
screwdriver	1	1179	3	9	1.386	3	9051
shoe	1	737	1	2	4.382	1	14105
skis	0.95	1039	1	4	0	3	20764
sock	1	712	1	3	2.944	1	8316
strawberry	1	1052	3	8	1.946	2	16771
sword	0.92	1084	1	3	2.89	3	10243
telescope	0.98	1011	3	8	2.197	3	21547
tie	0.98	758	1	2	3.555	3	19103
tomato	0.98	962	3	6	2.708	3	8388
tree	1	796	1	3	5.257	1	26074
umbrella	1	738	3	7	2.708	3	15140
MEAN	0.9834	881.06	1.54	3.98	3.107	2	16134
SD	0.0257	137.77	0.7269	1.679	1.448	0.9592	8092

Appendix 6B 2: List 2, target items with norms

Item	Name Agr't	RT (ms)	Syllables	Phonemes	Frequency	AoA	Visual Complexity (KB)
basket	0.98	832	2	5	3.219	2	23651
bat	1	764	1	3	2.708	2	16687
bone	1	872	1	3	4.248	3	14370
bottle	0.9	956	2	4	4.762	1	6551
bowl	0.98	831	1	3	3.526	1	9408
bus	1	771	1	3	4.382	1	23164
cake	1	789	1	3	3.555	1	16237
candle	1	831	2	5	2.833	3	8385
car	1	751	1	2	5.872	1	9255
chain	1	943	1	3	3.892	3	12912
cheese	1	843	1	3	3.466	1	12988
cigarette	0.94	1016	3	7	4.277	3	7988
dog	1	702	1	3	4.754	1	12012
dragon	1	891	2	5	2.303	3	19272
feather	0.98	977	2	4	3.091	3	21626
flower	1	754	2	4	4.543	1	15082
foot	0.98	758	1	3	5.79	1	7638
frog	1	751	1	4	2.303	1	14773
ghost	1	849	1	4	3.466	3	23538
girl	0.92	861	1	3	6.084	1	15540
guitar	0.98	870	2	4	2.079	3	12032
hair	0.98	999	1	2	5.298	1	41463
harp	0.96	914	1	3	1.386	3	14170
horse	1	809	1	3	4.89	1	18397
iron	1	856	2	3	4.277	3	16843
jacket	0.92	881	2	5	3.761	1	30351
key	1	738	1	2	4.466	1	7493
king	1	898	1	3	4.605	3	31165
lemon	0.96	911	2	5	2.773	3	8524
match	1	910	1	3	4.06	3	13078
mouse	0.92	961	1	3	2.944	1	13250
nail	1	1086	1	4	3.258	2	9585
pear	1	949	1	2	1.946	3	18960
pen	1	753	1	3	3.296	1	9078
pineapple	0.98	871	3	6	1.386	3	20721
pumpkin	1	909	2	7	1.099	2	18960
pyramid	0.98	987	3	7	2.079	3	19838
rake	0.98	828	1	3	1.099	3	5156
rocket	0.9	854	2	5	2.708	3	18164
shark	0.96	1014	1	3	3.045	3	14311
sink	0.96	984	1	4	2.773	1	26560
skunk	0.98	1044	1	5	0	3	16683
spoon	1	777	1	4	2.773	1	7344
tiger	0.91	1072	2	4	2.565	1	45476
toaster	0.96	860	2	5	0.693	3	13290
toilet	1	825	2	5	3.367	3	22049
train	1	838	1	4	4.407	1	18361
whistle	1	790	2	4	2.303	3	10521
well	0.96	991	1	3	1.792	3	12965
witch	1	879	1	3	3.497	3	27723
MEAN	0.9794	876	1.44	3.82	3.274	2.08	16672
SD	0.0294	93.16	0.6053	1.228	1.340	0.9558	8249

Appendix 6B 3: List 3, target items with norms

Item	Name Agr't	RT (ms)	Syllables	Phonemes	Frequency	AoA	Visual Complexity (KB)
ball	1	886	1	3	4.718	1	13345
banana	1	808	3	6	2.197	1	8767
belt	1	812	1	4	3.296	2	18762
box	1	753	1	4	4.635	1	18074
bread	0.98	773	1	4	4.317	1	10161
bridge	0.98	862	1	4	4.205	3	27543
camel	1	892	2	4	3.258	3	26026
camera	1	725	3	5	3.611	2	16408
carrot	1	806	2	5	2.197	1	13201
clock	0.98	772	1	4	3.689	1	25639
cross	1	793	1	4	3.135	3	9790
crown	0.94	945	1	4	3.219	3	23655
desk	1	975	1	4	4.522	3	17761
drawer	1	994	2	3	3.219	1	16141
dress	1	840	1	4	4.477	1	23619
elephant	0.98	837	3	7	3.219	1	24585
eye	0.98	700	1	1	6.261	1	9104
fence	0.98	819	1	4	3.434	3	17349
fly	0.9	1080	1	3	3.611	3	11935
globe	0.98	883	1	4	2.485	3	24454
glove	1	848	1	4	2.996	3	11509
helicopter	1	793	4	9	2.833	2	18241
hose	0.96	983	1	3	1.609	2	26130
igloo	1	963	2	4	0.693	3	9673
knife	1	816	1	3	3.807	2	8773
ladder	1	988	2	4	2.833	2	25701
lightbulb	0.92	737	2	7	0	3	10034
man	0.94	978	1	3	7.396	1	15791
map	1	847	1	3	3.714	3	41029
mask	0.98	852	1	4	3.045	3	13646
monkey	1	794	2	5	2.944	1	18988
moon	1	804	1	3	4.094	1	3730
mop	0.94	933	1	3	1.386	2	14393
mountain	0.94	921	2	6	4.443	3	13588
nose	1	721	1	3	4.407	1	4703
nurse	0.96	1039	1	3	3.912	2	19385
onion	0.94	1100	2	5	2.833	3	11645
piano	1	798	3	5	3.332	3	19570
razor	0.94	1089	2	4	2.303	3	14404
ring	1	785	1	3	1.386	3	7652
robot	0.98	793	2	5	2.079	3	9502
saddle	1	1019	2	4	2.398	3	10307
saw	1	863	1	2	0.693	3	11302
slide	1	1003	1	4	2.565	1	20613
snake	1	775	1	4	3.178	3	23761
sun	1	762	1	3	5.03	1	18102
table	0.98	852	2	4	5.464	1	12010
typewriter	1	778	3	7	2.485	3	28850
whale	0.96	1050	1	4	2.485	3	15429
zebra	1	864	2	5	1.099	2	36034
MEAN	0.9828	870.06	1.54	4.14	3.223	2.14	17016
SD	0.0253	104.40	0.7539	1.357	1.375	0.8947	7637

Appendix 6C: Means and t-tests for Lists 1-3

Variable	List 1 mean	List 2 mean	List 3 mean	1-2 t	1-2 p	2-3 t	2-3 p	1-3 t	1-3 p
Name agr’t	0.983	0.979	0.983	1.088	.282	.941	.351	.163	.871
RT (ms)	881	876	870	.257	.798	.398	.692	.559	.579
Syllables	1.54	1.44	1.54	.963	.340	.928	.358	.000	1.00
Phonemes	3.98	3.82	4.14	.667	.508	1.651	.105	.667	.508
Frequency	3.107	3.274	3.223	.805	.425	.260	.796	.558	.579
AoA	2.00	2.08	2.14	.584	.562	.469	.641	1.022	.312
Visual complexity (KB)	16134	16671	17016	-.465	.644	.316	.753	-.763	.449