Université de Montréal

# Lexicosemantic processing in normal and pathological aging

par

Vanessa Taler

Département de sciences biomédicales

Faculté de Medecine

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Vanessa Taler

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ABSTRACT

Alterations in language processing are seen both in normal and in pathological aging. The present thesis examines the processing of a specific linguistic distinction, the mass/count distinction, in a variety of populations, with the goal of determining how this distinction is represented in the mental lexicon and how processing of this information is altered in cases of language pathology. Study one examines off-line processing of mass nouns (e.g., *honey*), count nouns (e.g., *table*), and metonymic nouns with a mass/count extension (e.g., *turkey*), also termed dual nouns, by individuals suffering from Alzheimer's disease (AD) and mild cognitive impairment (MCI). Results indicate that both groups have difficulty processing sense extensions in metonymic nouns, and that this impairment appears to be of the same nature and severity across AD and MCI subjects. Study two examines the on-line processing of these noun types in healthy younger and older adults, and study three examines this processing in individuals suffering from AD and MCI. Results suggest that, due to a lack of resources available for lexicosemantic processing, older adults do not insert the default (count) reading of dual nouns when processing them on-line. Furthermore, as in Study one, AD and MCI individuals are unable to process sense extensions of metonymic nouns. Again, the pattern of results was the same for AD and MCI subjects, lending credence to the claim that MCI represents an early stage of AD. Study four examined the off-line processing of mass, count and dual nouns in an individual suffering from a specific syntactic impairment, agrammatic aphasia, and an individual suffering from a specific semantic impairment, semantic dementia. The goals of this study were twofold: first, to specify the contributions of syntactic and semantic information to processing of mass/count information, and second, to identify the stages of processing required to successfully interpret these lexical items. Results show that both semantic and syntactic information are required for successful on-line processing of mass and count nouns, despite the fact that the distintion between these noun types is often captured using syntactic criteria. Taken together, the results found in these studies suggest that mass/count information is represented in the lexical entries of mass and count nouns, and that dual nouns are underspecified for this information, which is inserted on-line by means of a lexical rule. The form and operation of this rule are specified. We claim that AD and MCI subjects exhibit an impairment in use of this lexical rule, and that this may provide a sensitive early measure of cognitive impairment. Likewise, an impairment in the use of this rule is seen in agrammatic aphasia; in the case of individuals with semantic dementia, the use of the rule is intact, but impairments are seen at the level of access to semantic information and integration of semantic and syntactic information.

Keywords: Alzheimer's disease, mild cognitive impairment, semantic dementia, agrammatic aphasia, mass/count distinction, lexicosemantic processing

RÉSUMÉ

Les habiletés associées au traitement du language sont altérées au cours du vieillissement normal et pathologique. La présente thèse porte sur le traitement d'une distinction linguistique particulière entre les noms comptables et non-comptables (C-NC). L'un des objectifs était de determiner la façon dont cette distinction est représentée au sein du lexique mental. Un second objectif était d'étudier l'influence de certains troubles du language sur le traitement de cette distinction. Les études présentées dans cette thèse ont été effectuées auprès de diverses populations normales et cliniques. La première étude examine le traitement en temps réel de noms comptables (e.g., *table*), non-comptables (e.g., *miel*), et métonymiques avec une extension C-NC (aussi appelés noms duels; e.g., *dinde*). Les populations étudiées étaient composées de personnes atteintes de la maladie d'Alzheimer (MA) et de personnes atteintes de troubles légers de la cognition (TLC). Les résultats révelent que les patients MA et TLC présentent des difficultés dans le traitement des extensions de sense des noms métonymiques. Ces difficultés semblent de même nature et de sévérité équivalente pour les deux groupes de sujets. La seconde étude examine le traitement en temps réel des mêmes noms chez de jeunes adultes sains, ainsi que chez des adultes plus âgés. Pour sa part, la troisième étude examine le traitement en temps réel chez des patients MA et TLC. Les résultats révelent que les adultes plus âgés ne peuvent accéder à une interprétation comptable par défaut des noms duels lors du traitement en temps réel, dû à un manque de ressources permettant le traitement lexico-sémantique. De plus, tel qu'à la première étude, les patients MA et TLC sont incapables de traiter les extensions des noms métonymiques reliées au sense. Dans ce cas également, les résultats sont les mêmes pour les patients MA et TLC, supportant l'argument que les TLC représentent un stage préliminaire de la MA. La quatrième étude traitement de noms comptables, non-comptables et duels en temps réel chez une personne souffrant d'aphasie agrammatique (un trouble syntaxique spécifique) et un autre souffrant de démence sémantique (un trouble sémantique spécifique). Le premier objectif de cette étude consiste à spécifier les contributions de l'information syntaxique et sémantique au traitement des noms C-NC. Le second objectif est d'identifier les étapes de traitement nécessaires à une juste interprétation de ces items lexicaux. Les résultats démontrent que l'information sémantique autant que syntaxique est nécessaire à l'accomplissement du traitement en temps réel des noms C-NC, et ce malgré le fait que, du point de vue linguistique, ces items soient surtout décrits en termes syntaxiques. En somme, les résultats des quatre études de cette thèse suggèrent que l'information C-NC est représentée par les entrées lexicales des noms C-NC, et que les noms duels sont sous-spécifiés quant à cette information, qui est insérée en temps réel par l'entremise d'une règle lexicale. La forme de cette règle, ainsi que sa façon d'opérer, sont spécifiées. Nous proposons que les sujets MA et TLC manifestent un trouble de l'utilisation de cette règle lexicale, et que ce phénomène peut en soit constituer une mesure préliminaire adéquate d'un trouble cognitif. De même, on peut observer un trouble face à l'utilisation de cette règle chez des patients atteints d'aphasie agrammatique. Dans le cas de personnes atteintes de démence sémantique, l'utilisation de cette règle est intacte, mais des troubles peuvent être observés au niveau de l'accès à l'information sémantique, ainsi qu'au niveau de l'intégration de l'information sémantique et syntactique.

Mots clés: maladie d'Alzheimer, troubles légers de la cognition, démence sémantique, aphasie agrammatique, comptable, non-comptable, traitement lexicosémantique

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## List of Abbreviations

| | |
|---|---|
| Aβ | β-amyloid protein |
| AA | agrammatic aphasia |
| AD | Alzheimer's disease |
| ANOVA | analysis of variance |
| BA | Brodmann's area |
| BDAE | Boston Diagnostic Aphasia Examination |
| CBC | countability by context |
| COWA | Controlled Oral Word Association |
| CP | regular count plural |
| CS | regular count singular |
| DLP | dual plural |
| DLS | dual singular |
| ERP | event-related potential |
| freq. | frequency |
| FS | feature structures |
| gram. | grammatical |
| GMP | granularity mismatch problem |
| ISI | interstimulus interval |
| LAN | left anterior negativity |
| LDT | lexical decision task |
| LH | left hemisphere |
| LHD | left hemisphere damaged |

| | |
|---|---|
| LRL | lexical representation language |
| LSD | least squares difference |
| M | mass |
| MCI | mild cognitive impairment |
| MEG | magnetoencephalography |
| MMSE | Mini-Mental State Examination |
| MOCA | Montreal Cognitive Assessment |
| ms | milliseconds |
| NP | noun phrase |
| OC | older control |
| OIP | ontological Incommensurability Problem |
| pAD | probable Alzheimer's disease |
| PD | Parkinson's disease |
| PDP | parallel distributed processing |
| PET | positron emission tomography |
| pl. | plural |
| PPA | primary progressive aphasia |
| rCBF | regional cerebral blood flow |
| RH | right hemisphere |
| RHD | right hemisphere damaged |
| RK | "remember/know" paradigm |
| RT | reaction time |
| SD | semantic dementia |
| sing. | singular |

| | |
|---|---|
| SPI | serial-parallel-independent |
| ungram. | ungrammatical |
| WAIS | Wechsler Adult Intelligence Scale |
| WM | working memory |
| WRAT | Wide Range Achievement Test |

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# CHAPTER 1: INTRODUCTION

## 1. Overview

The present work examines lexicosemantic processing in the case of normal aging as well as in various language disorders. It focuses on a specific distinction in the English language, the mass/count distinction. The goals of this research are two-fold: first, we attempt to shed light on the issue of how differing noun types are represented within the mental lexicon by examining the way they are processed by healthy adults and, second, we aim to expand our understanding of the ways in which language can break down in the event of neuropathology.

The mass/count distinction is interesting from a number of perspectives. Firstly, it has been the focus of extensive debate in the theoretical linguistic literature in terms of the way in which it can best be characterized. This debate has focused on its semantic and syntactic characteristics, and evidence has been presented that both these types of information play a role in processing and representation of mass/count information. Furthermore, the mass/count distinction is widespread in natural language. All common nouns in English may be categorized as mass or count (or mass/count flexible; see section 6 below). Thus, processing of mass/count information is crucial for successful language performance. Hence, examination of the way this information is represented and processed, both in healthy individuals and those with language impairments, has the potential to clarify a number of outstanding questions with respect to semantics, syntax and their interaction.

The present research has both clinical and theoretical implications. On a theoretical level, it speaks to the issues of access and representation of differing noun types. We offer a novel proposal of how the mass/count distinction is represented, drawing on evidence from psycho- and neurolinguistics, and incorporating the observations provided in the theoretical linguistic literature with respect to the semantic, syntactic and contextual distribution of these noun types. The proposal is consistent with known facts about the neurobiology of language processing as well as long-recognized Hebbian learning mechanisms that can clarify data pertaining to the acquisition of these noun types.

On a clinical level, the current research sheds light on language impairments in differing clinical populations. In the case of Alzheimer's disease and mild cognitive impairment, this information represents the first step toward a possible tool for early diagnosis, highlighting subtle semantic impairments which may manifest very early in the disease course and allow differentiation between individuals who are simply at the bottom of the Gaussian curve in terms of neuropsychological performance and those who are manifesting the earliest clinical signs of dementia. This intriguing possibility will be discussed in more detail in the Conclusions section.

The current chapter is laid out as follows. Section two is devoted to an overview of the mental lexicon, what it contains, how information is represented and what occurs in lexical access. Findings with respect to lexical ambiguity, which form an integral part of this thesis, are also presented. Section three gives a brief overview of current theories of memory. These two sections lay the groundwork for the research presented in this thesis. In section four, we discuss the changes in cognitive function seen in healthy aging. A brief review is given of the various theories that have been put forward to account for these changes. Section five provides a summary of the changes in neurophysiological, language and cognitive function that are seen in various forms of pathological aging, namely Alzheimer's disease, mild cognitive impairment, semantic dementia and agrammatic aphasia. Section six reviews evidence for the processing and representation of mass and count nouns in English, focusing primarily on experimental evidence, both with neurologically impaired and with unimpaired participants. In section seven I discuss recent perspectives on the functional neurobiology of language, setting the stage for the arguments presented in the Conclusions section with respect to the way in which syntactic and semantic information interact in processing of the mass/count distinction. Finally, in section eight I outline the purpose and structure of the thesis, the logic behind the studies conducted and the way in which they follow from one another.

## 2. The mental lexicon

The concept of the "mental lexicon" is central to the studies reported in the current thesis. We thus begin this thesis with an overview of what the lexicon is, what information is contained therein, and how it is organized. A wealth of research on these issues has accumulated over the last three decades, and a number of competing hypotheses have been put forward dealing with the ways in which lexical information is stored and accessed.

### 2.1 What is the mental lexicon?

As a first approximation, the mental lexicon may be conceptualized as the internal dictionary that all speakers of a language carry in their brain. The lexicon contains syntactic, semantic, phonological and (in the case of literate speakers) orthographic information about the words that the person knows. This information is often conceived of as being organized into "lexical entries"; the lexical entry for a given word containing all the information the speaker possesses about that word.

The primary research questions that arise with respect to the mental lexicon are:

(a) How is information represented within the lexicon?

(b) Relatedly, what is in a lexical entry?

(c) How do we access this information?

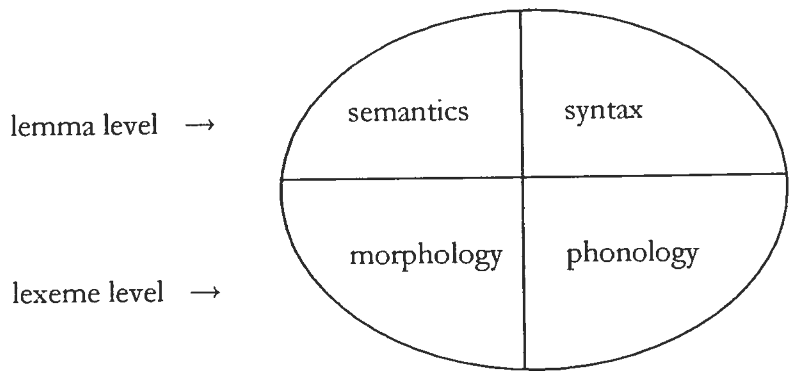
Before beginning, I offer a brief definition of relevant terms as they are used in the present work. The term "representation" will be used in this thesis to refer to the information that is contained within a lexical entry, and the term "access" to refer to the activation of that information that occurs when a speaker is recognizing or producing a word. The terms "process", "processing" etc., will be used to refer to a series of actions, changes, or functions bringing about a result, such as the activation of information contained in a lexical entry, or the computation of syntactic structure or rules.

We now turn to an overview of influential theories of lexical access and representation, beginning with a brief discussion of how lexical entries are thought to be structured.

### 2.1.1 Lexical entries

A lexical entry is the constellation of knowledge that a speaker has about a given lexical item in their language. Lexical entries are composed of syntactic, semantic, and morphophonological information, which has been postulated to be divided into the lemma (syntactic and semantic information) and the lexeme (morpho-phonological information; see Kempen & Huijbers, 1983), as illustrated in Figure 1.1 below:

Figure 1.1: Structure of a lexical entry




There exists a good deal of support for this model, including evidence from tip of the tongue states and speech errors in unimpaired speakers and language deficits in aphasia (for a review, see Levelt, Roelofs & Meyer, 1999), as well as neuroimaging studies indicating separable neural substrates for the two levels (e.g., Longoni, Grande, Hendrich, Kastrau & Huber, 2005).

The question of how this information is accessed has been extensively debated in the literature; some of the most influential theories are discussed in the following sections.

2.1.2 Access vs. activation

Some of the most well-established findings with respect to the organization of information in the mental lexicon are that words are recognized more quickly when preceded by a related word, or prime (e.g., as in the case of semantic priming[1]; Meyer & Schvanevelt, 1971), when they are frequent in the language (Savin, 1963), and that they may be recognized before their acoustic offset (Marslen-Wilson, 1973). This suggests that word recognition may best be seen not in terms of *access* to lexical information, but rather as *activation* of this information (Morton, 1969, 1970). Thus, higher or lower levels of activation may be required as a function of factors such as context and frequency with which a word has previously been seen by the speaker. Morton (1969, 1970) proposed a model in which word detectors (or *logogens*) stored semantic, visual and auditory information about a word. These logogens would become activated by input, which could be visual or auditory. Frequency and context effects were encoded via alterations in the logogen's firing threshold, whereby a highly frequent logogen has a lower threshold, and/or via alterations in the logogen's activation level, whereby a contextually appropriate logogen has a higher activation level. Thus, frequent and contextually appropriate lexical items fire more easily. This is in contrast to models such as Forster's (1979) serial search model, which postulated that lexical access proceeds through an ordered search of the lexicon. Within Forster's model, words are organized into "bins"; most frequent words are near the top, meaning that they will be searched first and thus accessed more quickly. However, words must be searched serially (i.e., one at a time), rather than each lexical items having a level of activation which is required to pass a certain threshold in order for activation of the word to occur.

The cohort model of spoken word recognition (Marslen-Wilson and Welsh, 1978; Marslen-Wilson and Tyler, 1980; Marslen-Wilson, 1987) extended Morton's insight that

[1] Priming may be defined as an increase in speed or accuracy in a decision as a consequence of prior exposure to part of the information.

word recognition is a question of activation rather than access. Within this model, the listener begins with a "cohort" of all potential lexical items, based on the acoustic input, and this cohort is reduced as more input is received, until a single alternative remains. That is, lexical entries are activated on the basis of acoustic fit. Context does not affect activation level per se, but rather affects the manner in which the cohort is selected. Frequency effects are accounted for in terms of "rise time", whereby goodness-of-fit results in more rapid activation for high-frequency items.

One important insight that is shared by the cohort and logogen models is that lexical access is best conceptualized in terms of parallel activation of lexical entries, rather than a serial search of the contents of the lexicon, as suggested by Forster (1979). This is supported by the well-established finding that alternative readings of homophones such as *bank* are activated in parallel (Swinney, 1979; Tanenhaus, Leiman & Seidenberg, 1979; see section 2.4 below), as well as by the finding that different lexical candidates may be activated by overlapping parts of the input (e.g., *bat* may be activated by *wombat*; Shillcock, 1990).

A second important stream of research on the mental lexicon has involved the issue of morphological complexity. Morphologically complex words (e.g. *teacher*) contain a root word (*teach*) and an affix (*-er*). The question of how these words are represented and accessed has formed one of the focal points of psycholinguistic research.

2.1.3 Morphology in the lexicon

A seminal study of morphological processing is that of Taft & Forster (1975). These authors found that morphologically complex words were recognized more slowly than monomorphemic words. They claimed that this is because morphologically complex words are accessed via location of the root word (which undergoes a process of "affix-stripping") and a subsequent search of its variations. For example, access to the word "teacher" would entail location of the word "teach" and a subsequent search of morphologically related words such as "teach", "teaches" etc. Marslen-Wilson, Tyler, Waksler and Older (1994), in contrast, present evidence indicating that the lexicon contains separate lexical entries for each morpheme; thus, both "teach" and "-er" would be accessed. However, in the case of semantically opaque words such as "department", only one lexical entry exists. These positions are in contrast to that espoused, for example, by Butterworth (1983) that morphological decomposition is used as a "fallback strategy" when a regularly inflected word cannot be located in the lexicon.

Dual-route models (e.g., Chialant & Caramazza, 1995; Schreuder & Baayen, 1995; Clahsen, 1999), in contrast, hold that multimorphemic words may either be accessed by breaking them down into their constituent morphemes or by accessing the full form of the word. Some of these models (e.g., Chialant & Caramazza, 1995) posit that the parsing (i.e., decompositional) route is only used for rare or novel word forms, while others (e.g., Schreuder & Baayen, 1995) hold that the two routes operate in parallel, and that a race takes place between them.. A second type of dual-route model, the words-and-rules system (e.g., Ullman, Corkin, Coppola, Hickok, et al., 1997; Pinker, 1999) posits a system in which irregularly inflected lexical items are stored in memory, while regularly inflected lexical items are computed on-line using a rule. These claims are supported by evidence from individuals suffering from neurological disease (notably Alzheimer's and Parkinson's disease), who show a double dissociation in terms of impairments in their processing of regular and irregular morphology.

The question that arises is whether the claim that morphological factors such as those discussed above play a fundamental role in language processing can be extended to languages other than English. Cross-linguistic research points to the conclusion that morphology does indeed play an important role in the organization of the lexicon across languages, although the precise nature of this role remains to be elucidated (for a review, see Clahsen, in press).

In sum, a wealth of evidence supports the position that morphological complexity plays a central role in lexical representation and processing. Different approaches have been put forward to account for this, each placing variable importance on the role of rules and stored word forms. What the approaches discussed thus far have in common, however, is the central tenet that morphological information takes the form of either rules or lexical representation.

We now briefly discuss a third type of model, which has challenged the assumptions underlying the models described above. These models, known as parallel distributed processing (PDP) models, represent lexical access and representation in terms of activations across a network of nodes or units, rather than in terms of representations which are acted upon (for example by rules).

### 2.1.4 Parallel distributed processing

A second branch of research on lexical access and representation holds that these functions are best modelled using *connectionist* or *neural network* models (e.g., Rumelhart & McClelland, 1986). These models are massively parallel systems in which lexical knowledge and processing are represented by means of a network of nodes or units[2]. These are linked via connections which may vary in weight (encoding the influence that input from the sending unit has on the receiving unit). The system includes three types of units: input, output and hidden units. These units operate as follows:

- Input units receive external inputs (e.g., the auditory or visual signal).
- Output units interact with the external world.
- Hidden units interact only with other units.

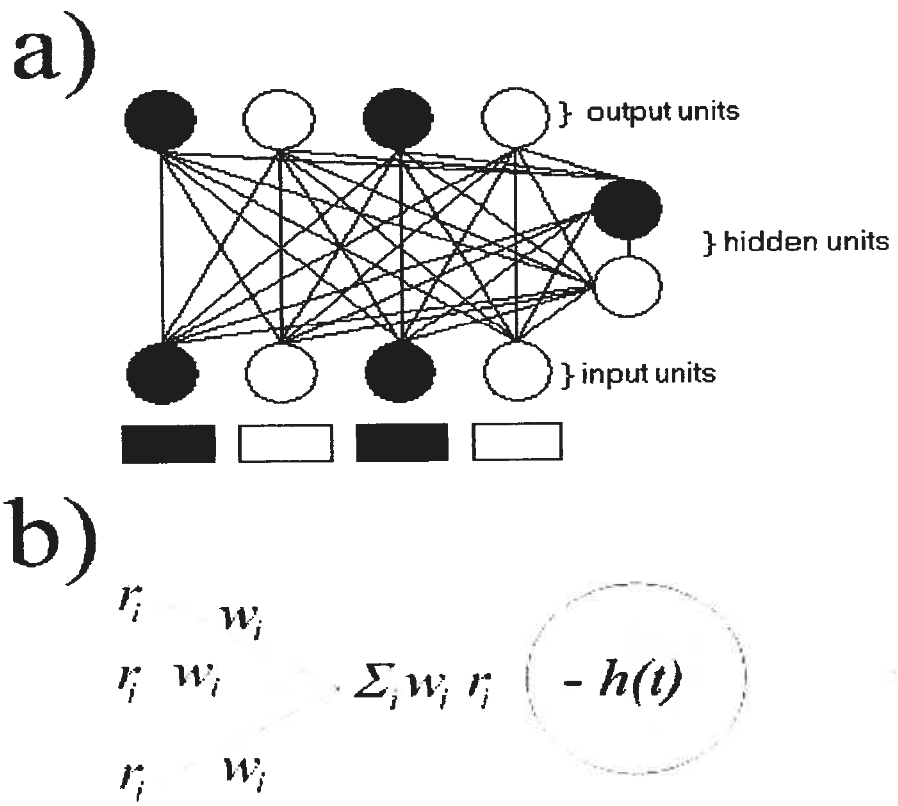
Any given unit may either be activated or not at any point in time. Activation is determined according to a number of factors: input, either from external sources or from other units within the network, as well as factors such as decay of previous activation. Each unit has an activation function which describes the way in which the various factors should be combined in order to determine the sum activation level of the unit in question. If activation exceeds a certain threshold, the unit is activated.

A very simple connectionist system is modelled in Figure 1.2 below. The network itself is illustrated in 1.2(a); black and white nodes represent activated and non-activated units respectively. As can be seen, the nodes are linked to one another with connections,

[2] It should be noted that these systems do not typically assume that a single node encodes a given piece of information; rather, knowledge is represented by a pattern of activation across the network.

which may be of varying weight. Figure 1.2(b) provides the function by which the various inputs are summed to determine the activation level of a given unit. In this figure, "r" represents the activation level of each node, "w" represents the weight of a connection, and "h" represents the transfer function, that is, the function that is used to determine whether the unit is activated or not.

Figure 1.2: A simple connectionist network




These systems have the advantage of a certain degree of neurobiological plausibility: nodes may be taken to represent neurons, and connections to represent synapses. Current approaches to the functional neurobiology of language (discussed more fully in section 7 below) point toward the conclusion that lexical information is likely represented in widely distributed cortical cell assemblies such as those postulated by neural network models.

However, these models suffer from a number of drawbacks. First, current neural network models typically require error feedback information during training in order to achieve good performance. This is in contrast to a child acquiring a language, where feedback is typically not provided. Furthermore, such models typically account for only a subset of language-related phenomena (e.g., acquisition of the English past tense). No model has been developed to date which can account fully for human language competence and performance. Finally, coding of the input and interpretation of the output of neural network models is experimenter-determined.

In sum, the lexicon is a highly complex system encoding a vast array of knowledge possessed by speakers about their language. More than three decades of research has revealed numerous factors that play a role in the organization and retrieval or activation of this knowledge. A number of different models have been proposed to account for these findings; each have appeal in terms of our knowledge of lexical processing, damage to the language system as a result of neurological disease, or our understanding of the basic principles of neurobiology. It seems likely that the most plausible model of human language will integrate aspects from each of these approaches.

The research reported in the current thesis focuses on the issue of the mass/count distinction (an overview of this distinction is given in section 6 below). It thus taps into the representation and access of semantic and syntactic information in the lexicon. We focus on the representation of these noun types in the lexicon, and the on-line (rule-based) processing that occurs when they are recognized in context. In section 6.2.5, we speculate on the possible neurobiological underpinnings of the reported findings, appealing to the concept of "word webs" of neurons that represent lexical knowledge. This claim is intimately linked with the idea of connectionist networks expounded upon above, thus pointing the way to a possible integration of the different approaches to the study of the mental lexicon, at least with respect to the mass/count distinction.

Having discussed various models and theories that attempt to capture the way information is represented in the lexicon, we now discuss other issues relating to research on the mental lexicon that are pertinent to the studies presented here. First, since the present research examines syntactic, semantic and lexical processing and representation, current conceptualizations of the roles that these play are discussed in Section 2.2. Second, in section 2.3 we discuss the advantages and shortcomings of the different tasks that were used (sentence grammaticality judgement, sentence-picture matching, and lexical decision), examining the processes that these tap into and possible drawbacks to their use. Finally, since much of the research reported on here examines a subclass of lexical ambiguity, metonymy, a brief overview of the findings with respect to representation of lexical ambiguity is provided in Section 2.4 (note that a more complete discussion of the processing of metonymy is provided in Section 6.2 below).

## 2.2 Syntax, semantics and the lexicon

Much research has been devoted to determining the extent to which our language system may be subdivided into separate components responsible for different aspects of language processing. With respect to the syntax/semantics divide, a plethora of evidence has suggested that two cognitively and neuroanatomically separable systems exist, one governing rule-based syntactic processing and the other governing semantics and lexically-bound syntactic knowledge (e.g., word category and verb subcategorization information; see Pinker, 1994, 1999; Ullman, 2001). Neurological damage may affect primarily syntactic knowledge (e.g., in agrammatic aphasia, see section 5.4 below) or semantic knowledge (e.g., in semantic dementia, see section 5.3 below). Furthermore, a great deal of research has suggested that left anterior cortical regions form the neural substrates for the syntactic system, whereas the neural substrates of the semantic system are postulated to be in left temporal regions[3].

However, there are a number of issues that must be held in mind when considering the ways in which we reach conclusions such as those mentioned above. These issues have been highlighted in a recent publication by Poeppel and Embick (in press). They identify two central problems with the current study of neurolinguistics, which apply specifically to neuroimaging studies, but are nonetheless pertinent to any research seeking to elucidate language-brain relations in any meaningful way:

1. The Granularity-Mismatch Problem (GMP): The objects with which neuroscience and linguistics operate are of different granularity. Theoretical

[3] See section 3.2 below for a discussion of a newer proposal that the neural substrates of the syntactic system are in frontal/basal ganglia circuits, and that the lexicon is based in a temporoparietal circuit.

linguistics invokes many fine-grained processes, whereas neurolinguistic approaches typically delineate language function more broadly. For example, neurolinguistics may refer to "syntax", stating that "Broca's area underlies syntactic function", while theoretical linguistics breaks syntax down into a multitude of subcomponents, processes and representations (see Embick & Poeppel, in press).

2. The Ontological Incommensurability Problem (OIP): Both linguistic theory and neuroscience operate with fundamental units or primitives (e.g., feature, noun phrase; neuron, long-term potentiation, i.e., a long-term increase in synaptic efficacy following high-frequency stimulation of afferent fibers). The connections between these units are unclear, complicating the task of drawing links between the two fields.

Poeppel and Embick (in press) propose a new programme of research which will render more feasible the bridging of neurobiological and linguistic research. They suggest that linguistic function must be viewed in a more fine-grained way than has been the case up until now in much neurolinguistic research. As such, linguistic theory can in fact inform neurobiology, rather than neurobiology exclusively informing linguistic theory, as has traditionally been taken to be the case in language/brain research. As Poeppel and Embick (in press, p. 13) put it:

> "Based on established and empirically well-supported distinctions drawn in linguistics [...] we work on the problem of how the brain encodes complex and abstract information in general, and linguistic information, in particular. [...] the basic assumption is that we study aspects of brain function by relying on a system whose cognitive architecture is well understood (like the visual system, for example)."

This approach is exemplified by a recent event-related potential (ERP) study providing neurobiological evidence of phonological feature underspecification in the mental lexicon (Eulitz & Lahiri, 2004), and by another which probes the neural response to the phonological feature [±voice] (Phillips, Pellathy, Yeung & Marantz, in preparation). In these studies, the authors examined the effect of an established linguistic entity on the brain's electrophysiological signal, thus using insights from theoretical linguistics to better understand the brain's functioning, rather than vice versa.

In designing the research presented in the current thesis, I have attempted to take these considerations into account. The distinction utilized, the mass/count distinction, is fine-grained at a linguistic level, tapping into both syntactic and semantic processing, and, we argue, in fact represents a linguistic primitive, whereby a distinctive feature [mass] encodes the difference between noun classes. As such, it represents an appropriate starting point for an examination of how cognitive alterations as seen in normal aging, as well as neurological damage, affect language processing at a more subtle level than a simple syntax/semantics divide. Thus, although we appeal to the notion of "syntactic competence" and "(lexico)semantic information"[4] when describing the performance of our participants, these notions in fact refer to a very specific subcomponent of syntactic/lexicosemantic knowledge and performance. "Syntactic competence", in this context, refers to (a) the lexically encoded knowledge about the syntactic status of differing noun classes; and (b) the representation and processing of specific syntactic

[4] Although we refer to "lexicosemantic information", it should be noted that the lexical and semantic levels are in fact divisible; see section 2.1 for a discussion of syntax and semantics in the lexicon.

rules relating to mass/count feature processing.[5] "(Lexico)semantic knowledge" refers to the knowledge possessed by the speaker about the referents of a given noun, and specifically, in this thesis, to their status as objects or substances (i.e., their "countness" or "massness"). It is of course the case that syntactic competence and lexicosemantic knowledge are terms that refer to a much broader class of processes and knowledge than the types described here.

Although the methodologies utilized in the experiments described here do not allow specification of the neurobiological underpinnings of the mass/count distinction per se, in that neuroimaging and electrophysiological methodologies are not included, they do indicate that the successful processing of mass/count information is probably dependent upon the integrity of a variety of brain regions. We can offer no definite hypotheses as to the role of these brain regions, but we do speculate as to the way in which mass/count information may be represented and processed at a neurobiological level, and attempt to draw links between known neurobiological processes and the theoretical account of the mass/count distinction that we propose (see section 7 of the Introduction and sections 6.2.4 and 6.2.5 of Chapter 6).

Given the complexity of the task of drawing links between performance on language tasks and linguistic theory, not to mention the neurobiological underpinnings thereof, a clarification of the advantages, drawbacks and postulated functions recruited by the

[5] This includes feature-matching between determiner and noun, as discussed by Gillon et al. (1999). as well as operation of lexical rules to process nouns of different classes in context. These rules are discussed in more detail in the studies themselves as well as in the Conclusions section of the present thesis.

various methodologies used in the present research is crucial; this is provided in section 2.3 below.

2.3 Methodologies

The studies reported here utilize differing methodologies designed to tap into different types of processing of linguistic information. In the following sections we briefly describe and critique these methodologies.

2.3.1 Sentence grammaticality judgement

In Studies 1 and 4, subjects performed a sentence grammaticality judgement task where sentence-final determiner-noun combinations were either grammatical or ungrammatical. Sample sentences are provided in 1a and 1b below.

1a. The baby likes every doll.

1b. *The girl doesn't love much doll.

Sentences were presented visually and left visible to the participants while the decision was being made; they were also read aloud to the participants. This avoids any modality-specific effect, such as better performance in the visual than the auditory modality.

Although grammaticality judgement tasks are often used in linguistics to assess linguistic competence in various populations, it should be noted that a number of objections may be raised to this approach. Grammaticality judgement tasks are subject to interference from a number of factors, including memory limitations, distractions, shifts of attention/interest, errors, false starts and hesitations, etc. (for a discussion, see Allen & Seidenberg, in press). Thus, it cannot be assumed that performance on grammaticality judgement tasks is perfectly reflective of speakers' linguisitic competence. Furthermore, being off-line, this task taps metalinguistic knowledge. It is thus far removed from natural language processing, and probably exploits difference processes, resources and networks.

Especially relevant to the current thesis, given the inclusion of participants diagnosed with AD, is the issue of working memory impairments and their influence on performance on grammaticality judgement tasks (see section 3.1 below for a discussion of working memory). These concerns may be alleviated, however, by evidence that working memory does not play a significant role in single-sentence grammaticality judgement in AD, but rather has been shown to manifest effects primarily at the discourse level (Almor, MacDonald, Kempler, Andersen & Tyler, 2001). This finding is also pertinent to the second task used in Studies 1 and 4, a sentence-picture matching task (see section 2.3.2).

Nonetheless, when interpreting data from a sentence grammaticality judgement task, the preceding factors must be borne in mind. The assumption underlying interpretation of this data is that these factors play an equivalent role across different stimulus categories, and should thus average out. Ideally, however, any conclusions drawn from this type of task should be bolstered by evidence from studies utilizing different methodologies (e.g., Studies 2 and 3 of the present thesis).

2.3.2 Sentence-picture matching

Studies 1 and 4 also utilized a sentence-picture matching task, where subjects were asked to match a sentence of the form "Point to the picture of (an) X" to a picture denoting the mass or count reading of a dual noun. Sample test items are shown in Figures 1.3 and 1.4 below:

Figure 1.3: Sentence-picture matching stimulus, count reading of dual noun

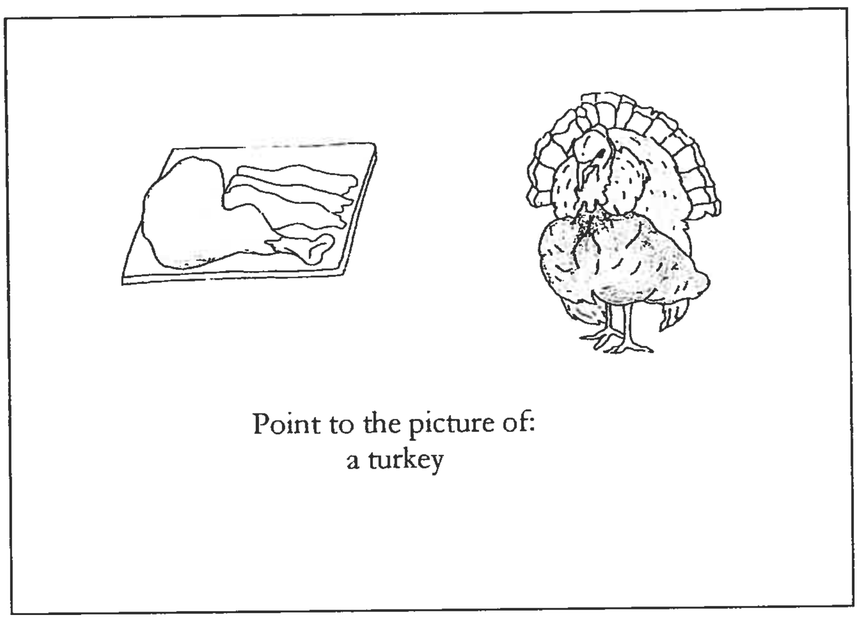
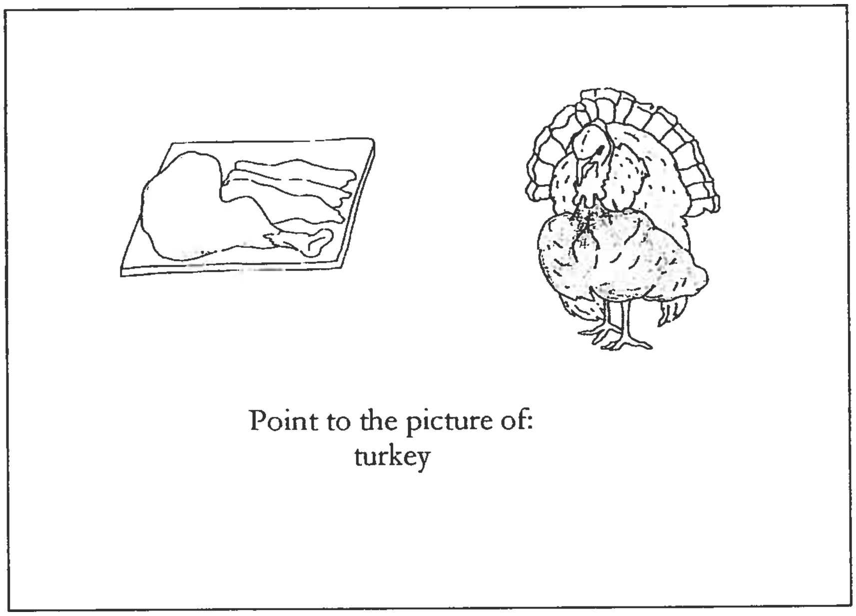


Figure 1.4: Sentence-picture matching stimulus, mass reading of dual noun




The subject is required to interpret the sentence (including, crucially, the determiner "a", indicating count, or the zero determiner indicating mass), then interpret the visual input and match the two. Similar concerns may be raised with respect to the issue of memory demands, attention, etc., as in the case of sentence grammaticality judgement tasks. A number of other issues also arise with respect to the additional task demands inherent in sentence-picture matching. First, unlike a sentence grammaticality judgement task, visual or visuoconstructive impairment will affect performance on this task. Second, the matching process itself places demands on executive processes, which may also be impaired in AD.

Confounds that have been demonstrated to affect sentence comprehension in AD, such as syntactic complexity (Emery, 1985; Emery & Breslau, 1989; Kontiola, Laaksonen, Sulkava & Erkinjutti, 1990; Bickel, Pantel, Eysenbach & Schröder, 2000) and number of propositions (Rochon, Waters & Caplan, 1994), were controlled in the task utilized in the studies reported here, in that the mass and count sentence readings differed only in terms of the inclusion of a determiner. Nonetheless, as noted in the Conclusions section of the current thesis, interpretation of the results of these studies is limited by the possibility that errors may be due to a number of other factors. This is especially true in the case of the AD individuals, who manifest a number of impairments other than linguistic, especially in memory and executive function. Thus, a second study assessing these individuals' performance in a lexical decision task (Study 3) was also conducted. The task demands associated with lexical decision tasks are discussed in Section 2.3.3 below.

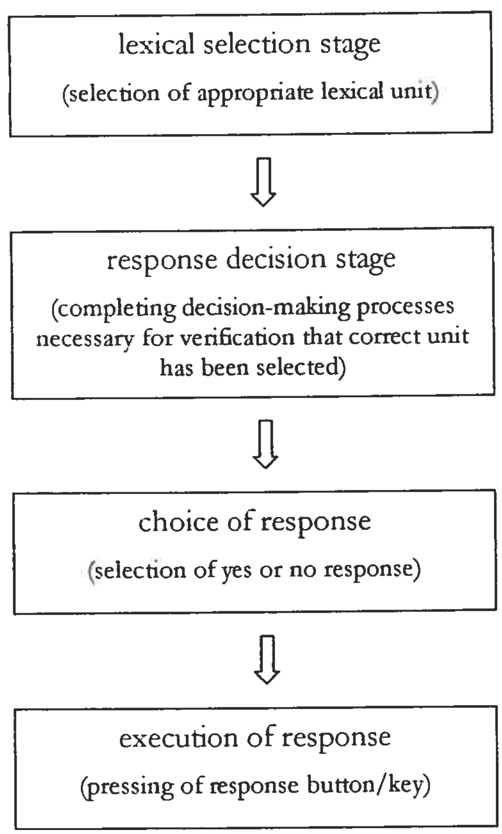
2.3.3 Lexical decision

In a lexical decision task (henceforth, LDT), participants are asked to determine as quickly and accurately as possible whether a visual or auditory stimulus constitutes a word in their language or not. Dependent variables include reaction time (RT) and accuracy. Numerous lexical characteristics have been shown to influence performance on this task, including frequency (e.g., Forster & Chambers, 1973), bigram frequency (e.g., Massaro, Venezky & Taylor, 1979), imageability (e.g., Strain, Patterson & Seidenberg, 1995), and neighbourhood density (e.g., Andrews, 1997). Thus, these factors must be carefully controlled when designing stimuli for an LDT.

In terms of task demands, an LDT presumably requires three processing stages: lexical access/activation, decision, and execution of the response. In a standard task, participants are instructed to press either a "yes" key or a "no" key to indicate whether the stimulus is a word, adding one stage: response choice. This also adds a memory component, since participants are required to remember which key corresponds to which response, and a possible source of variability, since errors may result from incorrect response selection rather than at the level of access or decision. These stages are shown in Figure 1.5 below.

Figure 1.5: Processing stages in yes/no LDT

(based on Perea, Rosa & Gómez, 2002)




In the experiments reported in Studies 2 and 3, a go/no-go LDT was utilized, whereby participants only responded to word stimuli. This type of task removes the need to perform the third processing stage (response selection), thus removing one possible source of variability. As such, it provides a more reliable measure of the variables of interest: RT differences engendered by different noun classes. Perea et al. (2002) have demonstrated that go/no-go LDTs provide faster and more accurate responses, as well as fewer processing demands, than do standard yes/no decision tasks.

Each of the stages outlined in Figure 1.5 nonetheless contributes sources of variability in an LDT. As such, when interpreting the results of such a task, it is important to recall that it is not only lexical access that is being measured, but rather lexical access + decision time (+ response choice in yes/no LDT) + time to execute response. This is particularly relevant for variables such as frequency, which have been demonstrated to exert a greater effect in an LDT than in other tasks that do not involve a decision component, such as naming and eye fixation times (Balota & Chumbley, 1990; Schilling, Rayner & Chumbley, 1998). However, caution is warranted when interpreting the effect of any independent variable on LDT performance; independent verification from another type of task or methodology, such as ERP, is necessary before the conclusion can definitively be drawn that different RTs in fact reflect differential lexical access/processing as opposed to alterations in the decision/execution component of the task.

Having discussed the methodologies utilized in the experiments reported here, we now turn to a central issue of the present thesis: lexical ambiguity.

## 2.4 Lexical ambiguity in the lexicon: findings and theories

Lexical ambiguity is a general term used to refer to lexical items which have more than one *meaning* or *sense*. The distinction between multiple meanings and multiple senses rests on the issue of whether the two referents of the lexical item are related or not. If they are, we term them "senses". If they are not, we term them "meanings".

This distinction, which rests heavily on speakers' intuitions of relatedness, may become clearer with exemplification. Consider the lexical item "bank" in the following contexts:

2a. John swam to the bank.

2b. John withdrew money from the bank.

In 2a, "bank" refers to the side of a river, whereas in 2b, "bank" refers to a financial institution. The two referents are unrelated, and hence "bank" is a *homonymous* word.

Now consider the word "chicken" in sentences 3a and 3b below:

3a. John ate some chicken.

3b. John cooked a chicken.

While "chicken" is being used in a different way in the two sentences, referring to a food in sentence 3a and to an animal in sentence 3b, the two referents are clearly related; thus, we refer to this lexical item as *polysemous*. Unlike homonymy, which is the result of historical accident, polysemy is productive: for example, we can use new animal words to refer to the meat of that animal:

3c. Scientists have discovered a new animal called a *caracol*. Apparently *caracol* is eaten frequently in Brazil.

Polysemy may be further subdivided into metonymy, where both referents are literal, as in sentences 3a and 3b above, and metaphorical polysemy, where one referent is literal and the other metaphorical. This is illustrated in sentences 4a and 4b below:

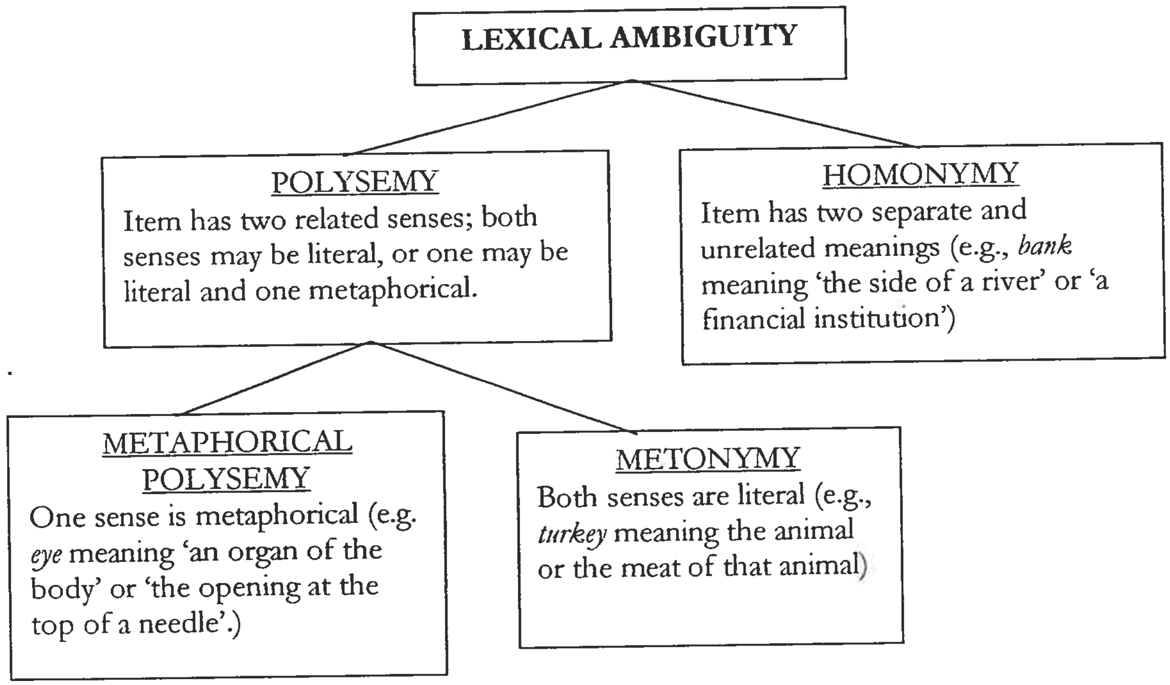
4a. John rubbed his *eye*.

4b. John passed the thread through the *eye* of the needle.

In the theoretical linguistic literature, it has been suggested that lexical ambiguity in fact falls on a continuum from pure homonymy to pure polysemy. Metaphorical polysemy thus falls closer to homonymy and metonymy falls closer to pure polysemy (Apresjan, 1974).

This taxonomy is laid out and exemplified in Figure 1.6 below.

Figure 1.6: Varieties of lexical ambiguity




Much research on processing of lexical ambiguity has been reported in the psycholinguistic literature. Research has focused on the issue of whether both meanings of an ambiguous word are activated when it is recognized (multiple access) or whether only the contextually appropriate meaning is activated (selective access). Despite the theoretical distinction that has been drawn between homonymy and polysemy, the majority of psycholinguistic research has focused on studies of homonymy (but see section 6.2 below for a discussion of studies focusing on processing of the mass/count distinction, including mass/count polysemy).

With respect to homonymy, it appears that activation of alternate meanings is dependent on a number of factors. These include context, whereby a highly constraining context may lead to activation of the contextually appropriate but not the inappropriate meaning (e.g., Swinney, 1979; Tanenhaus, Leiman & Seidenberg, 1979; Seidenberg, Tanenhaus, Leiman & Bienkowski, 1982; Tabossi, 1988), interval between prime and target (interstimulus interval, or ISI), whereby at a short ISI both meanings are activated but at a longer ISI the inappropriate meaning is suppressed (e.g., Swinney, 1979, 1991; Simpson & Burgess, 1985; Burgess & Simpson, 1988; Simpson & Krueger, 1991;), and frequency of the two meanings, whereby the more frequent meaning is more activated than the less frequent meaning (Simpson & Burgess, 1985).

In sum, the findings in the literature point to a model where all meanings are initially activated, although the degree of activation is modulated by context and frequency of the alternate meanings (Duffy, Morris & Rayner, 1988; Rayner & Frazier, 1989; Rayner, Pacht & Duffy, 1994; Rayner, Binder & Duffy, 1999), and the appropriate meaning is selected within 200ms of stimulus onset (see Klepousniotou, 2005).

Experimental results examining polysemy, in contrast, have indicated that these words are processed differently than homonymous words. They show shorter fixation times in reading tasks (Frazier & Rayner, 1990) and stronger priming (Klepousniotou, 2002) than homonymous words. Metonymic lexical items have also been demonstrated to be processed faster than homonymous items (Azuma & Van Orden, 1997; Rodd, Gaskell & Marslen-Wilson, 2002). These findings suggest that words with multiple senses are represented and/or accessed differently than words with multiple meanings. Processing of metonymic lexical items with a mass/count extension, as in examples 3a and 3b above, is discussed further in section 6.2, which focuses on studies examining processing of the mass/count distinction.

The research presented in this thesis investigates not only the unimpaired lexicon, but also the ways in which representation of and access to this information may be altered over the lifespan, both in healthy aging and in the case of neurological impairment. Given the emphasis on memory systems that is inherent in a work focusing on aging and Alzheimer's disease, in section 3 below we provide a brief overview of theories of human memory.

## 3. Theories of human memory

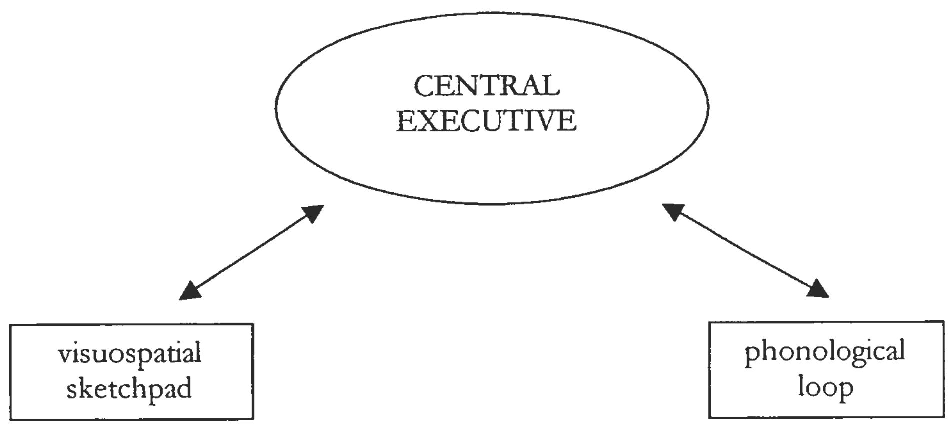
Human memory is not a unified system. Rather, it may be divided into a number of subcomponents, each responsible for different aspects of our memory function. These subcomponents are dissociable from one another, and may be differentially affected in neurological disease as well as in healthy aging. We offer a brief description of each postulated subcomponent in sections 3.1 - 3.4 below.

### 3.1 Short term and working memory

Short-term memory is the component of our memory system that allows the retention of information for brief periods of time. In 1974, Baddeley and Hitch proposed the term "working memory" (henceforth WM), to reflect the fact that this information is held in mind and manipulated over the short term. This manipulation includes integration, mental calculations and general reasoning.

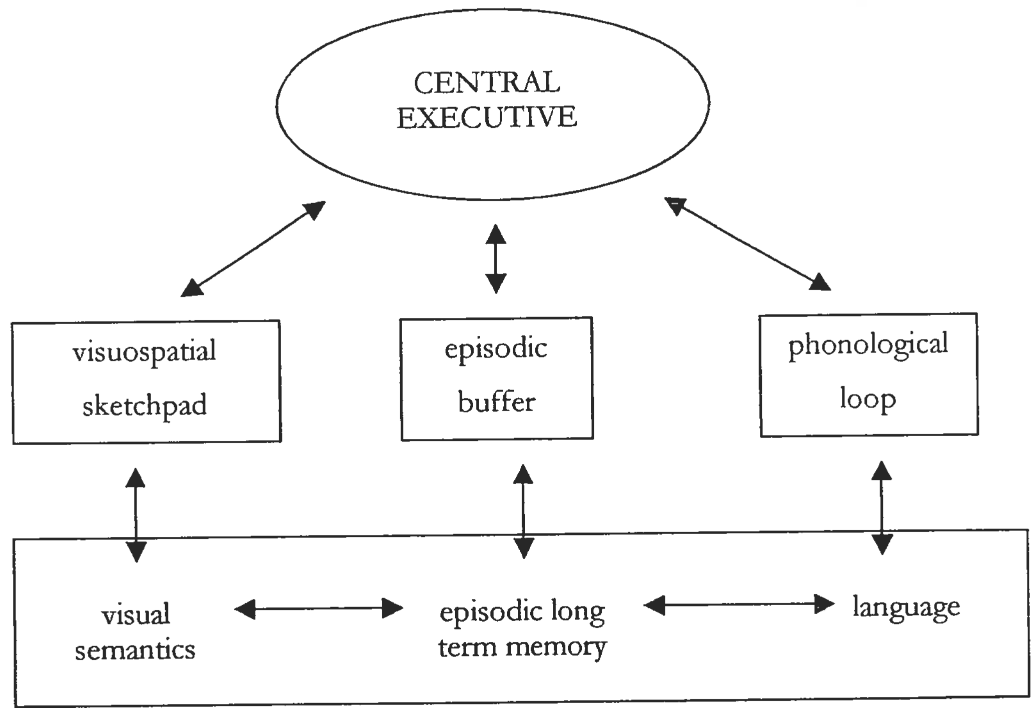
The original WM model proposed by Baddeley and Hitch (1974) holds that WM consists of 3 components. The first is the central executive, a control system of limited attentional capacity. The model also includes two subsidiary storage systems, the phonological loop, responsible for storing phonological information, and the visuospatial sketchpad, responsible for storing visual information. This model is illustrated in Figure 1.7 below:

Figure 1.7 Baddeley and Hitch's (1974) model of WM




This model is supported by neuropsychological evidence, whereby lesions may affect individual components of the system, as well as by functional neuroimaging evidence (for a discussion of the neural underpinnings of WM, see Baddeley, 2003). The model was subsequently revised (Baddeley, 2000) to account for the interactions that have been demonstrated between WM and long term memory. The revised model is shown in Figure 1.8.

Figure 1.8 Baddeley's (2000) revised model of WM




The episodic buffer is a limited capacity store that is responsible for binding information together in order to create integrated episodes. This component is accessible to conscious awareness and interacts with episodic long-term memory (discussed in section 3.5 below).

Thus it can be seen that damage to WM, specifically the phonological loop (thought to be located in the left temporoparietal region (BA40, see Baddeley, 2003) will affect language processing as a result of an inability to keep auditory information in WM.

We now provide a brief overview of the subcomponents of LTM: declarative memory (which can be subdivided into semantic and episodic memory) and procedural memory.

3.2 The declarative/procedural distinction

Numerous human and animal studies have demonstrated that there exists a distinction between declarative memory, which may be conceptualized as memory for "what", and procedural memory, which may be conceptualized as memory for "how" (Mishkin, Malamut & Bachevalier, 1984; Schacter & Tulving, 1994; Squire & Knowlton, 2000; Eichenbaum & Cohen, 2001; Poldrack & Packard, 2003). Declarative memory subserves the learning, representation and use of knowledge about facts and events (semantic and episodic knowledge; see section 3.3 below). Its neural substrates are thought to be located in the medial termporal lobe (hippocampus). Procedural memory, on the other hand, subserves the learning and control of procedures, either sensorimotor or cognitive, such as riding a bicycle or finding your car that you always park in the same place). Its neural substrates are thought to be located in frontal/basal ganglia circuits.

Ullman and colleagues (Ullman et al., 1997; Ullman, 2001, 2004) have proposed that separable language functions are dependent on the integrity of declarative and procedural memory. Specifically, "grammar" (i.e., the rules that a speaker applies when producing or comprehending language) are dependent upon procedural memory, whereas the lexicon is dependent upon declarative memory. This model was proposed in light of evidence that individuals suffering from AD, whose declarative memory is impaired, exhibited a deficit in production of the past tense of irregular English verbs (e.g., *go/went*) and individuals suffering from Parkinson's disease, whose procedural memory is impaired, exhibited a deficit in production of the past tense of regular English verbs (e.g., *jump/jumped*). However, this model has been challenged by claims that these findings may be replicated using a connectionist model that does not appeal to two separate systems (Joanisse & Seidenberg, 1999).

It has also been proposed that declarative memory can be separated into two subcomponents, episodic and semantic memory (Tulving, 1972). This is discussed in section 3.3 below.

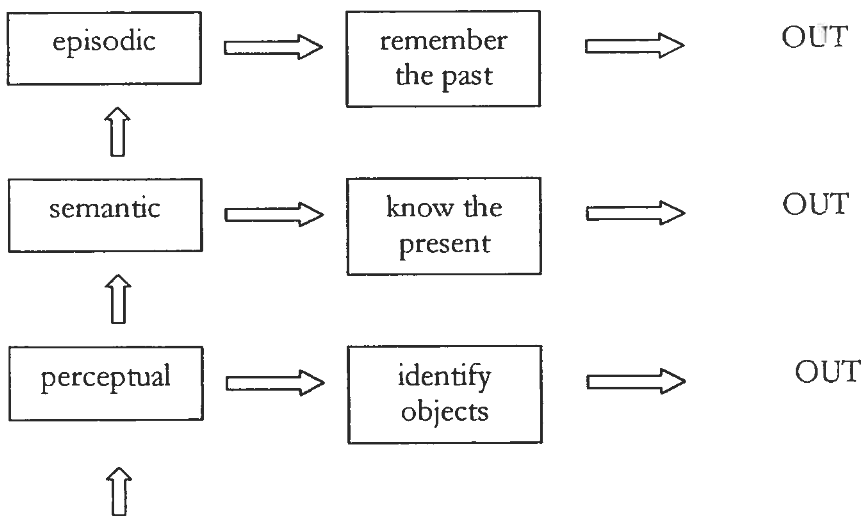
3.3 Episodic and semantic memory

As alluded to in section 3.2 above, the fact that declarative memory is responsible for the learning, representation and use of knowledge about both facts and events suggests that it may be dissociable into two separate systems, one responsible for memory for facts (semantic memory) and one responsible for memory for events (episodic memory). This distinction is supported, for example, by the fact that amnesic patients have a deficit in their capacity to store new episodic memories in the context of basically intact semantic memory. However, it has been demonstrated that these patients in fact typically show intact episodic memory from prior to the onset of their amnesia (Baddeley & Wilson, 1986; Wilson & Baddeley, 1998) and have deficits in encoding new semantic information, being unable, for example, to name the current president and not knowing words introduced into the language subsequent to the onset of their amnesia (Gabrieli, Cohen & Corkin,. 1988).

Recent work has refined our approach to the episodic/semantic distinction. Conway (2001) suggests a distinction between episodic memory, which he uses to refer to recent recollective experience, and autobiographical memory, which is the accumulation of personal knowledge. Other researchers (especially Gardiner, 2001) have discussed the issue of testing of episodic memory, introducing a paradigm termed the "remember/know" (RK) paradigm. Experimental applications of this paradigm involve asking subjects not only whether they think they have seen a given item before (i.e., a standard recognition task) but also whether they explicitly *remember* seeing the item, or whether they just "know" (e.g., sense that the item is familiar). Theoretical, experimental and neuroimaging research converge on the conclusion that there are indeed two separate components at work in traditional recognition paradigms (for a discussion and review, see Tulving, 2001).

A second question which arises is which memory system comes first, semantic or episodic. That is, does semantic knowledge build on episodic or vice versa? Baddeley (2001) has suggested that semantic memory may best be conceptualized as "the residue of many episodes". Tulving (1995), on the other hand, suggests that the reverse is true: the creation of episodic memory is in fact based on semantic memory. He terms his model the SPI (serial – parallel - independent) model, since, according to this model, encoding is serial, storage is parallel and retrieval is independent. The model is represented in Figure 1.9 below:

Figure 1.9: Tulving's (1995) SPI model




Thus, the perceptual level makes information available to the semantic and episodic systems. The semantic system is responsible for storing and processing of facts, and the episodic system "extends the processing of objects and facts to the 'self' in 'subjective time'." (Tulving, 2001, p. 1509).

In terms of neurological disease, light has been shed on the issue of how best to characterize the distinction between episodic and semantic memory by the study of individuals who, due to progressive neurological disease, begin to lose their knowledge of the meaning of words, even common ones. These individuals, diagnosed with *semantic dementia*, lost the information in an orderly fashion, first losing specific terms, and then gradually losing more general superordinate terms. This syndrome is discussed in greater detail in Section 4.4 below.

The current thesis focuses on the issue of how one aspect of our knowledge of words, mass/count information, is represented and accessed. The question of declarative versus procedural memory is thus pertinent, given that both semantic and syntactic factors play a role in this representation and access, meaning that integrity of both memory systems is presumably necessary for successful processing of this information. The controversy surrounding the episodic/semantic distinction has been highlighted here because included in the subject pool that participated in the current experiments are individuals with profound episodic and semantic memory disorders (AD patients) and one individual with a focal semantic deficit (semantic dementia), as well as healthy older adults, a population whose memory capacities are altered relative to younger adults. An understanding of current conceptualizations of how human memory works is thus necessary if the data presented here are to be interpretable. Thus, in the following sections we review the literature on alterations in memory and language processing in these populations.

## 4. Cognitive function in healthy aging

Extensive research on aging has indicated that, even in the absence of neuropathology, changes in cognitive function are seen over the course of the lifespan. These changes are particularly evident in tasks that require self-initiated processing, such as cued and free recall (Craik & Jennings, 1992); on the other hand, tasks that require less effortful retrieval, such as implicit retrieval, are typically found to be less impaired (for a review, see Craik, 2000). Likewise, no decrement is seen over the lifespan on tasks that rely on world knowledge, such as vocabulary scores (Park, 2000), and, indeed, older adults sometimes even perform better than younger adults on these measures (Salthouse, 1993).

Different memory systems have been found to be differentially affected by the aging process. Procedural memory, as assessed by priming tasks, is found to be intact in healthy adults; in fact, priming effects are, if anything, greater than in younger adults (Laver & Burke, 1993). Working memory, on the other hand, has been found to exhibit significant age-related decline (Wingfield, Stine, Lahar & Aberdeen, 1988; Dobbs & Rule, 1989; Craik, Morris & Gick, 1990). Episodic memory has generally been found to be relatively more affected than semantic memory (Light, 1996; Burke, MacKay & James, 2000; Wingfield & Stine-Morrow, 2000; see Craik, 2000, for a review), although the latter has also been found to be affected to a certain extent. For example, older adults often manifest word-finding difficulty (Burke, MacKay, Worthley & Wade, 1991), as well as difficulty in retrieving proper names (Cohen & Faulkner, 1986; Maylor, 1990).

4.1 Lexicosemantic knowledge

One important component of semantic memory is lexicosemantic knowledge, that is, knowledge of words and their meanings. Previous research has suggested that no age-related decline is seen in lexicosemantic organization and processing. Similar performance by younger and older adults has been reported on a variety of tasks aimed at examining the organization of lexicosemantic knowledge, such as generation of word associations (Lovelace & Cooley, 1982; Bowles, Williams & Poon, 1983; Burke & Peters, 1986) and category exemplars (Howard, 1980).

However, these results have been challenged by research demonstrating that age differences are in fact seen in lexical production and category representation. For example, Brosseau and Cohen (1996) report a study in which older and younger adults were asked to generate associations to 30 semantic category names. The most common responses differed across the two groups for 21 of the 30 categories, suggesting an alteration in organization of semantic information in healthy elderly adults relative to young adults. Similarly, Dommes and Le Rouzo (2004) report a study of lexical ambiguity in which older and younger adults produce different familiarity ratings to homophonous lexical items, and older adults show a greater effect of semantic priming in selecting pictures representing the two meanings of the homophones. Where a neutral prime was used, pictures were selected on the basis of the familiarity ratings the subjects had previously provided. These authors interpret this as indicating differential organization of the lexicon in older and younger adults.

On-line studies of lexicosemantic processing have demonstrated similar response patterns in older and younger adults. For example, in lexical decision, older adults are at least as accurate as younger adults (Bowles & Poon, 1981, 1985; Howard, 1983), although older adults' overall response time has been demonstrated to be somewhat slower than that of younger adults (Tainturier, Tremblay & Lecours, 1989; Allen, Madden & Crozier, 1991; Allen, Madden, Weber & Groth, 1993).

Likewise, factors such as frequency have been shown to exert a similar effect on older and younger adults' lexical processing. Nonetheless, some studies have hinted at changes in the way in which lexical information is processed over the lifespan. Spieler and Balota (2000) conducted an analysis of data from a word-naming task comprising 2,820 items, and found differential effects for lexical and sublexical factors in older and younger adults. Specifically, while frequency, word length, and orthographic neighbourhood density all predicted reliable amounts of variance in naming latencies for both subject groups, frequency had a relatively greater effect on the older adults' performance. That is, a lexical factor (frequency) exerted a greater influence on older adults' performance than did sublexical factors (neighbourhood density, word length), relative to the performance of younger adults. This result was interpreted as reflecting older adults' greater reading experience.

Neuroimaging and electrophysiological studies have also indicated age-related differences in language processing. Federmeier, Van Petten, Schwartz & Kutas (2003) had older and younger adults listen to natural speech for comprehension while ERPs were recorded; sentences contained lexically associated or unassociated word pairs, and were either meaningful or syntactically legal but meaningless. Attentional and lexical associative effects were similar across the two subject groups, but message-level (context) effects were significantly delayed in older adults. The authors interpret these results as indicating that longitudinal changes in language processing occur primarily in higher-order processes. On the other hand, Miyamoto, Katayama and Koyama (1998) report alterations in older adults' electrophysiological response to stimuli primed by semantically mismatched items; a reduction in the N400 component was seen in older adults relative to younger adults. The authors attribute this to larger semantic networks and more diffuse semantic activation in older adults.

Madden et al. (1996) and Madden, Langley et al. (2002) conducted a positron emission tomography (PET) study examining older and younger adults' neural activation while performing a lexical decision task. They found that, while behavioural responses were similar, neural activation differed across the two groups. Madden et al. (1996) found greater occipito-temporal activation in the younger adults, while Madden, Langley et al. (2002) found greater activation in Brodmann's area 37 in the older adults, and greater activation in Brodmanns' area 17 in the younger adults. The data from the latter study were re-analysed by Whiting, Madden, Langley, Denny, et al. (2003) to investigate the effects of lexical and sublexical components, that is, word frequency and word length, respectively, on the two participant groups. They found that the frequency effects seen in older adults were related to activation in Brodmann's areas 17, 18 and 37 of the left hemisphere, while word length effects in this groups were related only to activation in Brodmann's area 17. The authors conclude that, while performance differences on this task across the lifespan are typically not seen in behavioural measures, the neural mechanisms underlying word identification are affected by the aging process. An increase in orthographic familiarity and a strengthening of the semantic representation associated with a given lexical entry are taken to occur with aging, leading to an increased reliance on the neural areas underlying these functions.

In sum, although certain changes are seen in language processing across the lifespan, these changes are usually located at the level of higher-order processing, or in executive processes, such as attention or working memory. Behavioral measures do not typically reveal longitudinal changes in lower-level lexicosemantic processing.

However, there do exist some studies suggesting that such alterations do indeed occur. These include both behavioral studies (e.g., Brosseau & Cohen, 1996; Spieler & Balota, 2000; Dommes & Le Rouzo, 2004) showing alterations in semantic organization in the lexicon, and by neuroimaging studies (e.g.. Madden et al., 1996; Madden, Langley et al., 2002; Whiting et al., 2003) which have demonstrated changes in neural activation associated with word length and frequency. As such, it is clear that much remains to be understood about the precise nature of lexicosemantic processing across the lifespan.

4.2 Theories of cognitive aging

A number of theories have been put forward to account for the changes in cognitive function seen across the lifespan. Salthouse (1991, 1996) proposed the "processing speed theory", which holds that longitudinal declines in cognitive function are caused by a generalised cognitive slowing. Salthouse (1996) postulates two mechanisms that play a role. The first is the "limited time mechanism", whereby older adults may not have the time available to perform later components of a given cognitive task if they require more time to complete earlier components. The second is the "simultaneity mechanism", whereby the results of earlier cognitive operations may no longer be available by the time that later operations have been completed. As a result of this mechanism, older adults will manifest impaired performance even on non-speeded tasks, since the results of earlier cognitive operations may not be available to them. Further, this theory predicts that the most age-related decline will be seen on the most complex tasks, since it is on these tasks that the greatest effect on later components will be seen.

A second influential hypothesis accounting for cognitive aging was put forward by Craik and Byrd (1982). They claim that longitudinal declines are a result of deficits in working memory, which have been extensively demonstrated in the literature to occur in older adults (Wingfield, Stine, Lahar & Aberdeen, 1988; Dobbs & Rule, 1989; Craik et al., 1990). Relative to younger adults, older adults possess a reduced capacity to store, retrieve and transform information on-line, indicating that processing resources are more limited. The result of this deficit in working memory is that older adults manifest a decrement on tasks for which information must be held in working memory, such as tasks in the auditory (as opposed to the visual) modality, and dual task paradigms. Deficits in working memory have been put forward to account for a number of age-related changes in language processing, such as discourse processing (Light & Albertson, 1993) and syntactic analysis (e.g., Kemtes & Kemper, 1997).

Hasher & Zacks (1988) put forward an alternate theory which rests on the claim that older adults' decrements in cognitive function are a result of their difficulty in inhibiting irrelevant information when performing cognitive tasks. As a result, task-irrelevant information enters into working memory and is maintained over a prolonged period of time. A variety of evidence has been marshalled to support this theory; for example, older adults are more likely to maintain disconfirmed inferences (Hamm & Hasher, 1992), and exhibit stronger negative priming (Hasher, Stoltzfus, Zacks & Rypma, 1991), whereby a response that must be inhibited on a given trial becomes the basis for the correct response on a subsequent trial.

Finally, Lindenberger and Baltes (1994) have claimed that nearly all age-related variance across a variety of cognitive tasks can be accounted for in terms of decreased sensory function. The evidence for this claim is drawn from the Berlin Aging Study, in which adults between the ages of 70 and 103 performed 14 different cognitive tasks.

Reductions in visual and auditory acuity were found to be the best index of decline in these tasks across the different age groups. Furthermore, sensory measures accounted for all variance in speed of processing, but not vice versa. A second study (Lindenberg & Baltes, 1997) examined a sample of adults ranging in age from 25 to 103. Systematic declines in all aspects of cognition were demonstrated across the lifespan, and these were mediated by sensory function. The rate of decline did not vary as a function of education, occupation, social class nor income, suggesting that these declines are based on biology rather than social factors. This is consistent with Lindenberg and Baltes's (1994) claim that declines in sensory acuity can predict declines in cognitive function since they are both correlated with cerebral integrity.

It seems likely that the most plausible account of age-related changes in cognition will incorporate aspects of each of these theories. Each account has a solid theoretical basis; changes in processing speed, working memory, inhibitory function and sensory acuity do indeed occur in older adults and each of these likely has a broad influence on cognitive functioning. It is probable that different tasks will tap into different aspects of cognitive aging. As such, alterations in performance in any given task may best be accounted for by appealing to one or more of these theories. For example, as mentioned above, alterations in processing speed will probably have their most profound influence in more complex tasks, such as sentence (as opposed to single-word) processing. Likewise, reductions in working memory capacity will likely have a strong influence in tasks that tap into this component, such as dual task paradigms. Hasher and Zacks's (1988) theory that reductions in inhibitory function underlie older adults' decrements in cognitive function is probably most relevant with respect to tasks that incorporate a significant inhibitory component, such as a task where subjects are required to suppress task-irrelevant information. That is, all of these factors are in play at all times, but different tasks will highlight different aspects of the complex multi-factorial nature of cognitive aging.

Particularly important to bear in mind when conducting research designed to examine cognitive function in older adults is the fourth hypothesis presented, that the majority of age-related changes in task performance can be accounted for in terms of sensory acuity. While the other factors mentioned above certainly play a role in cognitive aging, it is paramount that sensory acuity issues be taken into consideration in task design. Only when a task is designed such that sensory acuity cannot account for performance alterations and/or participants' sensory capacities are evaluated and this is taken into account in analysis of the results, can we begin to assess the influence of other factors on subject performance.

Given the diverse hypotheses regarding the fundamental mechanisms at work in normal aging, it is clear that much work remains to be done in terms of understanding the processes underlying age-related changes in cognitive function. Chapter three of the current thesis examines lexicosemantic processing in healthy younger and older adults, with the objective of shedding further light on this issue, as well as providing a baseline for later studies with populations exhibiting pathological aging. A brief overview of findings with regard to linguistic function in these populations is given below.

## 5. Cognitive function in pathological aging

Participants from two patient populations participated in the research reported here: subjects suffering from Alzheimer's disease and mild cognitive impairment. Study four also reports the performance of one patient diagnosed with semantic dementia and another with agrammatic aphasia. The following sections provide a brief summary of the impairments seen in these different populations.

### 5.1 Alzheimer's Disease

Alzheimer's disease (AD) is the most common dementing disease and accounts for more than half of dementia cases (Canadian Study of Health and Aging Working Group, 1994). Although definite diagnosis of AD cannot be made until autopsy, individuals may be diagnosed with probable AD on the basis of clinical criteria, listed in Table I below.

Table I NINCDS-ADRDA criteria for a diagnosis of probable AD (from McKhann et al., 1984)

- dementia established by clinical examination and documented by the Mini-Mental Test; Blessed Dementia Scale, or some similar examination, and confirmed by neuropsychological tests;
- deficits in two or more areas of cognition;
- progressive worsening of memory and other cognitive functions;
- no disturbance of consciousness;
- onset between ages 40 and 90, most often after age 65; and
- absence of systemic disorders or other brain diseases that in and of themselves could account for the progressive deficits in memory and cognition.

Diagnosis of possible, probable and definite AD are made as follows (Cummings, 2004):

1. Definite AD: clinical diagnosis + confirmation at autopsy.
2. Probable AD: typical clinical syndrome but no confirmation at autopsy
3. Possible AD: atypical clinical features but no alternative diagnosis apparent; no confirmation at autopsy.

In terms of cognitive profile, the most typical clinical features of AD are memory impairment, language and visuospatial deficits, and impairment in executive function. Patients typically also exhibit modifications in personality and behaviour. Motor and sensory deficits, gait disturbances and seizures are also seen, albeit typically later in the disease course. However, a good deal of heterogeneity is seen in this group. All AD individuals exhibit a memory impairment, but this may co-occur with diverse cognitive symptoms; disproportionate aphasia, agnosia, or apraxia may be seen, and there also exists a frontal variant of AD in which executive function is disproportionately impaired (for a review and discussion of possible neurobiological bases for these subtypes of AD, see Cummings, 2000).

In terms of language performance, the majority of patients exhibit anomia (word-finding difficulty) even very early in the disease course (Appell, Kertesz & Fisman, 1982; Bayles & Kaszniak, 1987). Further, timed (on-line) studies of language processing in AD have revealed response time alterations, particularly a generalized slowing (Nebes & Brady, 1992), relative to elderly controls. AD patients exhibit intact phonological abilities (Murdoch, Chenery, Wilks & Boyle, 1987) and are not typically found to manifest syntactic impairments (Bayles, 1982; Kempler, Curtiss and Jackson, 1987). However, some authors (e.g., Grossman, Mickanin, Onishi & Hughes, 1995) have claimed that subtle syntactic impairments can be seen in this subject group . (For a review of language performance in AD, see Caramelli, Mansur & Nitrini, 1998.)

There exists a general consensus that AD patients exhibit significant impairments in semantic abilities, in contrast to relatively intact syntactic and phonological abilities (Irigaray, 1973; Whitaker, 1976; Schwartz, Marin & Saffran, 1979; Bayles & Kaszniak, 1987; Kempler et al., 1987; Light & Burke, 1993; Kertesz, 1994; Patel & Satz, 1994). Clinically, these semantic impairments are typically assessed using confrontation naming and verbal fluency tasks. In mild AD, most naming errors take the form of production of superordinate labels (e.g., "animal" for "giraffe") or semantically related items (e.g., "clock" for "watch"; Bayles, Tomoeda & Trosset, 1990; Hodges, Salmon & Butters, 1991). It has been argued that this pattern of errors reflects loss of knowledge of specific attributes; in contrast, superordinate knowledge tends to be preserved (Martin & Fedio, 1983; Chertkow & Bub, 1990). Verbal fluency tasks, in which participants are required to produce as many items as possible fulfilling a given criterion within a limited time frame, typically one minute, may be divided into semantic fluency tasks, where the criterion is semantic (e.g. "Name as many animals as you can"), and letter fluency tasks, where the criterion is orthographic (e.g., "Name as many words as you can that start with the letter A"). Verbal fluency is substantially reduced in AD (Ober, Dronkers, Koss, Delis & Friedland, 1986; Butters, Granholm, Salmon, Grant & Wolfe, 1987), and semantic fluency has been found to be more affected than letter fluency (Monsch, Bondi, Butters, Salmon, et al., 1992; Pasquier, Lebert, Grymonprez & Petit, 1995).

Another way of assessing the integrity of semantic memory is through semantic priming tasks, whereby memory is measured via facilitated performance on a given item when it is preceded by a semantically related item. Semantic priming paradigms thus assess the integrity of semantic memory in an implicit fashion, as opposed to the naming and verbal fluency paradigms described above. As mentioned above, priming is preserved in healthy aging (Laver & Burke, 1993). In contrast, early studies of semantic priming in AD (e.g., Ober & Shenaut, 1988) demonstrated a significant reduction in the priming effect. However, later studies indicate that the nature of semantic priming performance in AD is significantly more complicated than had originally been thought. Chertkow, Bub & Seidenberg (1989) tested a group of six AD patients on a series of off-line tasks, followed by a primed lexical decision task. They found substantially greater priming (hyperpriming), as well as slowed lexical decisions, on those items whose representations were degraded according to the results of the off-line tasks. Thus, counterintuitively, *increased* priming on a lexical decision task could be taken to indicate damage to the semantic system in AD.

Taken together, these results point to linguistic impairments in AD being located at the level of the lexicon, in contrast to a relatively intact grammar. Nonetheless, the question of the exact nature of the deficit remains open; that is, whether AD patients' linguistic impairments are the result of impaired access to semantic information, while the semantic representations remain intact, or whether they are reflective of damage to the representations themselves (see, e.g. Nebes & Brady, 1991; Hodges, Salmon & Butters, 1992). Several studies with mild to moderate AD patients have indicated that impairment in certain items is consistent across different tasks, supporting the interpretation that the lexicosemantic impairment in AD is a result of damage to the semantic system rather than impaired access (e.g., Huff, Corkin & Growdon, 1986; Chertkow & Bub, 1990).

In order for an individual to be diagnosed with AD, significant impairments in two or more domains of cognition must co-occur with dementia; that is, the individual must exhibit significant impairments in daily functioning. If an individual exhibits memory impairments relative to age-matched healthy controls in the absence of dementia, and other possible causes, such as depression, can be ruled out, the individual may be diagnosed with mild cognitive impairment. A brief description of this syndrome, as well as a discussion of its potential connection to AD, is provided below.

5.2 Mild cognitive impairment

Mild cognitive impairment (MCI) is a term that was recently introduced by the World Health Organization (see also Petersen, Smith, Waring, Ivnik, Tangalos and Kokmen, 1999). It is designed to capture the point on the continuum of cognitive states between normal aging and dementia (see Chertkow, 2002 for a discussion). The criteria for MCI are given in Table II below.

Table II: General criteria for mild cognitive impairment

from Chertkow (2002)

| |
|---|
| Subjective complaint of memory loss. |
| Objective impairment of ability. |
| Generally preserved other ability. |
| No other obvious medical neurologic or psychiatric explanation for the memory problems. |
| Individual does not meet criteria for dementia |

Of particular interest in research with MCI individuals is the issue of whether MCI represents an early stage of AD. Although there exists significant variation in conversion rates across studies, on average it has been found that approximately 15% of MCI individuals convert to AD annually. A review of the principal studies in the literature is available in Laurent & Thomas Antérion (2002). It appears, however, that a subset of

MCI individuals will not convert to AD, even ten years after onset of MCI (Chertkow, 2002).

At the neuropathological level, at least some MCI individuals exhibit the same profile that is seen in very early AD, specifically neurofibrillary tangles in the hippocampus and entorhinal cortex (Chertkow, 2002). Decreased hippocampal volume has also been found to occur (Jack, Petersen, Xu, O'Brien, et al., 1999). However, postmortem examinations of patients with MCI have revealed that cholinergic markers in the cortex are not altered in these cases (Bouras, 2002, cited in Chertkow, 2002).

In terms of neuropsychological function, a great deal of heterogeneity is seen in MCI (Lautenschlager, Riemenschneider, Drzezga & Kurz, 2001). Certain researchers have advocated further subdivision of MCI, depending on the cognitive domain(s) affected. Petersen et al. (2001) define the majority of MCI patients as suffering from "amnestic MCI", meaning that they are suffering from memory impairment, but that other cognitive domains are intact; these MCI individuals are more likely to develop AD. Alternatively, MCI patients may exhibit impairment in a single cognitive domain other than memory; in this case, it is likely that the patients will develop some other neurodegenerative disease, such as primary progressive aphasia (Chertkow, 2002). In still other cases, patients may manifest subtle impairments across a range of domains, or "multiple domain MCI" (Lopez, Jagust, DeKosky & Becker, 2002).

These findings leave open the question of whether or not MCI constitutes an early ("pre-demential") stage of AD, and, if so, in what proportion of cases. Following an extensive literature review, Laurent and Thomas Antérion (2002) conclude that MCI represents a pre-demential stage of AD in 70-80% of cases. Nonetheless, it must be borne in mind that there still exists significant controversy in terms of the definition of MCI, and there exist at least seven different operational definitions for MCI (Chertkow, 2002). As would be expected, differences in cohort definition lead to differences in conversion rates from MCI to AD, and studies range widely in terms of the conversion rates found.

Both off-line and on-line studies of lexicosemantic processing in AD and MCI populations are reported in chapters two and four of the present thesis. We now turn to a review of cognitive function in the remaining populations that are studied in this thesis: semantic dementia and agrammatic aphasia.

5.3 Semantic dementia

Semantic dementia (SD) is a recently described clinical condition involving a specific deterioration in the ability to name or comprehend concepts, in the absence of impairments to phonology or syntax, and otherwise relatively spared cognition. Mesulam (1982) described a series of six cases of progressive language impairment in the absence of generalized dementia; these were the first clinical descriptions of a syndrome which became known as primary progressive aphasia (PPA). It soon became clear that PPA was a heterogeneous disorder; although patients typically manifested anomia (word-finding difficulty), differences were seen in the degree of semantic, syntactic and phonological impairment, and findings from structural and functional neuroimaging were also variable from case to case. A division was thus drawn between fluent and non-fluent PPA.

Patients suffering from non-fluent PPA show a pattern similar to that of Broca's aphasics. Those patients suffering from fluent PPA, on the other hand, show a progressive loss of knowledge of the meaning of both words and objects; that is, they demonstrate an impairment in semantic memory, but intact episodic memory. This led to the designation "semantic dementia" (Snowden, Goulding & Neary, 1989).

In most cases of SD, magnetic resonance imaging and autopsy findings indicate primary involvement of the temporal lobe, specifically the temporal pole and inferolateral region, although both grey and white matter are found to be implicated, and there are conflicting findings in the literature with respect to the degree of hippocampal involvement (Garrard & Hodges, 2000). Although in the majority of cases patients do not reach autopsy until their deficit is no longer restricted to semantic memory, there does exist one case in the literature where an SD patient died early in the disease course and an autopsy was performed (Harasty, Halliday, Code & Brooks, 1996). In this case, atrophy was found to be restricted to the left inferior and middle temporal gyri. Subcortical white matter, hippocampus, basal ganglia and parahippocampal gyri were spared.

In terms of language function, these patients are found to have fluent, grammatically correct speech, but a lack of content words. Phonological aspects of language are found to be intact. Anomia is universally found, although circumlocutions or generic words such as "stuff" may be inserted instead. Semantic paraphasias are also occasionally seen. A sample of the language of an SD patient is given below (taken from Garrard & Hodges, 1999):

> Patient (on being shown a picture of a soldier): Oh gosh, this seems to be, oh come on, try and remember the name; I know what they are cause there's three of these, so it's not the two and three, it's the one which, er... some of them will be in Britain because, er, you know with our stuff in Britain, some of them are also outside Britain, some of them are also in Britain as well. What d'you call them again because N.'s son, no, not son, his brother, he's one of these as well.

SD patients also show reductions in exemplar generation in the category fluency test, in which patients are asked to generate as many exemplars of a given category (such as animals) within a minute. They exhibit impairments in repetition of sentences but not single-word repetition. In terms of reading, surface dyslexia is seen, whereby these patients exhibit normal performance on regularly spelled words, but difficulty with words with an irregular grapheme-phoneme correspondence, such as "pint".

In sum, these patients show profound language impairments and reduced knowledge about the meaning of objects, but preserved abilities in other cognitive areas. This pattern of impairment may best be captured in terms of damage to semantic memory; hence the term semantic dementia. The core features of SD are listed in Table III. (For a further review and discussion of this syndrome, see Mesulam, 2003.)

Table III: Core features of semantic dementia

(from Garrard & Hodges, 1999).

| | |
|---|---|
| Age at onset | <65 |
| Disease progression | Generally rapid |
| Spontaneous speech | Fluent, grammatically correct, devoid of function words |
| Paraphasias | Semantic |
| Comprehension:<br>Single word<br>Syntax | <br>Impaired<br>Intact |
| Repetition | Normal for single words |
| Episodic memory | Preserved for recent events |
| Frontal 'executive' functions | Intact in early stages |
| Visuospatial & perceptual skills | Intact |
| Behaviour | Appropriate initially; frontal components appear later |
| MRI findings | Focal polar and inferolateral temporal lobe atrophy, often worse on left |

The final participant in the studies included in this thesis was diagnosed with agrammatic aphasia. Given that the mass/count distinction bears upon both semantic and syntactic issues, this individual was included in order to tease apart the semantic and syntactic contributions to processing of mass/count information. The reasoning behind the inclusion of this individual in the present research is elaborated upon in Section 8 below.

We now turn to a brief review of the characteristics of agrammatic aphasia.

5.4 Agrammatic aphasia

Agrammatic aphasia is an acquired language disorder that is usually the result of brain damage, such as a stroke. Patients suffering this disorder manifest what may be described as "telegraphic" speech, whereby speech is effortful, functional categories such as determiners and tense markings are often omitted, and anomia (word-finding difficulty) is observed. A typical utterance is given below. The patient is attempting to describe the Cookie Theft picture from the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1972).

> Kid … kk … can … candy … cookie … candy … well I don't know but it's writ … easy does it … slam … early … fall … men … many no … girl … dishes … soap … soap … water … water … falling pah that's all … dish … that's all.
>
> cookies … can … candy … cookies … cookies … he … down … that's all. Girl … slipping water … water … and it hurts … much to do … Her … clean up … Dishes … up there … I think that's doing it … [the examiner asks: What is she doing with the dishes?] discharge … no … I forgot … dirtying clothes [?] dish [?] water … [the examiner probes: What about it?] slippery water … [?] scolded … slipped.

(from Obler & Gjerlow, 1999)

Until the 1970's, it was believed that comprehension was intact in these patients; however, Caramazza and Zurif (1976) demonstrated that subtle comprehension deficits are indeed seen in agrammatic aphasia. They tested these patients on semantically reversible and semantically irreversible passive sentences, such as those shown in 4a and 4b:

4a. The boy that the girl kissed is tall. (semantically reversible)

4b. The ball that the boy kicked is red. (semantically irreversible)

They found impaired comprehension in sentences of type 4a, but not in sentences of type 4b, which provide semantic cues to their correct interpretation. These and similar later findings have revealed that agrammatic aphasics generally exhibit both production and comprehension deficits, although dissociations have been attested in the literature (e.g., Caramazza & Miceli, 1991). Various hypotheses in terms of a breakdown in syntactic competence (e.g., Grodzinsky, 1984, 2000; Mauner, Fromkin & Cornell, 1993; Grodzinsky & Finkel, 1998) or processing limitations (e.g., Hartsuiker & Kolk, 1998) have been proposed to account for the morphosyntactic impairment characteristic of agrammatic aphasia (for a review, see Nadeau, Rothi & Crosson, 2000).

Lexical access has also been found to be abnormal in this population. Specifically, verbs tend to be more impaired than nouns (see, e.g., Bastiaanse & Jonkers, 1998), although abnormalities in lexical access of ambiguous nouns have also been demonstrated (Swinney, Nicol & Zurif, 1989). The present research (Chapter 5) examines the performance of an agrammatic aphasic subject on tasks designed to tap semantic and syntactic aspects of the mass/count distinction, with the goal of further specifying the role that these two types of information play in processing different noun types. A brief review of the mass/count distinction in English follows below.

6. The mass/count distinction

English nouns may be defined as either proper nouns, common nouns or pronouns. Common nouns may be either *mass* or *count*. This distinction may be captured in terms of syntactic criteria:

Table IV: Syntactic distribution of mass and count nouns

| **Mass nouns** | **Count nouns** |
|---|---|
| Cannot be pluralized (*two honeys) | Can be pluralized (two trees) |
| Cannot take the indefinite article (*a honey) | Can take the indefinite article (a tree) |
| Take only quantifiers that do not denumerate (much honey) | Take only quantifiers that denumerate (many trees) |

There also exists a category of nouns which may take either a mass or a count reading (e.g., *turkey*). Following Gillon, Kehayia & Taler (1999), we term these items "dual nouns". Duality constitutes a form of metonymy (see section 2.4 above for a discussion of lexical ambiguity in the lexicon).

Although the distribution of mass and count nouns can be captured in terms of the syntactic environments in which they appear, there is nonetheless significant disagreement among linguists as to which criteria are in fact most appropriate to characterize the mass/count distinction. Four major approaches may be identified; these are outlined below (see Joosten, 2003 for further discussion).

6.1 Theoretical linguistic approaches to the mass/count distinction

Proponents of the *grammatical viewpoint* (e.g., Bloomfield, 1933) hold that the mass/count distinction is a purely grammatical one, and can be captured according to the criteria listed in Table IV. Under this view, semantic factors play no role whatsoever in this distinction. While this adequately captures the mass/count distinction distributionally, it ignores the likelihood that the correlation between the use of mass nouns to refer to "stuff" and of count nouns to refer to "things" is more than merely coincidental. For example, Markman (1985) examined the mass/count status of 48 basic level categories in 18 languages from several language families, and found a 99% agreement in this status cross-linguistically.

The *ontological viewpoint*, most famously espoused by Quine (1960), claims that the mass/count distinction holds between referents; that is, it is a distinction between real-world entities. The principles of "cumulative reference" and "Cheng's condition" (Cheng, 1973) have been invoked to characterize these criteria. The former holds that "any sum of parts which are water is water" (Quine, 1960); that is, if you add water to water, you still have water. The latter is a reversal of this condition: "Any part of the whole of the mass object which is *w* is *w*" (Cheng, 1973). That is, if you remove water from water, you are still left with water; mass nouns refer *distributively* as well as cumulatively. Ter Meulen (1981) summarizes these properties in terms of "homogeneous reference": referents of mass nouns have a homogeneous structure, whereas referents of count nouns have a heterogeneous structure.

A number of objections may be raised to these claims. First, these criteria may just as well be applied to plural count nouns (Gillon, 1996): if you add horses to horses, you are still left with horses; likewise, if you remove horses from horses, you still have horses. Second, this account does not capture language differences; for example, the noun *spaghetti* is mass in English but plural in Italian. Finally, these criteria do not translate well to abstract nouns such as *crisis* and *quality*, nor to dual nouns admitting both a mass and a count reading (Joosten, 2003)

Proponents of the *semantic viewpoint* (e.g., Wierzbicka, 1991; Jackendoff, 1992) claim that the mass/count distinction is best seen in terms of the way that the world is conceptualized by language users; that is, the mass/count distinction "resides in the meanings of the nouns themselves, and not in the things they name". Count nouns are conceptualized in an individuated fashion, and mass nouns in an unindividuated fashion. Again, this account can be considered inadequate for several reasons (Joosten, 2003). First, some mass/count alterations do not appear amenable to an account in which this distinction is determined by the way in which the world is conceptualized by language users (e.g., peas/rice). In these cases, such an account appears somewhat ad hoc. Second, the semantic viewpoint does not explicitly account for dual nouns, which alternate between mass and count (although it could of course be argued that speakers may conceptualize a given noun as count in one context and mass in another).

A fourth view of the mass/count distinction is the *contextual view* (e.g., Pelletier, 1979; Bunt, 1985). Under this view, mass- or countness is not a feature of the noun itself, but rather of the noun phrase (NP). This is illustrated both by the phenomenon of dual nouns, and by the thought experiment proposed by Pelletier (1979), known as the "universal grinder", which demonstrated the flexibility of nouns to appear in mass and count contexts. The universal grinder is a machine that can grind any substance, converting it from individuated to unindividuated – that is, from a "count" substance to a "mass" substance. Thus, sentences such as "There is book all over the floor" are rendered grammatical.

Gillon (1996) also discusses a number of circumstances under which mass/count conversion occurs; that is, where a so-called mass noun may be used as count, or vice versa. In the latter case, these include (a) type conversion, where a mass noun is used as a count noun in order to denote a type thereof; (b) unit conversion, where a mass noun is used as count in order to denote a unit thereof; (c) in the case of emotions, conversions of the type whereby the noun is used to denote "that which gives rise to the emotion"; and (d) conversions of the type whereby the noun is used to denote instances of the denotation of the mass noun. Examples of this are given below (from Gillon, 1996, pp. 29-30):

5a. Only two coffees are sold in this store: Ethiopian and Costa Rican.

5b. I ordered a pizza, not a slice of pizza.

5c. Carol has two anxieties: her job and her children.

5d. Elizabeth made many efforts to contact her lawyer.

Gillon (1996) proposes a series of lexical rules to account for these conversions (p.30):

6a. $|C(M)|_c = \{x\text{: is a unit of } |M|_c\}$

i.e., a mass noun may be converted to a count noun whereby the count noun refers to a *unit* of the mass noun; for example, a coffee = one unit (cup) of coffee.

6b. $|C(M)|_c = \{x: \text{is a kind of } |M|_c\}$

i.e., a mass noun may be converted to a count noun whereby the count noun refers to a *kind* of the mass noun; for example, a grain = a kind of grain.

6c. $|C(M)|_c = \{x: \text{is an instance of } |M|_c\}$

i.e., a mass noun may be converted to a count noun whereby the count noun refers to an *instance* of the mass noun; for example, an effort = an instance of effort (see example 5d).

6d. $|C(M)|_c = \{x: \text{is a source of } |M|_c\}$

i.e., a mass noun may be converted to a count noun whereby the count noun refers to an *instance* of the mass noun; for example, an anxiety = a source of anxiety (see example 5c).

where M denotes a mass noun, C denotes a count noun, and $| \quad |_c$ denotes the conversion operation.

Gillon (1996) also enumerates a number of subtypes of conversion from count to mass nouns: (a) animal names used to denote the meat or fur of that animal, or vegetable names used to denote "the largest aggregate of those parts considered suitable for human consumption"; (b) tree names used to denote the wood from that tree; (c) conversion whereby count nouns are used as mass to denote "parts which contribute to the enlargement or enhancement of the product" (p.32); and (d) cases where the mass-or counthood of the lexical item depends on whether or not the denotation is "atomic"; that is, whether or not it is individuated. These cases are exemplified below:

4a) John likes to eat chicken.

4b) The sideboard is made of oak.

4c) Bill got a lot of house for $100,000. (example from Gillon, 1996)

4d) She tied the parcel with string.

One drawback with respect to the types of lexical rules enumerated by Gillon (1996) is that these rules are essentially a listing of conditions under which mass/count conversion may occur, without any principled account of why these conditions (or lexical items) allow conversion. The question which arises with respect to types (a), (b) and especially (d), where there is no clear preference for a mass or a count interpretation of the noun in the absence of context, is whether these reflect ambiguity or underspecification. This question has been partially answered in the literature (see sections 4.1 and 4.2 below), and the research presented here also provides an account of these cases.

Returning to the issue of the contextual viewpoint of the mass/count distinction, while this accounts elegantly for instances where conversion occurs easily, there are certain objections that may be raised (Joosten, 2003). First, not all nouns may be used in both mass and count contexts; Galmiche (1989) offers the French counterexamples **du kilo* and **de la catégorie*. Second, certain contexts are underspecified or ambiguous with regard to mass/count information (e.g., *that chicken*). And third, it must be borne in mind that the majority of nouns favour either a mass or a count reading.

In light of the objections that may be raised to the various accounts of the mass/count distinction, Joosten (2003) claims that a multidimensional approach is necessary, and proposes the following characterization of this distinction (p.227):

- (Non)countability is intimately connected with reality, though a plausible account for it can only be given when it is analysed in terms of a possible conceptual restructuration of that reality;
- (Non)countability is primarily a property of NPs, but nouns may differ in the degree that they occur in count or mass environments;
- When conceptualisation and reality do not match, this deviation may be (lexically/contextually) motivated or unmotivated. There is always a degree of arbitrariness in language.

Thus, Joosten (2003) essentially claims that each account of the mass/count distinction has validity, and that the most plausible account will integrate aspects of each viewpoint. This is consistent with the findings in the literature so far; processing of mass/count information has been found to be altered in a variety of neurological disorders affecting diverse language functions (see section 6.2.2 below). Likewise, it is consistent with recent insights into the neurobiological representation and processing of language, which views the neural substrates of language as being composed of widely distributed cell assemblies (e.g., Pulvermüller, 1999, 2001; see section 7 below).

The interaction of semantic and syntactic aspects of the mass/count distinction is addressed specifically in Chapter 5 of the present thesis, which assesses the performance of patients suffering from specific syntactic and semantic impairments on a sentence grammaticality judgement task and a sentence-picture matching task focusing on this distinction.

A number of studies examining processing of these noun types exist in the literature. We now turn to a brief overview of the principal findings, first reviewing those studies that examined neurologically unimpaired populations, and then turning to those studies examining the performance of populations with various types of neurological impairment.

## 6.2 Evidence for processing of different noun types

### 6.2.1 Unimpaired populations

Several studies exist of processing of various noun types in unimpaired populations. Gillon, Kehayia and Taler (1999) examined processing of a variety of noun types, including mass, count and dual nouns, in a simple and a primed lexical decision task. In the simple lexical decision task, it was found that mass nouns yielded longer RTs than did count nouns. In the primed lexical decision task, nouns of various types were used as targets and determiners with which they formed a grammatical or ungrammatical combination were used as primes. It was found that grammatical combinations yielded shorter RTs than did ungrammatical combinations. The authors took these results as support for the claims that: (a) mass and count nouns may be distinguished using a feature [mass], (b) accessing this feature slows recognition, and (c) a mismatch in mass/count information (i.e., the feature [mass]) between a determiner and a noun results in slowed access.

Azuma and Van Orden (1997) and Frazier and Rayner (1990) both examined processing of polysemous items and compared this with processing of homonymous items, using a reading task and a lexical decision task respectively. Both these studies found faster processing of polysemous items than of homonymous items; the former showed shorter fixation times in a reading task as well as shorter RTs in the lexical decision task. Similarly, in a cross-modal priming study examining processing of various types of ambiguous nouns, Klepousniotou (2002) found that metonymic nouns exhibited shorter RTs and greater priming than did homonymous nouns. The author interpreted this as indicating that only the basic sense of metonymic nouns is stored in the lexicon, and that mass/count information is inserted on-line by means of a lexical rule, such as the one postulated by Copestake and Briscoe (1995) and Pustejovsky (1995). This lexical rule is discussed further in Chapters 3-5.

6.2.2 Impaired populations

There exist a few studies in the literature examining the processing of mass, count and dual nouns in various impaired populations. In an off-line sentence-picture matching task, Shapiro, Zurif, Carey and Grossman (1989) examined the ability of Broca's and Wernicke's aphasics to access the mass and count interpretations of both homonymous nouns, such as *punch*, meaning either the drink or "a blow to the face", and of metonymic nouns with a mass/count extension, such as *turkey*. They presented the subjects with sentences of the form "Point to the picture of X" or "Point to the picture of an X", where X represents the ambiguous lexical item, along with a picture representing the two possible meanings or senses of the item. A similar task utilizing proper and common nouns (e.g., "Point to the picture of Penny" vs. "Point to the picture of a penny"). Broca's aphasics exhibited significantly poorer performance for the mass/count distinction than for the proper noun/common noun distinction, with especially poor performance on mass nouns. The pattern of results of fluent aphasics was not interpretable. The authors interpret the performance patterns of the Broca's aphasics as indicating that the proper noun/common noun is a universal semantic distinction, whereas the mass/count distinction is more purely syntactic, and thus is a source of difficulty for agrammatic subjects.

Unfortunately, no distinction was drawn between the two types of lexical ambiguity in Shapiro et al.'s (1989) study. In chapters 2 and 5 of this thesis, studies are presented where patients suffering from a variety of neurological disorders (AD, MCI, semantic dementia and agrammatic aphasia) participated in an identical sentence-picture matching task, but where all stimuli were dual nouns.

Grossman, Carvell and Peltzer (1993) and Grossman, Mickanin, Onishi and Hughes (1995) conducted studies examining processing of mass and count items by patients suffering from Parkinson's disease (PD) and AD, respectively. In both these studies subjects performed a sentence-picture matching task, a grammaticality judgement task and a sentence completion task. These tasks were designed to tease apart the semantic and syntactic information contained in the determiners *much* and *many*. Both patient groups were found to be impaired. In the case of PD patients, patients were found to be impaired in accessing syntactic information about the quantifier (i.e., information about its mass/count status), as well as judging the grammaticality of short sentences containing mass and count nouns. Some patients were also impaired in the sentence completion task. The authors take these results to reflect a multifactorial impairment. AD patients, on the other hand, showed difficulty with processing syntactic information in all three experiments, independent of any difficulty they experienced in interpreting the meanings of words. The authors conclude that these patients have an impaired appreciation of the conceptual relations underlying the mass/count distinction.

Semenza, Mondini and Cappelletti (1997) report on the case of an agrammatic aphasic subject who exhibits an impairment that is specific to mass nouns, in the absence of any other grammatical deficit, including in the use of count nouns. This impairment was demonstrated across a number of off-line tasks tapping both comprehension and production, including sentence grammaticality judgements, sentence completion and sentence production. These data are interpreted as reflecting an impairment at the lemma level of lexical retrieval (Kempen & Huijbers, 1983), grammatical rules, which are stored at that level, are thus independently stored and accessible.

Finally, Klepousniotou and Baum report on processing of lexically ambiguous items, both out of context (2005) and in context (in press), by right hemisphere damaged (RHD) [6] and non-fluent aphasic left-hemisphere damaged (LHD) patients, as well as healthy elderly individuals. In the first study, homonymous items, metonymic items and

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[6] Five of the eight RHD patients had cortical damage in areas subserved by the middle cerebral artery, and three had subcortical lesions

metaphorically polysemous items served as primes, and inter-stimulus interval was varied. The goal of this study was to determine the timecourse of activation of the different senses or meanings of ambiguous lexical items, and whether this was affected by focal brain damage. It was found that both the primary and the secondary senses of metonymic items were activated, and that neither right- nor left-hemisphere damage affected this activation. In the second study, the ambiguous items were embedded in sentence contexts which biased the dominant or subordinate meaning of the item. Healthy elderly individuals and LHD participants exhibited initial activation of both senses of the items, followed by contextually appropriate meaning selection. The RHD subjects, on the other hand exhibited activation of both senses of metonymic and homonymous items at both ISIs, and limited activation of the subordinate sense of metaphorical polysemous items.

The results found in the literature to date are summarized in section 4.2.3 below; the contributions of the present work are then reviewed in section 5.

6.2.3 Summary of findings in the literature

The results in the literature up to now suggest the following conclusions:

- mass/count information is represented in the lexicon and processed on-line; one possible way of representing this information is by means of a feature [mass] contained in the lexical entries of mass nouns (Gillon et al., 1999);
- metonymic lexical items engender shorter fixation times and more priming than homonymous lexical items (Azuma & Van Orden, 1997; Klepousniotou, 2002); one possible account for this is that the lexical entries of metonymic nouns do

not contain mass/count information; rather, this information is inserted on-line, according to context, by means of a lexical rule (Klepousniotou, 2002);

- semantic and syntactic aspects of mass/count information appear to be separable, and diffuse brain damage can affect one aspect of this knowledge (Grossman et al., 1993, 1995);
- focal brain damage may cause category-specific impairments (loss of knowledge about mass nouns; Semenza et al., 1997), but does not appear to alter the activation of the senses of metonymic nouns (Klepousniotou & Baum, 2005, in press).

There clearly remains much research to be conducted to determine with more precision the way in which mass/count information is represented and accessed. For example, it is not clear exactly what role semantic and syntactic factors play in processing and representation of mass/count information, a topic of interest both in theoretical linguistics and in psycholinguistics. The research to date has suggested that semantic and syntactic factors both play a role, but a number of issues preclude definitive conclusions on the matter. First, there is the issue of stimulus control; for example, Shapiro et al. (1989) discusses processing of mass/count flexible lexical items in aphasic and RHD populations, but does not distinguish between homonymous and metonymic items. Second, the majority of studies examining polysemy contrast these lexical items with other types of lexical ambiguity (Azuma & Van Orden, 1997; Klepousniotou, 2002; Klepousniotou & Baum, 2005, in press). There is a gap in the literature with respect to the comparative processing of mass nouns, count nouns, and mass/count flexible nouns. Finally, little research exists examining on-line processing of mass/count information, and even less with impaired populations. I attempt to address some of these issues in the current thesis, contrasting mass/count flexible items with mass and count nouns, testing a number of individuals with different types of language impairments, and controlling stimuli for a variety of linguistic and psycholinguistic variables.

Although the methodologies used in the present studies do not speak to the issue of the neural substrates of the representation and processing of mass/count information, in Chapter 6, I nonetheless attempt to situate my findings within the framework of functional neurobiology of language. It is thus of interest to briefly review the literature on the neuroanatomical substrates and neurophysiological processing postulated to underlie language processing; I do so in Section 7 below.

## 7. Perspectives on the functional neurobiology of language

The earliest studies of the cerebral representation of language focused on a function-region mapping, analysing the location of brain lesions and correlating this with declines in language function. Classically, language has been thought to reside in two regions of the left hemisphere: Broca's area (Brodmann's areas 44 and 45; Brodmann, 1909) and Wernicke's area (the posterior region of Brodmann's area 22). These areas were first identified as underlying language function by the French neurologist Paul Broca (1861), who observed a profound impairment in language production but essentially intact comprehension in his patient Tan, and Karl Wernicke (1873), who observed comprehension deficits in two patients of his who had suffered lesions to the brain region which would later be dubbed Wernicke's area, located posterior to the Sylvian fissure.

The trend of attempting to correlate specific regions of the brain and associated linguistic functions was dominant throughout the nineteenth century and much of the twentieth. Lichtheim (1885), a professor of medicine whose research in this area was highly influential, put it thus:

> "[neurologists] should then be able to determine the exact place of any discontinuity in these paths and account for its symptomatic manifestations with the same precision as we do for those of a motor or sensory paralysis depending on a lesion of the peripheral nerves."
>
> (cited in Obler & Gjerlow, 1999)

This approach was extended by a number of neurologists in the twentieth century, including notably Geschwind (1965), who extended the "language map" to include regions of the supramarginal and angular gyri, as well as the arcuate fasciculus, a tract of white matter which connects Broca's and Wernicke's areas.

However, recent work utilizing both classic lesion analysis and neuroimaging techniques has demonstrated the inadequacy of a simple area-function mapping approach to the localization of language in the brain. As Damasio, Tranel, Grabowski, Adolphs, & Damasio (2004) put it:

> "[t]he problem with the classical anatomical account is not that it is wrong but that it is quite incomplete… Any current consideration of the macrosystems involved in the processing of language requires the involvement of many other brain regions, connected by bidirectional pathways, forming systems that can subsequently cross-interact."

These authors undertook an analysis of the neural systems dedicated to word and concept retrieval, examining data both from a large number of patients with brain damage (n=169), and from PET studies of naming and concept retrieval. In their analysis of the naming and recognition performance of brain-damaged individuals, these authors found that naming is more often impaired with left hemisphere (LH) lesions, recognition (i.e., concept retrieval) deficits are associated with lesions that are more bilaterally distributed across the hemispheres, and recognition-only deficits with right hemisphere (RH) lesions. These authors also found that deficits in naming and/or recognition of specific categories of concrete nouns (e.g., tools, fruits/vegetables, faces etc.) are related to spatially separable regions. The results of the functional neuroimaging studies were in general agreement with these findings: regional separation was found between different categories, and the areas activated included large areas outside of the classical language areas (e.g., occipital cortex for naming animals, posterior inferior temporal lobe and supramarginal gyrus for naming tools, etc.).

According to Damasio et al. (2004), a number of conclusions follow from these findings. First, word retrieval involves areas outside classical language areas. Second, damage to a given area may impair naming but not recognition, while damage to other areas may damage recognition and thus preclude naming. That is, system components primarily dedicated to word retrieval may be separated from those primarily dedicated to concept retrieval. Third, words and/or concepts from different categories depend on the integrity of separable brain regions. This suggests that several partially integrated systems support word and/or conceptual retrieval. Finally, dysfunction sites (as revealed by lesion studies) are consistent with activation sites (as revealed by neuroimaging studies).

The authors interpret this evidence within the theoretical framework proposed and discussed by Damasio (1989a,b, 2000), Damasio and Damasio (1994), and Damasio, Damasio et al., (1990). This framework posits that the system of mental processes operates as follows:

1. The system operates on *images,* which are explicit, sensory on-line mental patterns. These may be of any sensory type (e.g., visual, auditory). The neural substrate for these images is a neural pattern located in or around sensory cortices. These patterns are constantly changing on the basis of both external and internal inputs.
2. The factual knowledge base and "know-how" mechanisms used to process images, actions, etc., are represented in *dispositions*, which are implicit (non-conscious) and whose use produces explicit outcomes (e.g., reconstruction of image from memory). These are located in higher-order and limbic cortices, as well as in subcortical nuclei (e.g., basal ganglia, amygdala).
3. Dispositions are held in *convergence zones*, which are made of microcircuits and are not resolvable with neuroimaging.
4. Convergence zones of comparable size are distributed within *convergence regions*, such as the temporal pole, inferior temporal cortex, etc.

The basic neuroanatomic design of these convergence zones and regions is taken to be available prior to individual experience, and is subsequently altered by individual learning. Thus, while certain convergence zones are expected to be found in the same convergence region across individuals, a good deal of variability is expected in the distribution of micro-scale convergence zones across individuals, as well as across tasks in the same individual. Therefore, inter- and intra-individual consistency is expected only at the large scale.

Naming an object, for example, is taken to require integrity of the following neural structures[7]:

a) structures supporting conceptual knowledge;
b) structures supporting the implementation of word-forms (in terms of vocalization; i.e., classical language areas);
c) intermediary structures for "words", which are engaged by the structures in (a) and trigger the structures in (b). These structures will vary depending on the type of word being retrieved; for example, naming a tool vs. naming George W. Bush.

This system is proposed to operate in reverse when an individual is presented with a word stimulus and is required to retrieve a concept.

The preceding discussion illustrates the complexity of the neural systems involved in any language task. Damasio et al.'s (2004) framework holds that different neural circuits are required for concept versus word retrieval, and suggests that different cortical regions will be recruited according to the task.

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[7] Note that, as acknowledged by Damasio et al. (2004), this system is a very simplified version of the processes that actually occur in word retrieval/production. See the discussion of the mental lexicon in section 2 above for a more detailed view.

We turn now to the question of how lexical information may be represented on a neurophysiological level. Pulvermüller (2001) offers a discussion of how established neuroscientific principles can guide our understanding of the neurophysiological underpinnings of language processing. His claims rest on the following principles:

1) there exist ordered afferent and efferent cortical projections in modality-specific areas;
2) massive information mixing occurs in the cerebral cortex, whereby information from various modalities is merged (see, e.g., Braitenberg & Schüz, 1998);
3) connection strength between neurons is strongly correlated with their synchronous firing (Fuster, 1997); the result is linked cell assemblies, which may underlie all higher-order cognitive processes (Hebb, 1949);
4) language is lateralized in the left hemisphere (Broca, 1861; for a discussion, see Pulvermüller, 1999).

According to Pulvermüller (2001), it follows from these principles that information from different sensory modalities is connected in a functional web which is distributed across the cortex. The formation of these webs is dependent upon Hebbian learning, that is, the synaptic strengthening which occurs as a result of synchronous firing of neurons.

These webs underlie all higher-order processing, including language. The representation of words and concepts thus involves a "word web", a neural network which is broadly distributed across various brain regions[8]. Different word classes are not represented in an all-or-nothing manner; rather, the strength of association (and thus activation) may differ for different words of the same general class. For example, consider the distinction between visual-associated words (e.g., animals) and action-associated words (e.g., tools). Rather than there existing a cortical area responsible for processing visual-associated verbs (primary visual cortex) and another for processing action-associated verbs (motor cortex), it appears that these items fall on a continuum with respect to the strength of visual or action association:

> "In fact, most, if not all, concrete words elicit both visual and action associations, but frequently with gradual differences; for example, strong visual associations but only weak associations to actions. Correspondingly, the density of neurons in visual and action-related areas should gradually differ between a primarily action-related word and a primarily visually-related one. The postulated differential topographies of word webs imply meaning-related processing differences between word categories." (Pulvermüller, 2001, p.521).

With respect to syntactic information, Pulvermüller (2002) proposes that syntactic processing is based on the operation of "sequence detectors", which have been demonstrated to operate in the visual system of animals to detect movement (McCulloch & Pitts, 1943; Kleene, 1956). This system is characterized by the existence of elements responsible for the detection of serial order information. For example,. a neuron $\gamma$ receives input from neurons $\alpha$ and $\beta$, which detect a stimulus appearing in adjacent

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[8] This concept carries implications for the neural underpinnings of a lexical decision task. Upon detecting an incoming verbal stimulus, word activation is dependent on *ignition* (Braitenberg, 1978) of the functional web underlying this stimulus; this occurs very rapidly (within 100-200ms after stimulus onset), latency being dependent upon axonal conduction delays and temporal summation of activity in the relevant neurons (Pulvermüller, 2002). This is supported by the finding that very early word/pseudo-word differences may be found in the N1-P2 component of the ERP waveform (Rugg, 1983).

sections A and B of the visual field respectively; neuron $\gamma$ detects movement in the AB direction.

Pulvermüller (2002) proposes that similar sequence detectors may receive input from word webs. Such a system allows the development of generalized syntactic rules, by the following mechanism:

- $\gamma$ becomes frequently active together with word webs $\alpha_1$ and $\beta_1$, where $\alpha$ and $\beta$ represent lexical categories such as N or V;
- strong associations are thus built between $\gamma$, $\alpha_1$ and $\beta_1$ resulting in the neuron responding reliably to sequences such as "first $\alpha_1$, then $\beta_1$";
- similarly, the neuron learns to respond to "first $\alpha_1$, then $\beta_2$" and"first $\alpha_2$, then $\beta_1$"
- the generalization that "first $\alpha_2$, then $\beta_2$" follows from the earlier learning steps (substitution-based associative learning)

In sum, Pulvermüller (2002) claims that lexical items are represented in "word webs", and that syntactic processing occurs by means of "sequence detectors" which are functional webs whose input comes from the aforementioned word webs.

It must be borne in mind throughout the present thesis that the terms "syntax/ syntactic information" and "semantics/semantic information" are merely shorthand used to refer to the cluster of neurons which underlie the representation of the syntactic or semantic information and whose activation makes this information available for processing. This is of course true of any discussion of language representation and processing, even the most theoretical: it is the case that any language function has a neural substrate, and that when we appeal to terminology representing any type of language function, we are referring to generalizations about the neurons responsible for encoding this linguistic information and/or the pattern of neural activation that occurs during its processing. The theoretical framework described in this section will be especially relevant in the Conclusions section (Chapter 6), which presents a tentative model of the lexical representation of mass/count information.

Before presenting the studies themselves, I present a brief overview of the structure and purpose of this thesis, motivating each study and describing how they fit together.

## 8. Purpose and structure of the thesis

The purpose of the current thesis is twofold. First, it aims to explore the representation of different noun types within the mental lexicon. This is an issue that has received limited attention in the literature, although formulating an adequate account of the mass/count distinction has been the topic of debate amongst theoretical linguists for decades. It is also of significant interest in psycho- and neurolinguistics, combining as it does both syntactic and semantic factors, and thus constituting an ideal case to examine the syntax/semantics interface. The second goal of this thesis is to assess the way in which these noun categories are processed, both in healthy populations and in the case of language dysfunction. To this end, participants from a variety of populations were assessed using both off-line and on-line tasks; these studies are presented in Chapters 2 - 5.

In the conclusion, I address the various accounts of the mass/count distinction that have been put forward in the literature: syntactic, semantic and contextual. I postulate a re-conceptualization of the mass/count distinction that integrates aspects from each account, and is plausible in terms of known facts about neurobiological functioning and language acquisition., as well as addressing the findings presented in the body of the thesis regarding the performance deficits seen in various populations.

Study 1 (Chapter 2) aimed to assess the effect of semantic deficits on the syntactic and semantic processing of mass, count and dual nouns. AD and MCI participants, as well as healthy elderly controls, performed a sentence grammaticality judgement task and a sentence-picture matching task assessing their capacity to access mass-count information off-line. The results of this task suggested an impaired capacity to access the mass reading of dual nouns in both patient groups, although the participants' performance on grammaticality judgement was unimpaired. Further, the pattern of performance exhibited was qualitatively and quantitatively identical across the two groups.

This unexpected result raises a number of issues. First, the finding that MCI and AD individuals exhibit similar performance across the two tasks raises the interesting possibility that processing of this distinction may provide a window into very early deterioration in semantic capacities in AD. It may of course be argued that the identical performance across the two groups may simply be a result of poor task sensitivity, whereby participants manifest a ceiling effect in the grammaticality judgement task, and a floor effect in the sentence-picture matching task. That is, differences in linguistic performance between AD and MCI may exist, but not have been detected by the off-line tasks used in this study. Furthermore, a small number of participants in both groups appeared to manifest a performance deficit as a result of attentional rather than linguistic factors. This raises the possibility that the performance of the large number of individuals who appeared to manifest a linguistic deficit may in fact be better explained in terms of attentional deficits. These issues are addressed in Study 3 (Chapter 4), this study is discussed in more detail below.

The second issue raised in Study 1 is the observed dissociation between syntax and semantics: syntactic information about mass and count nouns appears to remain available to AD and MCI individuals although they exhibit an impairment in a task tapping into semantic information. This issue is further explored in Study 4 (Chapter 5), in which individuals with specific deficits in semantics (semantic dementia) and syntax (agrammatic aphasia) were tested on the same tasks.

Given the results seen in Study 1, we thus decided that a measure of on-line processing of mass, count and dual nouns in AD and MCI may provide greater sensitivity than the tasks used in Study 1, and possibly reveal differences between the two groups that were undetected in the previous study. This possibility is bolstered by the finding that word reading thresholds are affected in AD and in MCI individuals who progress to AD (Massoud, Chertkow, Whitehead, Overbury & Bergman, 2002); these individuals required longer exposure to a target word before they were able to read it aloud. This result suggests that AD is sensitive to the chronometric aspects of cognition very early in the disease course, and that a timed task such as the one used in Studies 2 and 3 is appropriate for examining lexicosemantic decline in these individuals. Studies 2 and 3 (Chapters 3 and 4) therefore aimed to assess the processing of these different noun types in an timed (speeded lexical decision) task in normal aging, MCI and AD.

Study 2 aimed to provide a baseline for Study 3; it examined access to these noun types in healthy young and elderly controls. It is crucial that we understand any performance alterations that occur over the course of the lifespan prior to attempting a characterization of performance deficits in neurological disease. The findings demonstrated alterations in recognition performance for dual nouns in healthy elderly. It was found that older adults recognized singular dual nouns significantly more quickly than singular count nouns, although no such distinction was seen between plural count and dual nouns. Younger adults, on the other hand, manifested similar RTs to dual and count nouns both in the singular and the plural, although a subset of low frequency dual nouns appear to be recognized more quickly. We suggest that this is due to older adults' treating a larger set of nouns as dual (i.e., underspecified for mass/count information), possibly due to a reduction in the resources available to them for lexicosemantic processing and/or of generalized cognitive slowing.

Study 3 compared the performance of older adults revealed in the previous study to that of AD and MCI participants. As in Study 1, no difference was found between the performance of these two patient groups. Unlike older adults, they appear to process dual nouns as count, which is consistent with the finding in Study 1 that these patients have difficulty selecting the mass reading of dual nouns. We claim that this performance pattern suggests an impairment in the capacity to apply the lexical rule necessary for successful processing of dual nouns (Copestake & Briscoe, 1995; Klepousniotou, 2002). The form and operation of this rule is specified in Chapter 4.

Finally, Study 4 (Chapter 5) aims to further explore the dissociation between semantic and syntactic processing that was seen in Study 1. We offer a more complete account of the various stages which must be completed for successful processing of mass, count and dual nouns. A patient suffering from a pure syntactic deficit (agrammatic aphasia) as well as a patient suffering from a pure semantic deficit (semantic dementia) performed a sentence grammaticality judgement task and a sentence-picture matching task, which assessed their capacity to access syntactic and semantic information about mass, count and dual nouns. The findings suggest that intact semantic and syntactic knowledge are required to process these items, shedding light on the various theoretical accounts of this distinction put forward in the literature, and consistent with Joosten's (2003) claim that a multidimensional account of the mass/count distinction is the most plausible.

The implications of these findings for the theoretical representation of the mass/count distinction are presented in the Conclusions. We offer a re-conceptualization of the representation and processing of mass/count information which integrates the various theoretical approaches to this distinction, is integrable into a framework of the neurobiological basis of language such as that proposed by Pulvermüller (1999, 2001, 2002) and is consistent with the findings presented in the current thesis, as well as prior results from studies of language acquisition, psycho- and neurolinguistics.

We also discuss briefly the possible clinical implications of the current work in terms of early prognosis of AD. Although the findings are very preliminary, they nonetheless offer a possible direction for future exploration of the deficits seen in MCI individuals at high risk of converting to AD, delineation of which is a crucial step in identifying individuals who are at risk for this disease.

We now turn to the studies themselves. The theoretical and clinical implications of the findings presented in the following four chapters (chapters 2-5) are discussed in the final conclusions section of the thesis, in Chapter 6.

# Chapter 2 (Study 1): Processing of mass/count information in Alzheimer's disease and mild cognitive impairment

Vanessa Taler[1,2] and Gonia Jarema[1,2,3]

[1]Institut Universitaire de Gériatrie de Montréal, Montréal, Québec, Canada

[2]Département de Sciences Biomédicales, Université de Montréal, Montréal, Québec, Canada

[3]Département de Linguistique, Université de Montréal, Montréal, Québec, Canada

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Abstract

This study examines the processing of a specific linguistic distinction, the mass/count distinction, in patients suffering from Alzheimer's disease (AD) and mild cognitive impairment (MCI). Fourteen AD and ten MCI subjects were tested using a sentence grammaticality judgement task where grammaticality violations were caused by determiner-noun mismatches, as well as a sentence-picture matching task to assess their ability to access mass and count readings of dual nouns. Considerable heterogeneity was observed within each subject group, and performance across groups was almost identical. It is concluded that a combination of linguistic and attentional and/or learning factors are responsible for the range of impairments; specifically, a subset of subjects exhibit no linguistic nor attentional/learning impairment, another subset exhibit only an attentional and/or learning impairment but no linguistic impairment, and a third subset (comprising more than half of the subjects included in this study) exhibit a linguistic impairment. It is postulated that the latter group have difficulty processing sense extensions in metonymic nouns. It is further claimed that, at least within the limits of the study, language impairments appear to be of the same severity and nature across AD and MCI subjects.

Introduction

Extensive research undertaken with patients suffering from Alzheimer's disease (AD) has demonstrated that these patients exhibit an impairment in semantic abilities (for a review, see Smith, Chenery and Murdoch, 1989; Smith, Murdoch and Chenery, 1989; Caramelli, Mansur and Nitrini, 1998). It has generally been claimed that syntax is more or less intact in AD (see, e.g., Irigaray, 1973; Bayles, 1982; Cummings, Benson, Hill and Read, 1985; Murdoch, Chenery, Wilks and Boyle, 1987). However, Grossman, Mickanin, Onishi and Hughes (1995) conducted a series of experiments assessing grammatical abilities in AD subjects across different tasks and found that these subjects experienced difficulties with grammatical features.

Another group of patients who, like AD patients, have a short- or long-term memory impairment, is that of patients diagnosed with mild cognitive impairment (MCI). MCI is a relatively new term, introduced by the World Health Organization (see also Petersen, Smith, Waring, Ivnik, Tangalos and Kokmen, 1999), which is designed to capture the point on the continuum of cognitive states between normal aging and dementia (see Chertkow, 2002 for a discussion). The criteria for MCI are given in Table V. Unlike AD patients, MCI patients exhibit no significant daily functional impairment. If memory loss is severe and the patient suffers significant functional impairment, the diagnosis is dementia rather than MCI.

Table V: General criteria for mild cognitive impairment

from Chertkow (2002)

| |
|---|
| Subjective complaint of memory loss |
| Objective impairment of ability |
| Generally preserved other ability |
| No other obvious medical neurologic or psychiatric explanation for the memory problems |
| Individual does not meet criteria for dementia |

Although the figure varies somewhat from study to study and according to the definition of MCI used, on average about 15% of MCI patients evolve to AD annually (see Laurent and Thomas Antérion, 2002, for an overview of the principal studies reported in the literature). However, there exists some controversy as to whether all MCI patients will eventually progress to AD (Chertkow, 2002); in this author's cohort of 90 MCI patients, it appears that around a quarter of the patients will not progress to AD ten years after the onset of memory problems. Some autopsy studies show that MCI patients exhibit the neuropathological changes also seen in AD: neurofibrillary tangles and senile plaques in the hippocampus (see Laurent and Thomas Antérion, 2002) and decreased hippocampal volume (Jack, Petersen, Xu, O'Brien, Smith, Ivnik, Boeve, Waring, Tangalos and Kokmen, 1999). Following an extensive literature review, Laurent and Thomas Antérion (2002) conclude that MCI represents a pre-demential stage of AD in 70-80% of cases. In view of the fact that MCI and AD may constitute different stages of the same disease, and as a step toward establishing with greater specificity the nature of the linguistic impairment in MCI and AD, the studies reported in this paper investigate the availability of information regarding the mass/count distinction in English-speaking AD and MCI subjects.

The mass/count distinction

Although attempts have been made to distinguish mass and count nouns according to semantic criteria, that is, a distinction between "stuff" and "things", it is in fact more accurate to distinguish them along syntactic lines. Unlike count nouns, mass nouns (e.g., *honey*, *garlic*) cannot take the plural (**two garlics*), cannot take the indefinite article (**a honey*), and cannot take quantifiers that necessarily denumerate (**many honeys*). However, unlike count nouns, they can take quantifiers that do not necessarily denumerate (e.g., *much*, *little*). In addition to the fact that adequate semantic criteria to distinguish between these two classes of nouns have not been developed (see Gillon, 1999, for a discussion), cross-linguistic evidence points to semantic criteria being insufficient. For example, the noun *furniture* is mass in English, but *meubles* is plural in French, although if the criteria for distinguishing between mass and count nouns were purely semantic, they should belong to the same class.

One way of characterising the differing distributions of mass and count nouns in English is by postulating that mass nouns carry the feature [mass] ([M]) (Gillon, Kehayia and Taler, 1999). Using a simple and a primed lexical decision task, Gillon et al. (1999) demonstrated that mass nouns yield longer reaction times (RTs) than count nouns in young controls, and that RTs to these items are faster when they are primed by a determiner with which they form a grammatical combination. This result suggests that the mass feature is psychologically real. The second conclusion which may be drawn from this result is that this feature is monovalent. That is, mass nouns carry the feature [M], but count nouns carry no such feature; rather, they are unspecified for this distinction, and the default is that a noun is count. If the feature were bivalent, and mass nouns carried the feature [+M], while count nouns carried the feature [-M], no difference in RT would be expected, since the time required to access the feature should be equal in both cases.

A third category of nouns included in the present study is the class known as *dual* nouns, that is, nouns which take both a mass and a count reading (e.g., *a chicken* vs. *some chicken*). Duality constitutes a type of polysemy, that is, a type of lexical ambiguity where a single word has two (or several) related senses, as distinct from homonymy, where two words have the same pronunciation and written forms but distinct, unrelated meanings. For example, *bank* may mean the side of a river or a financial institution (see Cruse, 1986; Lyons, 1977). It appears that this distinction is correlated with native speakers' instincts as to whether meanings are connected or not; if they are connected, this indicates that the word is polysemous, whereas if they are not, this indicates that the word is homonymous (Lyons, 1977). Metonymic polysemy, of which duality is a subtype, is defined as polysemy where the two senses of the word are both literal, as opposed to metaphorical polysemy where the basic sense is literal whereas the secondary sense is a metaphorical extension of this meaning (e.g. *eye* meaning 'organ of the body' as well as its metaphorical extension 'hole in a needle'; see Klepousniotou, 2002, for a discussion).

Recent work by Klepousniotou (2002) indicates that metonymic words are processed differently from other types of lexical ambiguity. In Klepousniotou's study, 45 native speakers of English participated in a cross-modal sentence priming lexical decision task. Stimuli consisted of polysemous and metonymic words, and control words matched for ambiguity type and frequency. Priming sentences were biased either to the primary or to the secondary meaning of the ambiguous words. Metonymic words yielded faster RTs and greater priming effects than did homonymous words, suggesting that recognition of these different types of words entails different processes. The author concludes that homonymy relies on a process of sense selection, and that an exhaustive listing of the word's different senses is stored in the lexicon. On the other hand, in the case of polysemy (particularly metonymy), a lexical rule operates on the basic sense, which is stored in the lexicon, to create the extended senses.

This conclusion is supported by Azuma and Van Orden (1997), who found that related ambiguous words were accessed faster than unrelated ambiguous words, and by Frazier and Rayner (1990), who demonstrated that words with multiple senses showed shorter fixation times in a reading task than words with multiple meanings. Klepousniotou (2002) takes these results as evidence that dual nouns possess one central sense, and that extensions to this sense are generated on-line, as proposed by Copestake and Briscoe (1995) and Pustejovsky (1995). This is in contrast to the position that a list of potential senses are stored in the lexicon, a view espoused by Kempson (1977), among others.

A few studies examining the preservation of this feature in pathological language exist in the literature. Shapiro, Zurif, Carey and Grossman (1989) used a sentence-picture matching task with fluent and non-fluent aphasic subjects. The design of the experiment, which is replicated in Experiment 2 of this study, asked subjects to distinguish mass and count readings of nouns using the presence or absence of a determiner as a cue. Stimuli included both dual nouns (e.g. *fish, lamb*, which are also used in the present study) and homonymous items with a mass meaning and a count reading (e.g., *corn* meaning "a vegetable and an irritation on a toe, *punch* meaning the drink or a hit to the face). Both groups of aphasic subjects were impaired in distinguishing the two readings, although the results were not broken down according to noun type (polysemous vs homonymous). Combining these results with those from a similar task using the proper/common noun distinction, in which patients did not exhibit an impairment, Shapiro et al. (1989) conclude that the proper/common noun is a universal semantic distinction whereas the mass/count distinction is more purely syntactic.

Grossman, Carvell and Peltzer (1993) examined the mass/count distinction in Parkinson's disease (PD), using three paradigms. The first was a sentence-picture matching task where subjects were required to use the grammatical and semantic information contained in a quantifier such as "much" or "many" to distinguish between small and large amounts of mass and count substances. The second task was a grammaticality judgement task where sentences contained a grammatical or ungrammatical quantifier-noun combination. The third was a sentence completion task. They found that 65% of their PD subjects experienced some difficulty with quantifiers. Grossman et al. (1995) examined quantifier-noun agreement with mass and count nouns in AD. The tasks used in this study were the same ones used in Grossman et al. (1993). The authors found that the AD subjects experienced difficulty in all three tasks, and claim that this was attributable to grammatical rather than semantic features, as the subjects were able to interpret the quantifiers "much" and "many" as referring to large amounts, but unable to interpret the mass/count information that they contain.

Semenza, Mondini and Cappelletti (1997) examined the case of an Italian-speaking aphasic patient with a selective deficit in using mass nouns across a series of tasks, including naming on definition, naming in sentence completion, semantic judgements, semantic associations, sentence grammaticality judgements, and sentence completion and production. The patient exhibited no other deficit in grammar. The authors interpret this as an impairment at the lemma level of lexical retrieval, indicating that specific grammatical rules stored at this level are independently represented and accessible.

In the first experiment of the present study, reported below, AD and MCI subjects performed a sentence grammaticality judgement task designed to determine whether these subjects have access to and are able to use mass/count information. The sentences tested the subjects' ability to detect an error in agreement between a mass or count noun and its determiner. Given that some authors claim that MCI may be taken to represent a pre-demential stage of AD in a majority of cases, and that language impairment tends to worsen as AD progresses, it is predicted that AD subjects should exhibit more impaired performance on the tasks reported here than MCI subjects.

## Experiment 1

### Method

Participants. 14 subjects meeting the criteria for probable Alzheimer's disease (pAD) (McKhann, Drachman, Folstein, Katzman, Price and Stadlan, 1984), ten subjects diagnosed with Mild Cognitive Impairment (MCI), and 20 normal controls participated in the study. All were native speakers of English. Subjects with a prior history of neurological or psychiatric disease were excluded. Subjects were recruited from the Jewish General Hospital in Montreal. Details on individual AD subjects are provided in Table VI, and details on MCI subjects are provided in Table VII. Control participants ranged in age from 55 to 80; their average age was 61.4 years. Their level of education ranged between 8 and 20 years; the average was 14.5 years.

Table VI – AD subject characteristics

| Subject | age | educ. | severity of dementia | MMSE | years post-onset | medications |
|---|---|---|---|---|---|---|
| ER | 85 | 12 | mild | 26 | 5 | Aricept |
| HG | 83 | 10 | mild | 27 | 2.5 | Aricept |
| WG | 82 | 12 | mild | 28 | 4 | donepezil |
| RW | 79 | 10 | mild | 25 | 4 | Aricept |
| BW | 59 | 15 | mild | 22 | 1.5 | Aricept |
| AS | 77 | 13 | mod/sev | 18 | 9 | Aricept |
| JW | 74 | 7 | mod/sev | 15 | 2 | acetylcholinesterase inhibitor |
| CB | 86 | 11 | mild | 29 | 2 | Aricept |
| LP | 78 | 5 | mild | 20 | 3 | Aricept |
| SF | 80 | 7 | mild | 24 | 2 | Reminyl |
| FC | 81 | 8 | mild | 21 | 3 | Aricept |
| RC | 93 | 12 | mild | 23 | 1.5 | Exelon |
| PY | 82 | 12 | mild | 23 | 2 | Aricept |
| SM | 90 | 8 | mild | 20 | 8 | Aricept |

Table VII – MCI subject characteristics

| Subject | Age | Education | MMSE | years post-onset |
|---|---|---|---|---|
| NB | 62 | 12 | 29 | 10 |
| MS | 85 | 7 | 26 | 8 |
| MM | 75 | 11 | 28 | 5 |
| PB | 72 | 7 | 28 | 8 |
| JH | 79 | 10 | 26 | 3 |
| LK | 72 | 18 | 27 | 10 |
| JS | 72 | 12 | 30 | 7 |
| JR | 74 | 17 | 27 | 3 |
| DSG | 81 | 12 | 29 | 5 |
| MSK | 71 | 18 | 25 | 3.5 |

Stimuli. Subjects were asked to perform a grammaticality judgement on 40 sentences in English, given in Appendix 1. These sentences were formed using grammatical and ungrammatical determiner-noun combinations sentence-finally. Ten mass nouns were each presented in both a grammatical and an ungrammatical context, as were ten count nouns, for a total of 20 grammatical and 20 ungrammatical sentences. The same determiners were used for ungrammatical and grammatical sentences. Only items on which control subjects performed at ceiling were included. An error committed in either the grammatical or the ungrammatical context resulted in both being excluded from analysis. This left ten count nouns and seven mass nouns, as control subjects only committed errors on mass nouns (total N = 34). The test items were preceded by an explanation of the task, an example of a grammatical and an ungrammatical sentence, and then four practice items, two grammatical and two ungrammatical. The ungrammaticality of these example and practice items was not due to a determiner-noun mismatch, but rather a violation in subject-verb agreement, an inappropriate auxiliary verb, or an incorrect preposition. Subjects were asked to rate the "acceptability" of the sentences; ungrammatical sentences were semantically coherent.

Results

As indicated above, 34 items were included in the analysis. Thus, each AD and MCI subject received five scores, one out of 34, indicating the total number of sentences judged correctly, two out of ten (number of grammatical and ungrammatical count noun sentences judged correctly) and two out of seven (number of grammatical and ungrammatical mass noun sentences judged correctly). Total scores out of 34 for AD and MCI subjects are reported in Figures 2.1 and 2.2 below.

Figure 2.1: AD subject results, experiment 1

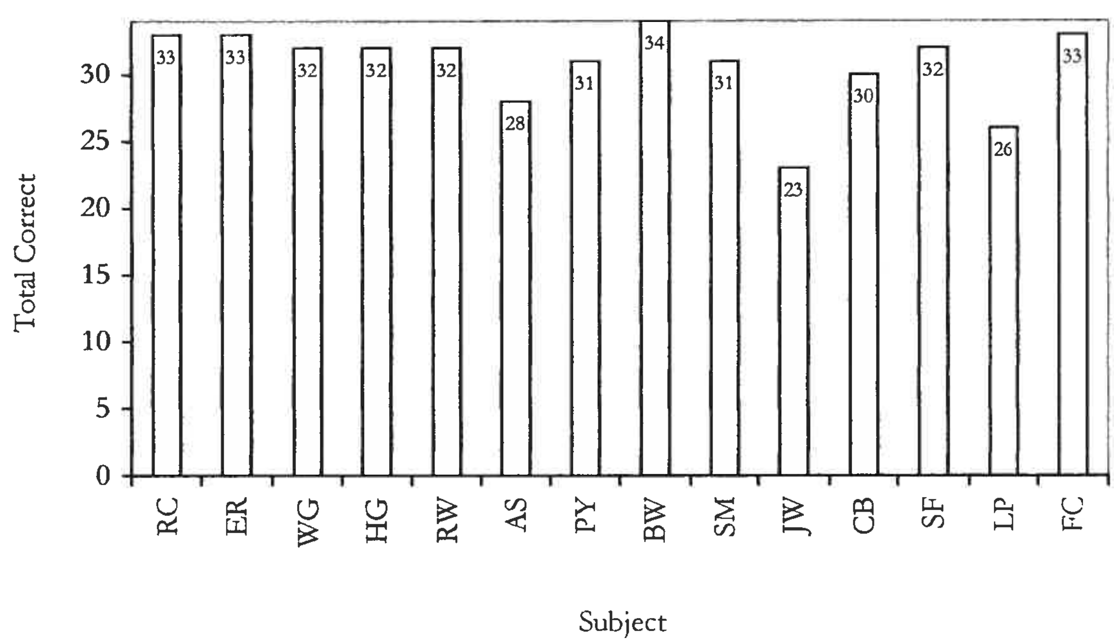
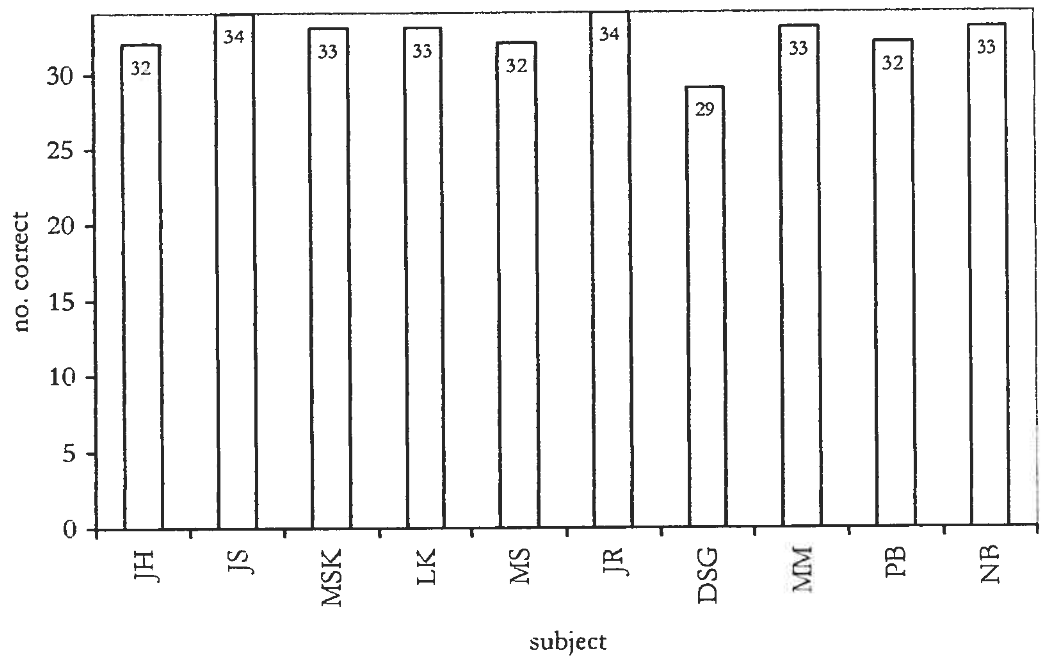


Figure 2.2: MCI subject results, experiment 1




Overall, the subjects did not exhibit great difficulty with this task. A Fischer analysis shows that only four subjects show a significant impairment: AS, JW, and LP, who were diagnosed with AD, and DSG, who was diagnosed with MCI. The distribution of errors differs in these subjects, and the breakdown according to noun class and grammaticality is given in Table VIII. These error patterns are discussed and interpreted below.

Table VIII: Number of errors and items incorrectly judged in each category for impaired subjects

| SUBJECT | count gram. | count ungram. | mass gram. | mass ungram. |
|---|---|---|---|---|
| JW<br>items incorrectly judged | 2<br>a swan<br>a beetle | 4<br>*much button<br>*much beetle<br>*a bit of medal<br>*a bit of swan | 2<br>much paint<br>much snow | 2<br>*a snow<br>*a pork |
| AS | 2<br>a swan<br>a beetle | 3<br>*much beetle<br>*a bit of medal<br>*a bit of swan | 0 | 1<br>*a snow |
| LP | 3<br>a swan<br>each cat<br>a beetle | 1<br>*a bit of needle | 1<br>much paint | 3<br>*each gold<br>*every mustard<br>*a pork |
| DSG | 2<br>every doll<br>a needle | 0 | 3<br>a bit of mustard<br>much paint | 0 |

AS committed five out of six errors on sentences containing count nouns; the sixth error was committed on a mass ungrammatical item. Interestingly, he committed errors on the same two items in both the grammatical and the ungrammatical conditions: *swan* and *beetle*. These items also caused difficulty for JW and LP. Also, five of the six errors involved the quantifiers "a" and "a bit of"; the sixth involved the quantifier "much". Thus, it seems likely that AS's errors in the grammaticality judgement task are due to difficulty interpreting these quantifiers and/or to an item-specific deficit.

JW's errors were distributed across all four sentence categories; like AS, JW's errors were concentrated on certain quantifiers; in fact, every incorrectly judged sentence contained "a", "a bit of" or "much".

LP committed six of eight errors in the count grammatical and mass ungrammatical conditions. The remaining two errors were a rejection of a grammatical sentence containing the quantifier "much" and the acceptance of an ungrammatical count sentence containing the quantifier "a bit of". The count noun quantifiers included in the experiment were "a", "each" and "every", and sentences in the grammatical count and ungrammatical mass conditions were formed using these quantifiers. Although LP correctly judged some sentences containing these quantifiers, he did commit errors on six of 17 tokens, a rate close to chance. It is thus possible that he too has a quantifier-specific impairment.

Finally, DSG, the only MCI subject who showed an impairment on this task, committed five errors, all of which were in the grammatical condition. No pattern is seen in the quantifiers that caused her difficulty. One possible explanation for her response pattern is that she rejected sentences for reasons other than determiner-noun mismatch. It may be the case that this subject rejected some grammatical sentences for semantic/pragmatic reasons, indicating that she did not fully understand the task at hand. The fact that she rejected all ungrammatical sentences indicates that she does not have difficulty detecting quantifier-noun violations.

Degree of impairment appears to have an effect on performance in this task. The three AD subjects who showed an impairment in this task were also the three who had the lowest MMSE scores, and two were categorized as having moderate to severe AD, as opposed to the remaining subjects in the AD group, who were categorized as having mild AD. The one MCI subject who was impaired in this task appears not to have a linguistic impairment, but rather may have rejected some grammatical sentences due to semantic or pragmatic factors. That is, she may have been judging something other than the grammaticality of the sentences. Above we have suggested that the response patterns of JW, AS and LP indicate quantifier-specific impairments, which leads us to suspect a grammatical impairment. This result is consistent with that of Grossman et al. (1995), who found that AD subjects were able to interpret the semantic but not the grammatical information contained in the quantifiers *much* and *many*.

The second experiment aimed to establish with greater specificity the nature of the deficit in access to and/or representation of mass/count information in AD and MCI. The same subjects that participated in Experiment 1 were asked to perform a sentence-picture matching task to distinguish between mass and count readings of dual nouns. The stimuli were designed not to tax short term memory, meaning that a failure to perform the task should rather be attributable to either linguistic or attentional factors, or a combination of the two. As in Experiment 1, it is hypothesised that AD subjects' performance should be more impaired than that of MCI subjects.

## Experiment 2

### Method

Participants. The subjects that took part in this experiment were the same as those that took part in Experiment I; that is, 20 healthy older controls, 14 subjects meeting the criteria for a diagnosis of probable AD, and ten subjects meeting the criteria for a diagnosis of MCI.

Stimuli. Each stimulus consisted of two pictures representing the mass and count readings of a dual noun, accompanied by one of two possible sentences: either "Point to the picture of X" or "Point to the picture of an X". For example, a picture of a chicken and a picture of chicken pieces were accompanied by the sentence "Point to the picture of chicken" (for the mass reading) or "Point to the picture of a chicken" (for the count reading). Twenty-four items were included, and each item was presented with both the mass and the count readings, for a total of 48 items, which were randomised. Only items on which control subjects performed at ceiling were included; errors were committed by at least one control subject on seven of the 24 items, for a total of 17 items presented with both mass and count readings (total N = 34). In order to maximise comparability between control subjects' responses and those of the AD and MCI groups, all 48 stimuli presented to the control subjects were also presented to the AD and MCI subjects, in the same order, although only the 34 items on which control subjects reached ceiling were included in the analysis.

Results and Discussion

Each subject received three scores out of seventeen. The first was the number of count readings correct, the second was the number of mass readings correct, and the third was the total correctly distinguished, that is, the number of items on which the subject correctly selected both the mass and the count reading. The rationale behind this is that subjects may simply choose the picture they feel best represents *chicken*, for example, and select that picture regardless of the presence or absence of a determiner. This pattern of results would mean that the subject is not using mass/count information to make the decision. For example, a subject who consistently chooses the count picture for both mass and count readings will score 17/17 for the number of count readings correct, and 0/17 for the number of mass readings correct, for a total of 0/17 items correctly distinguished. The total score is the best indication of the subject's ability to use the information contained in the determiner to distinguish between mass and count readings of dual nouns, and thus, although all scores are reported, the total score is the one used in the analyses. The AD subjects' scores are shown in Figure 2.3, the MCI subjects' in Figure 2.4. Asterisks next to a subject's code indicate that the subject manifested an impairment in Experiment 1.

Figure 2.3: AD subject results, experiment 2

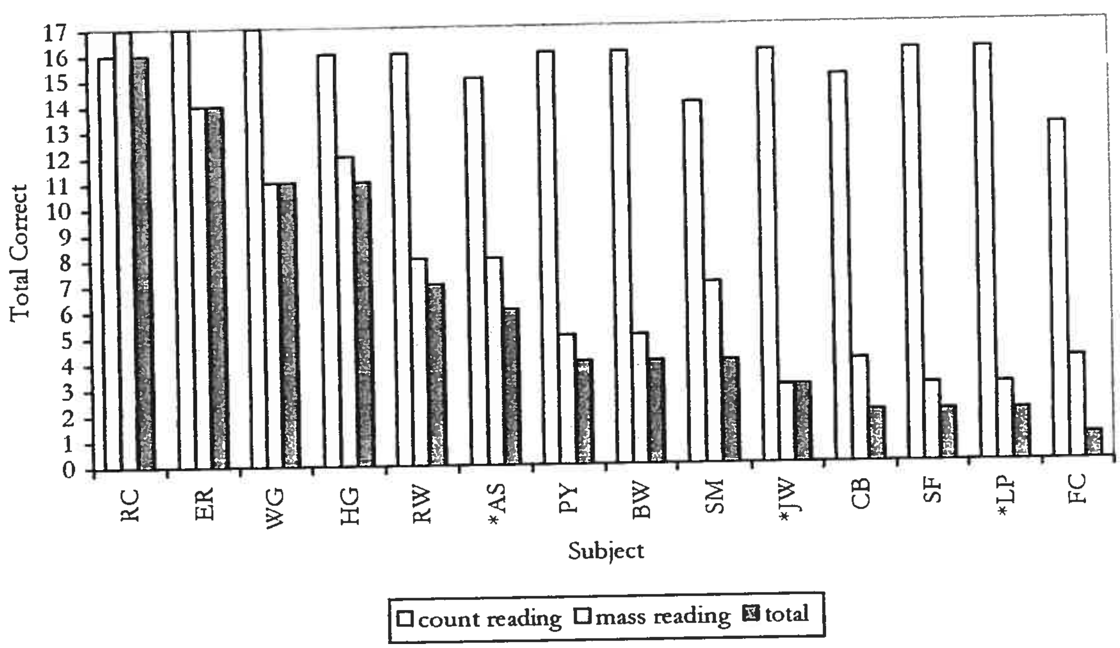
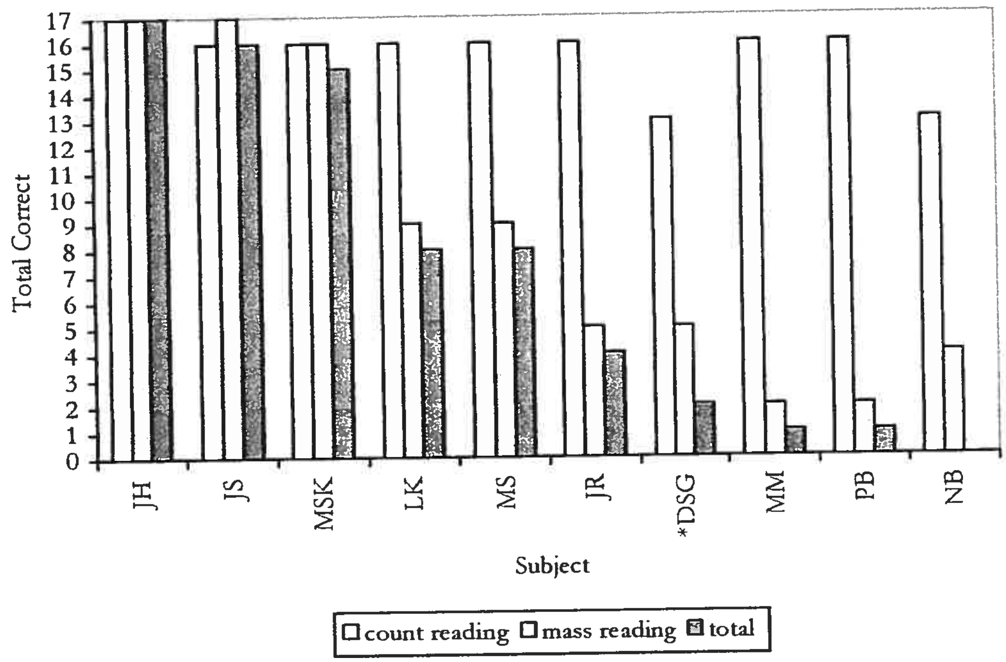


Figure 2.4: MCI subject results, experiment 2




It can be seen that there is considerable heterogeneity within both diagnostic groups. An initial analysis indicates that two AD and three MCI subjects exhibit control-like performance, scoring between 14 and 17 out of 17 correct. The remaining 19 subjects exhibit varying degrees of impairment, scoring between zero and 11 correct. Fischer post-hoc analyses reveal a significant difference between the highest-scoring impaired subjects (WG and HG, who each scored 11/17) and those subjects who scored 4/17 or less ($p<0.05$), but not between WG, HG and the four subjects who scored between six and eight out of 17. That is, the performance of those subjects who scored between 6/17 and 11/17 (four AD and two MCI subjects) is significantly better than that of the remaining eight AD and five MCI subjects. For the purposes of this discussion, we will designate these groups as Group I (control-like), Group II (somewhat impaired), and Group III (severely impaired).

When examining more closely the performances of the subjects in Group II, there appear to be two different response patterns. Four of the subjects, WG, RW, HG and LK, commit the majority of their errors near the beginning of the test (median error position out of 48 items = 16), and "figure out" what the test requires at some point near the middle. The most extreme example of this is provided by RW, who committed errors on the first eight mass readings presented to her, then realised what the requirements of the test were, and successfully distinguished the remaining nine. The distribution of errors of the other two subjects in this group, AS and MS, is different; the errors are distributed throughout the test (median error position = 22), and 13 of the 14 items which were correctly distinguished by these subjects were also successfully distinguished by at least one subject in Group III.

These results lead to two conclusions. First, there appears to be a hierarchy of difficulty in this test. Items such as *hair* are easier to distinguish than items such as *pumpkin*. This may be correlated with the frequency of the mass reading of the item, a possibility which is addressed below. The second conclusion which can be drawn is that the nature of the impairment in these two groups appears to be distinct. The pattern exhibited by the first four subjects is sometimes confirmed by the subjects exclaiming, for example, "Oh, I understand! That's *a* chicken, and that's *chicken*!" It appears that the deficit these subjects exhibit is not linguistic, but rather related to attention and/or learning. Once they have learnt the requirements of the task, their performance improves, becoming control-like. The pattern exhibited by AS and MS, on the other hand, suggests that these subjects are aware that there are different readings of some dual nouns, but take other dual nouns to admit only a count reading. That is, their performance appears to pattern with that of the subjects in group III; they exhibit an impairment which, although less severe than that of the group III subjects, is primarily linguistic in nature, involving access to or representation of information about mass and count readings of dual nouns.

It will have been noted that subjects JW, LP and DSG, who exhibited an impairment in Experiment 1, also exhibit a severe linguistic impairment in Experiment 2, scoring two or three out of a possible 17. Subject AS exhibits a less severe impairment, scoring 6/17 in Experiment 2 and falling into Group II. It is nonetheless argued that this impairment is primarily linguistic rather than attentional; the subject has lost mass/count information about certain items but not others. The fact that subjects need to interpret the determiner "a" in order to successfully perform the sentence-picture matching task argues against the suggestion that AS is impaired in interpreting this determiner, as was suggested in the discussion of Experiment 1. Rather, it is more likely that he suffers from an item-specific deficit. The two nouns on which he showed an impairment, "swan" and "beetle", are both animal terms, which are often impaired in AD (see discussion below).

In order to assess whether the subjects' better-preserved ability to distinguish certain items was related to the relative frequency of the mass and count readings of the items, a frequency-rating task was administered to 23 native speakers of English with no history of neurological or psychiatric disease. The subjects' ages ranged from 24 to 73 (average age = 40) and their level of education ranged from 11 to 21 (average yrs of education = 16.7). Subjects were presented with the same items as the ones used in Experiment 2, and asked to decide how often they thought the items were used in English on a scale of one to five. The items were presented in pairs in order to facilitate understanding of their different senses, and subjects were instructed to decide how often each word was used in each of the different ways. It was made clear that the task was not a comparison task; that is, they were asked to judge each item individually rather than deciding which sense was more frequent. Thus, the two senses could have the same frequency, or one sense could be more frequent than the other.

In our analyses, the average count frequency of each item was subtracted from the average mass frequency to give a single numerical value, ranging between –4 and +4, to each item. This numerical value represents the relative mass and count frequency of each item, with –4 representing a very high frequency of the count reading relative to the mass reading, and +4 representing a very high frequency of the mass reading relative to the count reading. These values are given in Table IX below. 12 of the 17 items fall into subgroups; on the premise that certain items (such as wood terms) may be influenced by subgroup frequency, averages for these subgroups are also included in Table IX.

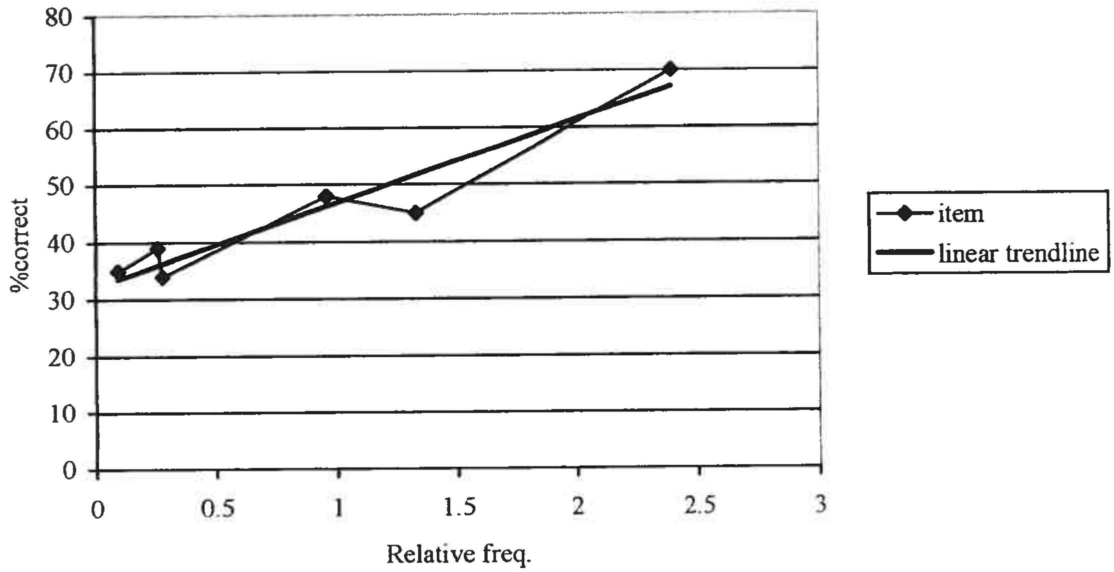
Table IX: Relative mass-count frequency by item and subgroup

| ITEM | TYPE | FREQ | |
|---|---|---|---|
| lamb | animal | 0.78 | |
| fish | animal | 1.22 | |
| lobster | animal | 1.04 | |
| turkey | animal | 1.26 | |
| | AVERAGE FOR ANIMAL | | 1.01 |
| pumpkin | vegetable | -0.26 | |
| onion | vegetable | 0.35 | |
| tomato | vegetable | 0.39 | |
| avocado | vegetable | 0.36 | |
| potato | vegetable | 0.57 | |
| | AVERAGE FOR VEGETABLE | | 0.28 |
| cedar | wood | 0.96 | |
| oak | wood | 1.30 | |
| pine | wood | 1.74 | |
| | AVERAGE FOR WOOD | | 1.33 |
| ribbon | other | 0.09 | |
| brick | other | 0.26 | |
| sausage | other | 0.96 | |
| liver | other | 1.22 | |
| hair | other | 2.39 | |

First, it will be noticed that, with only one exception, pumpkin, all the items are judged to be more frequent in the mass than the count senses. Although it may appear that one possible interpretation of this is that subjects misunderstood the task and included both mass and count senses when judging a mass term, this is belied by the fact that all subjects except two judged some count terms as more frequent than their respective mass terms. Although *on average* the mass terms are more frequent, on an individual basis this is not the case across all items.

The second observation that can be taken from these results is that the wood terms and the item *hair* are significantly more frequent in mass than in count readings, as predicted. However, other items such as *turkey* and *liver*, which showed higher error rates, show the same frequency pattern. The fact that the wood terms patterned together suggests a subgroup effect. To test this, the average relative frequencies of these groups (taken from Table IX) and of the individual items which did not fit into subgroups were graphed against the percentage of correct responses by all AD and MCI patients. Animal terms, as well as the term *liver*, which were fairly frequent in the mass reading compared to the count reading, (animal average = 1.01; '*liver*' average = 1.22), were disproportionately affected, with only 26% and 27% correct responses respectively. They have thus been excluded from Figure 2.5. Many researchers (see e.g., Chan, Salmon and De La Pena, 2001; Fung, Chertkow, Murtha, Whatmough, Peloquin, Whitehead and Templeman, 2001; Montanes, Goldblum and Boller, 1995) have shown category-specific deficits in AD, and it seems likely that this plays a role in this case; animal terms are relatively more affected than other types of items. The term '*liver*' was the only item in this test which refers to an animal part, and thus it is not surprising that it was disproportionately affected.

Figure 2.5: Item/.subgroup frequency by percentage correct




It can be seen in Figure 2.5 that the correlation between relative frequency of mass and count readings of the items (or subgroups of items where applicable) and patients' error rates is fairly strong. Thus we argue that the fact that certain items were better preserved than others is a function of these items' higher relative mass frequencies, which render the mass senses more accessible. The exception to this rule is animal terms, where previous studies have demonstrated that AD subjects may suffer category-specific impairments. This offers an explanation for the hierarchy of difficulty of items that was observed in Experiment 2.

General discussion

The experiments reported here show that AD and MCI subjects have access to mass/count information, as they are generally able to use it to judge the grammaticality of sentences. However, their performance on a sentence-picture matching task assessing their ability to use information contained in a determiner to distinguish between mass and count readings of dual nouns was impaired in a majority of AD and MCI subjects. We suggest that the reasons for this impairment vary across subjects.

First, it is important to note that performance was not determined by patient group; that is, the same differential pattern of impairment was observed in the AD and the MCI groups. Furthermore, the performance was similar across the two groups: AD subjects received an average score of 6.2 (±4.9) and MCI subjects received an average score of 7.2 (±6.7). Thus, the two groups will be collapsed for the first part of the discussion. The ramifications of the fact that the performance of the two groups was almost identical will then be discussed.

Each patient's performance fell into one of three patterns – control-like performance (Group I), somewhat impaired performance (Group II), or very impaired performance (Group III). More than half of subjects (13 of 24) fell into Group III. Ability to detect agreement errors in determiner-noun combinations was basically intact across the three groups. Below we discuss some possible explanations for the impairment manifested by subjects in Groups II and III.

Attentional and/or Learning Factors

As was discussed above, four of the subjects in Group II demonstrated a response pattern which suggested the possibility that attentional and/or learning difficulties were a source of impairment. These were the subjects who selected the count reading of mass nouns for the first part of the test, but at some point realized that the absence of a determiner required a mass reading. In linguistic terms, we suggest that these subjects perform similarly to the four unimpaired subjects in Group I and to the controls. They appear to have access to the two readings of dual nouns and are able to use grammatical information in performing this task.

It appears that none of the subjects in Group III (scoring between zero and four out of 17) fall into this group; that is, their deficit does not seem to be primarily attentional. The fact that they were essentially unable to distinguish between mass and count readings for the duration of the test suggests that linguistic factors are at play. Furthermore, the higher the frequency of the mass reading of a given item relative to its count reading, the more likely these subjects were to distinguish correctly between the two readings. This further suggests that, for these subjects, certain dual nouns have both mass and count readings, whereas others do not. If the subjects' deficit were attentional, one would expect more variability in terms of correct responses.

Semantic Factors

15 of the 24 AD and MCI subjects that participated in this study exhibited a pattern of impairment consistent with a linguistic deficit. This includes the subjects in Group III, as

well as MS and AS, the two subjects in Group II whose responses indicated that their ability to respond correctly to the two readings of a given item was mediated by factors other than their understanding of the task at hand. These two subjects responded correctly to 8/17 items and 6/17 items respectively, and these items were distributed across the test rather than clustered at the end. This suggests that their ability to respond correctly to certain items has to do with the individual items themselves.

As mentioned above, it has been suggested (Copestake and Briscoe, 1995; Pustejovsky, 1995), and experimental evidence exists (Klepousniotou, 2002) that metonymous nouns, of which dual nouns are a subset, possess only one lexical entry and that sense extensions are processed on-line. If this is the case, there are two possible explanations for the performance of the subjects in Group III, that is, subjects who chose the count reading of a given dual noun for a majority of tokens, regardless of whether or not a determiner was present. On the one hand, it may be the case that a given item's lexical entry does not contain the information that this noun has different possible senses; on the other hand, this information may be available but access to it may be limited.

The fact that performance on a certain subset of items, those with higher relative mass frequency, was consistently better in this group than performance on the remaining items suggests that information regarding the different senses is available for these items across the three patient groups. If this is the case, then the subjects' failure to distinguish between the two readings of the remaining items may not be due to an inability to process sense extensions; rather, only the count reading of these items appears to be available. That is, the information contained in these items' lexical entries may be compromised.

Together with higher relative mass frequency, visual or perceptual distance between mass and count readings of a given item may also play a role. For example, the perceptual difference between, say, *oak* and *an oak* is greater than the difference between *wire* and *a wire*, one item which none of the subjects in this group distinguished correctly. However, this cannot be the only factor, as some items which caused difficulty for this group, such as *lamb*, another item which every patient in the group failed to distinguish, are clearly very distinct in their mass and count readings.

Grammatical Factors

It was suggested that in the most severe cases (JW, AS and LP), AD subjects exhibited a quantifier-specific impairment in the sentence grammaticality judgement task. One quantifier appeared to be affected in all three cases: "a". This carries implications for the interpretation of the results of Experiment 2. Since the mass and count readings of the dual nouns were distinguished only by the determiner "a", it is expected that these three subjects would experience difficulty with the task. In fact, AS did not fall into the most impaired group in Experiment 2, which suggests that in Experiment 1 this subject was manifesting an item-specific deficit (affecting the items '*swan*' and '*beetle*') rather than a quantifier-specific deficit.

The performance of the remaining 11 subjects who exhibited a severe impairment on this task cannot be due to a quantifier-specific impairment, as these subjects experienced no difficulty on the grammaticality judgement task. Rather, it may be due to the fact that the sentence-picture matching task is more difficult than the grammaticality judgement task. There are two levels of distinction between the two choices offered to subjects in the former task. On a semantic level, the distinction between the two readings is [M] versus no feature – that is, the count reading is taken to be the default or unspecified variant. On a grammatical level, this correlates with the absence (+mass) or presence (-mass, that is, count) of the determiner. The subjects were required to detect the grammatical distinction and use this to make the semantic distinction.

The grammaticality judgement task may be taken to be easier for two reasons. First, the nouns included admitted only a mass or a count reading, as opposed to the dual nouns in the sentence-picture matching task. Second, in the judgement task, a quantifier is always present, meaning that the subject may match features between quantifier and noun for every item. That is, for every item, there is a quantifier present which is marked either [M] (*much*, *a bit of*) or with no mass feature (*a*, *each*, *every*). No quantifiers were included which allow both a mass and a count reading. Furthermore, in no case was the subject required to interpret the *absence* of a determiner, that is, a Ø quantifier, as marked for mass. The sentence-picture matching task specifically required the subject to make this interpretation. It is possible that these subjects were unable to do this and thus chose the unmarked reading of the noun (i.e., the count reading) where the determiner was absent.

<u>Implications for a theory of lexical ambiguity processing in AD and MCI</u>

The results of this study suggest that AD and MCI subjects have impaired access to or representation of the different senses of metonymic lexical items. This does not necessarily extend to other homonymous items. Chenery et al. (1998) found in a primed cross-modal lexical decision task that AD subjects exhibited priming of the inappropriate associate of a homophone at a short interstimulus interval (330ms), as did control subjects. Clearly, the AD subjects had preserved access to both meanings of homophones. This suggests fundamentally different processing of homonyms and metonyms in these subjects. This is consistent with the results found by Klepousniotou (2002) in control subjects. In our study, AD and MCI subjects appear to have trouble with sense ambiguity, as they showed an impairment in distinguishing mass and count readings of dual nouns. This can be attributed to the fact that different mechanisms are at work in processing of homonymous and metonymic nouns (that is, nouns with meaning ambiguity and nouns with sense ambiguity). In the case of meaning ambiguity, it is hypothesized that each meaning has its own lexical item, whereas in the case of sense ambiguity the item possesses one central meaning in the lexicon, and sense extensions are processed on-line.

Thus the impairment appears not to be a result of a lack of access to a given lexical entry, but rather in the information within the entry. The information that a given item has a mass/count extension does not appear to be present. If more extensive testing of these lexical items reveals that these items are treated as count across different tasks, this would lend support to the claim that the information is in fact missing from the lexical entry rather than the subjects simply being unable to process the sense extension.

<u>The effect of patient group</u>

It was predicted that AD subjects would show a greater impairment than MCI patients, if it is the case that in a majority of cases MCI represents a pre-dementia stage of AD, as suggested by Laurent and Thomas Antérion (2002), and that language performance tends to worsen as the disease progresses (Emery, 1996). However, the results reported here do not support this assumption. On the contrary, the performance of the AD and MCI groups is strikingly similar. Although some subjects showed a degree of impairment in the grammaticality judgement task, all performed at levels significantly above chance. In the sentence-picture matching task, the pattern was quite different. The majority of subjects in both groups exhibited some level of impairment, and although some of this may be due to attentional and/or learning factors, linguistic factors clearly played a role in the majority of cases (15 of 19 impaired subjects).

As discussed above, the sentence-picture matching task is more difficult than the grammaticality judgement task for a number of reasons. Thus, it is reasonable to assume that this task would detect language impairments at an earlier stage. As such, there are a variety of possible explanations for the fact that the AD and MCI groups exhibited the same performance. The first is that the subjects are showing floor effects; that is, the task is simply too difficult for any subject with even a mild language impairment. The fact that similar results were seen in the second task could be a result of the opposite phenomenon: unless a subject is severely impaired, they are able to perform grammaticality judgements without great difficulty, resulting in ceiling effects. That is, the tasks used here may not be sufficiently sensitive to distinguish between the two patient groups.

The second possible explanation is that language impairments are in fact uniform across the subset of AD and MCI subjects whose language is affected by the disease. There are two possible patterns that would account for this. First, language may be affected before other cognitive functions in this subgroup; that is, patients may show a language impairment very early in the disease course, before the onset of dementia. Second, early declines in language capacity may occur at the point at which declines in other cognitive functions are sufficient for a diagnosis of MCI but not AD. After this initial decline, language may be relatively preserved. This would account for the very impaired performance by a majority of subjects in Experiment 2, together with the relatively intact performance in the easier task, the grammaticality judgement task, even in moderate to severe cases of AD. Further testing of language abilities in AD and MCI subjects across a variety of tasks is the only way to distinguish between these possibilities.

## Conclusions

The results of the present study show that processing of mass/count sense extensions is impaired in a majority of both AD and MCI subjects, although the ability of these subjects to correctly judge determiner-noun pairs for grammaticality is more or less intact. It has been proposed that these deficits are due to attentional and/or learning difficulties in a subset of these subjects, but that linguistic factors also play a role in the majority of cases. The linguistic impairment may be due to an inability to process these sense extensions on-line, or damage to the lexical entries themselves such that the subjects have access to only one reading of dual nouns. It may also be due to difficulty processing a O quantifier as mass. However, the fact that certain items appear to be better preserved across subjects than others supports the interpretation that the difficulties the subjects experience are due to damage to the lexical entries themselves rather than a grammatical deficit.

The second issue raised by this study is that of patient group. It was expected that the impairment would be more severe in AD subjects than in MCI subjects, but this was not the case. In fact, the subjects fell into three groups; diagnosis was not a factor in this grouping, which is based on performance on the sentence-picture matching task. A small number of the subjects (two of 14 AD subjects and three of ten MCI subjects) exhibited no impairment on this task; their performance was statistically indistinguishable from that of control subjects. A second group, including eight of 14 AD subjects and five of ten MCI subjects, exhibited a severe impairment in this task, scoring between zero and four out of a possible 17. Two of the AD subjects and one MCI subject in this group also exhibited a mild impairment in the grammaticality judgement task. The third group comprises two MCI subjects and four AD subjects, one of whom also exhibited an impairment in the grammaticality judgement task. It has been postulated that four of these subjects present a linguistic impairment, and thus pattern with the subjects in the second group, and that two present an attentional and/or learning impairment, and thus pattern with the first group. In sum, it has been demonstrated that the pattern of linguistic impairment in AD and MCI is heterogeneous, and while it affects the majority of subjects, a subgroup have spared linguistic function, at least in the tasks used here.

Notwithstanding the possibility that the similarity in performance across AD and MCI subjects may be due to floor effects in the sentence-picture matching task and ceiling effects in the grammaticality judgement task, it may also be the case that these subject groups present the same degree of impairment with respect to the mass/count distinction. In either case, it seems likely that any difference between these two subject groups which may not have been detected by the tasks used would be quantitative rather than qualitative in nature. Thus we claim that, in the tasks reported in the present study, AD and MCI subjects exhibit the same impairment, lending support to the theory that the cognitive impairments in MCI mirror those seen in AD.

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Appendix 1: Sentences used in Experiment 1

Examples: The man is eating soup.

*The man has eating soup.

Practice: Harvey has a very long beard.

*They are go to the supermarket.

My brother is a policeman.

*Ingrid made spaghetti to dinner.

Trials:

| **COUNT GRAMMATICAL** | **COUNT UNGRAMMATICAL** |
| --- | --- |
| The baby likes every doll. | *The girl doesn't love much doll. |
| The shirt is missing a button. | *The drycleaner loses much button. |
| The office sold every ticket. | *They didn't have much ticket. |
| The embassy is flying a flag. | *This shop doesn't have much flag. |
| The little boy fed a swan. | *The millionaire owns a bit of swan. |
| The woman bought a lamp. | *The house has a bit of lamp. |
| The cat is stalking a beetle. | *The lizard kills much beetle. |
| The soldier cleaned each medal. | *He has earned a bit of medal. |
| The neighbour fed each cat. | *The baby doesn't like much cat. |
| The woman bought a needle. | *The seamstress wants a bit of needle. |

| MASS GRAMMATICAL | MASS UNGRAMMATICAL |
|---|---|
| The child wants a bit of mustard. | *The boy spread every mustard. |
| The meal included a bit of rice. | *The children ate each rice. |
| The store doesn't have much paint. | *The dog spilled a paint. |
| That ring doesn't contain much gold. | *The man polished each gold. |
| Florida doesn't get much snow. | *James is clearing a snow. |
| The tide didn't move much sand. | *Harry couldn't weigh every sand. |
| Norman ate a bit of pork. | *The waitress served a pork. |

Appendix 2: Items used in Experiment 2

| | Count Reading | Mass Reading |
|---|---|---|
| TURKEY | A live turkey | A piece of turkey on a plate |
| PUMPKIN | A whole pumpkin | Pumpkin pieces on a plate |
| OAK | An oak tree | A plank of wood |
| CEDAR | A cedar tree | A plank of wood |
| LAMB | A live lamb | A piece of lamb on a platter |
| LIVER | A liver (the organ) | Pieces of liver on a platter |
| FISH | A live fish | A fish fillet on a platter |
| BRICK | A whole brick | Pieces of brick in a pile |
| PINE | A pine tree | A plank of wood |

| | | |
|---|---|---|
| AVOCADO | A whole avocado | A cut up avocado on a chopping board |
| LOBSTER | A live lobster | Lobster pieces on a plate |
| TOMATO | A whole tomato | Chopped up tomato on a plate |
| ONION | A whole onion | Chopped up onion on a plate |
| SAUSAGE | A whole sausage | Pieces of sausage on a platter |
| POTATO | A whole potato | Mashed potato in a bowl |
| RIBBON | A ribbon in a girl's hair | Ribbon on a spool |
| HAIR | A single hair | A girl's head in profile with long hair covering the side of her head |

References

Artero, S. and Ritchie, K. (2002) Le déclin cognitif léger chez les personnes âgées: nosologie et statut clinique. *Revue Neurologique* 158(10): 5S5-5S10.

Azuma, T. and Van Orden, G. (1997) Why SAFE is better than FAST: The relatedness of a word's meanings affects lexical decision times. *Journal of Memory and Language* 36: 484-504.

Bayles, K. (1982) Language function in senile dementia. *Brain and Language* 16:265-280.

Caramelli, P, Mansur, L.L. and Mitrini, R. (1998) Language and communication disorders in dementia of the Alzheimer's type. In Stemmer, B. and Whitaker, H. (eds.) *Handbook of Neurolinguistics*. Academic Press: San Diego.

Chan, A., Salmon, D. and De La Pena, J. (2001) Abnormal semantic network for "animals" but not "tools" in patients with AD. *Cortex* 37(2): 197-217.

Chenery, H., Ingram, J. and Murdoch, B. (1998) The resolution of lexical ambiguity with reference to context in dementia of the Alzheimer's type. *International Journal of Language and Communication Disorders* 33(4): 393-412.

Chertkow, H. (2002) Mild Cognitive Impairment. *Current Opinion in Neurology* 15: 401-407.

Copestake, A. and Briscoe, T. (1995) Semi-productive polysemy and sense extension. *Journal of Semantics* 12:15-67.

Cruse, D.A. (1986) *Lexical Semantics*. Cambridge, U.K.: Cambridge University Press.

Cummings, J., Benson, D., Hill, M. and Read, S. (1985) Aphasia in dementia of the Alzheimer's type. *Neurology* 35: 394-397.

Emery, V. (1996) Language Functioning. In R. Morris (ed.) *The Cognitive Neuropsychology of Alzheimer-Type Dementia*. Oxford University Press: Oxford.

Frazier, L. and Rayner, K. (1990) Taking on semantic commitments: Processing multiple meanings vs. multiple senses. *Journal of Memory and Language*. 28: 181-200.

Fung, T., Chertkow, H., Murtha, S., Whatmough, C., Peloquin, L., Whitehead, V., and Templeman, F. (2001) The spectrum of category effects in object and action knowledge in dementia of the Alzheimer's type. *Neuropsychology* 15(3):371-9

Gillon, B. (1996) The lexical semantics of English mass and count nouns. In E Viegas (ed.) *Breadth and Depth of Semantic Lexicons*. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Gillon, B., Kehayia, E. and Taler, V. (1999) The mass/count distinction: Evidence from on-line psycholinguistic performance. *Brain and Language* 68(1-2): 205-211.

Grossman, M., Carvell, S. and Peltzer, L. (1993) The sum and substance of it: The appreciation of mass and count quantifiers in Parkinson's Disease. *Brain and Language* 44: 351-384.

Grossman, M., Mickanin, J., Onishi, K. and Hughes, E. (1995) An aspect of sentence processing in Alzheimer's disease: Quantifier-noun agreement. *Neurology* 45: 85-91.

Irigaray, L. (1973) *Le langage des dements*. The Hague: Mouton.

Jack, C., Petersen, R., Xu, Y., O'Brien, P., Smith, G., Ivnik, R., Boeve, B., Waring, S., Tangalos, E., and Kokmen, E. (1999) Prediction of AD with MRI-based hippocampal volume in mild cognitive impairment. *Neurology* 52: 1397-1403.

Kempson, R.M. (1977) *Semantic theory*. Cambridge, U.K.: Cambridge University Press

Klepousniotou, E. (2002) The processing of lexical ambiguity: Homonymy and polysemy in the mental lexicon. *Brain and Language* 81: 205-223.

Laurent, B. and Thomas Antérion, C. (2002) Incertitudes et limites du MCI: apport de la neuropsychologie. *Revue Neurologique* 158(10): 5S11-5S20.

Lyons, J. (1977) *Semantics* (Vol.2). Cambridge, U.K.: Cambridge University Press.

McKhann, G., Drachman, D., Folstein, M., Katzman, R., Price D., and Stadlan, E.M. (1984) Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRDA work group under the auspices of Health and Human Services Task Force on Alzheimer's Disease. *Neurology* 34, 939-944.

Montanes, P., Goldblum, M. and Boller, F. (1995) The naming impairment in living and non-living items in AD. *Journal of the International Neuropsychological Society* 1(1): 39-48.

Murdoch, B., Chenery, H., Wilks, V. and Boyle, R. (1987) Language disorders in dementia of the Alzheimer type. *Brain and Language* 31: 122-137.

Petersen, R., Smith, G., Waring, S., Ivnik, R., Tangalos, E. and Kokmen, E. (1999) Mild cognitive impairment: Conceptual basis and current nosological status. *Lancet* 355: 225-228.

Pustejovsky, J. (1995) *The generative lexicon.* Cambridge, MA: MIT Press.

Semenza, C., Mondini, S. and Cappelletti, M. (1997) The grammatical properties of mass nouns: An aphasia case study. *Neuropsychologia* 35(5): 669-675.

Shapiro, L., Zurif, E., Carey, S. and Grossman, M. (1989) Comprehension of lexical subcategory distinctions by aphasic patients: Proper/common and mass/count nouns. *Journal of Speech and Hearing Research* 32: 481-488.

Smith, S., Chenery, H. and Murdoch, B. (1989). Semantic abilities in dementia of the Alzheimer type. 2. Grammatical semantics. *Brain and Language* 36: 533-542.

Smith, S., Murdoch, B., and Chenery, H. (1989) Semantic abilities in dementia of the Alzheimer type. 1. Lexical semantics. *Brain and Language* 36: 314-324.

# Chapter 3 (Study 2): Lexical access in younger and older adults: the case of the mass/count distinction

Vanessa Taler[1,2,*] and Gonia Jarema[1,2,3]

[1]Institut Universitaire de Gériatrie de Montréal, Montreal, Quebec, Canada

[2]Department of Biomedical Sciences, Université de Montréal, Montreal, Quebec, Canada

[3]Department of Linguistics, Université de Montréal, Montreal, Quebec, Canada

*corresponding author

Address correspondence and requests for reprints to Vanessa Taler, Centre de Recherche Institut Universitaire de Gériatrie de Montréal, 4565 Chemin Queen-Mary, Montreal, Quebec, Canada H3W 1W5. [redacted]

Tel: (514) 340-2800

Fax: (514) 340-3548

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Abstract

Although lexicosemantic deficits are not typically seen in older adults, some studies indicate that age-related changes in semantic processing may occur. We had groups of older and younger adults perform speeded lexical decision on mass (e.g., honey), count (e.g., car) and dual nouns, which may be either mass or count (e.g., lamb). Singular dual nouns engendered significantly faster response times in older adults than mass and count nouns, whereas younger adults manifested similar response times to count and dual nouns. We suggest that these results are consistent with the hypothesis that reductions in processing speed and/or resources available for lexicosemantic processing underlie the performance alterations seen in healthy aging. In order to avoid the additional cost of activating mass/count information, older adults treat dual nouns as underspecified unless a mass or count reading is forced by context.

(137 words)

Keywords: cognitive aging, lexical access, visual word recognition, mass/count distinction

A considerable body of research on aging has revealed that various aspects of cognitive function are subject to age-related decline. These decrements appear in a variety of tasks, including memory tasks that require self-initiated processing, such as cued and free recall (Park, 2000) and tasks tapping into episodic memory (Burke, MacKay & James, 2000; Wingfield & Stine-Morrow, 2000; Light, 1996; for a review, see Craik, 2000). Older adults also manifest deficits in certain language tasks, such as word-finding difficulty (Burke, MacKay, Worthley & Wade, 1991) and difficulty in retrieving proper names (Cohen & Faulkner, 1986; Maylor, 1990).

Since these deficits are widespread across a number of tasks, researchers have suggested that there may exist a more central deficit that underlies the broad range of observed performance alterations. Several potential loci for this central deficit have been proposed. Salthouse (1991, 1996) suggested that these longitudinal declines may be caused by a generalized cognitive slowing. Craik and Byrd (1982), on the other hand, hold that deficits in working memory, which have been extensively demonstrated to occur in older adults (e.g., Craik, Morris & Gick, 1990; Dobbs & Rule, 1989; Wingfield Stine, Lahar & Aberdeen, 1988), may underlie the observed performance alterations. Hasher and Zacks (1988) suggest that older adults' difficulties lie in inhibiting task-irrelevant information. Finally, Lindenberger and Baltes (1994) have demonstrated that nearly all age-related variance in a variety of cognitive tasks may be accounted for in terms of reduced visual and/or auditory acuity.

One aspect of cognitive aging that has received limited attention in the literature is that of lexicosemantic processing. It has generally been thought that decrements in lexicosemantic organization and processing do not occur in healthy elderly adults: older and younger adults typically perform similarly on tasks that reflect the organization of lexicosemantic knowledge, such as generation of word associations (Bowles, Williams & Poon, 1983, Burke & Peters, 1986; Lovelace & Cooley, 1982) and category exemplars (Howard, 1980). Likewise, on-line studies examining lexicosemantic processing have shown similar response patterns in older and younger adults. For example, frequency has been found to have similar effects on lexical decision in older and younger adults, although overall reaction times are somewhat slower in older adults (Tainturier, Tremblay & Lecours, 1989; Allen, Madden & Crozier 1991; Allen, Madden, Weber & Groth, 1993).

However, there does exist some evidence to the contrary. Brosseau and Cohen (1996) found differences in generation of category exemplars in older and younger adults. Similarly, Dommes and Le Rouzo (2004) demonstrated that older adults produce different familiarity ratings and show a greater effect of semantic priming when accessing alternate meanings of ambiguous (homophonous) lexical items. Finally, Taler, Chertkow and Saumier (2004) demonstrate that older and younger adults demonstrate differential performance when interpreting novel noun-noun combinations, in which they are required to access and integrate semantic representations of familiar object words. These studies suggest that some alterations in lexicosemantic organization and/or processing may indeed occur in healthy adults.

There also exists some evidence that sublexical and lexical variables may play differing roles in lexical access in the two groups. Spieler & Balota (2000) found that, while frequency, orthographic neighbourhood density and word length all predicted reliable amounts of variance in naming latencies for both older and younger adults, older adults manifested a greater effect of frequency than of orthographic neighbourhood density and word length relative to younger adults. That is, a lexical factor (frequency) exerted a greater influence on older adults' performance than did sublexical factors (neighbourhood density, word length), relative to the performance of younger adults. This result was interpreted as reflecting older adults' greater reading experience.

Furthermore, recent neuroimaging studies suggest that the neural activation underlying lexical access may change with age, although this is not reflected in RT performance. Madden et al. (1996) and Madden, Langley et al. (2002) measured regional cerebral blood flow (rCBF) via positron emission tomography (PET) while subjects performed a lexical decision task. Both studies revealed age-related changes in neural activation during visual word recognition; specifically, the former study found greater occipito-temporal activation in the younger adult group, whereas the latter revealed greater activation in Brodmann's area (BA) 37 in the older adult group and greater activation in BA 17 in the younger adult group. Similarly, Whiting et al. (2003) conducted a PET study probing the effects of lexical and sublexical factors on visual word recognition in a sample of older and younger adults. It was found that, while RT data revealed no difference in the effects of frequency and word length on lexical access, PET data showed differential neural activation related to the frequency effect seen in lexical decision. That is, while frequency exerted a similar effect on RT in younger and older adults, these effects were related to activation in distinct cortical regions. Specifically, in older adults, word-frequency effects were related to activation in BAs 17, 18 and 37 of the left hemisphere, and word-length effects were related to activation in BA 17. Younger adults show no such relationship between the effects of word-length or frequency and activation in these cortical regions.

In summary, although behavioural measures do not typically reveal age-related decline in lexicosemantic processing, longitudinal alterations in lower-level language processing have been hinted at by some findings. A few studies examining lexicosemantic access and organization have reported differential performance in younger and older adults (Brosseau & Cohen, 1996; Dommes & Le Rouzo, 2004; Taler, Chertkow & Saumier, 2004). Neuroimaging studies have suggested that there may exist differences in patterns of neural activation during visual word recognition (Madden et al., 1996; Madden, Langley et al., 2002, Whiting et al., 2003). Likewise, in older adults lexical factors appear to have a greater effect on naming latencies than do sublexical factors (Spieler & Balota, 2000).

The present research aims to clarify further the nature of lexicosemantic processing in older adults, and to link our findings to the established models of cognitive aging described above. Although these models do not address the issue of lexicosemantics specifically, they were designed to account for a broad range of performance alterations and as such are pertinent to the research presented here. We approach this issue by exploiting a distinction that is ubiquitous in natural language: the mass/count distinction. This distinction, which applies to all common nouns in English (and many other languages), and underlies the linguistic distinction between form and substance, has been the subject of debate amongst theoretical linguists for decades, and has more recently come to the attention of psycho- and neurolinguists as constituting an ideal testing ground for the integrity of language systems in a variety of populations. It has been demonstrated to be sensitive to deficits in syntactic and semantic representation and processing (Grossman, Carvell & Peltzer, 1993; Semenza, Mondini & Cappelletti, 1997; Taler & Jarema, 2004, submitted; Taler, Jarema & Saumier, 2004), and has also been demonstrated to affect language processing in younger adults (Gillon, Kehayia & Taler, 1999; Steinhauer et al., 2001). A description of the the mass/count distinction is given below, followed by a brief summary of the findings reported in the psycho- and neurolinguistic literature.

The mass/count distinction

English common nouns may be classified as count nouns (e.g., car) or mass nouns (e.g., honey). The question of whether this distinction is best captured using semantic or syntactic criteria has engendered a prolonged debate in the theoretic linguistic literature (for a review, see Joosten, 2003). From a semantic point of view, count nouns denote "things" (e.g., cars) whereas mass nouns denote "stuff" (e.g., honey). Alternatively, mass and count nouns may be distinguished according to syntactic criteria. Count nouns may take an indefinite article (a car), may be pluralized (three cars) and take quantifiers that denumerate (many cars), whereas mass nouns cannot take an indefinite article (*a honey), cannot be pluralized (*three honeys) and take only quantifiers that do not denumerate (much honey).

Impairments in performance on tasks tapping into mass/count information have been demonstrated in individuals with a variety of neurological disorders, including semantic dementia (Taler, Jarema & Saumier, 2004), agrammatic aphasia (Semenza, Mondini and

Cappelletti, 1997), Alzheimer's disease (Taler & Jarema, 2004), and Parkinson's disease (Grossman, Carvell & Peltzer, 1993). Given that these populations exhibit a broad variety of linguistic deficits, it appears likely that neither a strictly syntactic nor a strictly semantic account will prove adequate; rather, integrity of both syntactic and semantic systems is likely necessary for successful processing of this distinction.

There also exists a class of nouns which may take either a mass or a count reading. For example, the noun lamb may take a count reading ("He cooked a lamb") or a mass reading ("He cooked some lamb"). Following Gillon et al. (1999), we will refer to these nouns as "dual nouns". Duality consitutes a type of polysemy; that is, the nouns possess multiple systematically related senses. This is in contrast to homonymy, where a lexical item possesses multiple unrelated meanings (e.g., punch meaning "a hit to the face" or "a beverage served at parties").

Previous research with young healthy participants has revealed processing differences across categories. Gillon et al. (1999) conducted a study which aimed to assess the psychological reality of the theoretical distinction between mass and count nouns, and specifically the proposal (Gillon, 1996) that this distinction may be captured by appealing to a feature [mass], which is possessed by mass nouns. The first experiment, which examined various categories of common nouns in English utilizing a visual lexical decision paradigm, found that count nouns were recognized significantly more quickly than mass nouns. In a second experiment, these nouns were primed by determiners with which they formed either a grammatical combination (e.g., that table) or an ungrammatical combination (e.g., *those table); it was found that both mass and count nouns were recognized significantly faster when primed by a determiner with which they form a grammatical combination. The authors interpreted these results as supporting the hypothesis that the lexical entries of mass nouns contain a feature [mass], and that access to this feature slows recognition of the lexical item. The fact that nouns were primed by determiners with which they formed a grammatical combination suggests that speakers engage in a process of feature-matching between determiner and noun. Given that count nouns were recognized more quickly than mass nouns, the feature was taken to be monovalent, such that count nouns carry no such feature.

Steinhauer et al. (2001) conducted an event-related potential (ERP) study examining processing of mass and count nouns in congruent and incongruent sentences, and found that count, but not mass, nouns engendered a left anterior negativity (LAN) but not an N400. These results demonstrate that processing differences between mass and count nouns do indeed occur in healthy young adults, and suggest that, at least within a sentence context, differential processing rests on syntactic factors, with which the LAN is commonly associated.

With respect to dual nouns, less research has been reported, and the majority has focused on the issue of lexical ambiguity rather than mass/count status. There are two reasons for this lacuna in the literature. First, since duality forms a subclass of polysemy, a type of lexical ambiguity in which items possess multiple related senses, it has frequently been contrasted with homonymy, whereby a lexical item possesses multiple unrelated meanings (e.g., bank), if it is in fact distinguished from homonymy at all. Second, theoretical linguistics has typically viewed dual nouns as having a basic sense (either mass or count), and to undergo conversion when seen in a context which forces the alternate reading (see, e.g., Copestake & Briscoe, 1995; Gillon, 1996; Frisson & Frazier, 2005); thus, dual nouns have often not been considered to form a class of their own.

Nonetheless, a number of interesting findings with respect to processing of polysemous items in general have been reported in the literature, and it appears likely that these findings are also true of dual nouns in particular. Polysemous lexical items have been demonstrated to evoke shorter fixation times in a reading task (Frazier & Rayner, 1990), shorter reaction times (RTs) in a lexical decision task (Azuma and Van Orden, 1997; Klepousniotou, 2002, Rodd, Gaskell and Marslen-Wilson, 2002) and greater priming (Klepousniotou, 2002) than do homonymous words. On the basis of these results, the latter author postulated that these nouns possess one central sense that is stored in the lexicon, and that sense extensions are generated on-line by means of a lexical rule. Thus, the more rapid recognition of polysemous items is taken to indicate less information within their lexical entries. In terms of dual nouns, this means that mass/count information is suggested to be generated on-line when these items are seen in context, rather than contained within the lexical entry.

In sum, the research to date shows that count nouns appear to be processed more quickly than mass nouns, presumably due to additional information within the lexical entry of mass nouns, and that dual nouns are processed more quickly than other ambiguous items, suggesting that both senses of these items are not stored within the lexicon, but rather generated on-line.

A second stream of literature that is pertinent to the present study is that examining the interaction between frequency and lexical ambiguity. The so-called ambiguity effect, whereby ambiguous words are recognized more quickly than non-ambiguous words (first reported by Rubinstein, Garfield & Millikan, 1970, and subsequently demonstrated by, e.g., Gottlob, Goldinger, Stone & Van Orden, 1999; Hino & Lupker, 1996; Jastrzembski, 1981; Jastrzembski & Stanners, 1975; Kellas, Ferraro, & Simpson, 1988; Millis & Button, 1989), has been shown to interact with frequency in naming but not lexical decision tasks (Hino & Lupker, 1996, Lichacz, Herdman, Lefevre & Baird, 1999); specifically, ambiguity effects are seen in both high and low frequency items in the lexical decision task (LDT), but only in low frequency items in the naming task. These findings were interpreted by Hino & Lupker (1996, 2002) as indicating that the ambiguity effect in the LDT is due to feedback between semantic and orthographic levels (which is presumably insensitive to frequency) whereas in naming, it is due to feedback between semantic and phonological levels (which is presumably sensitive to frequency).

One notable aspect of the Hino & Lupker (1996) study is that both homonymous and polysemous items were classified as ambiguous; no distinction was drawn between them. This was also the case for subsequent work in the same stream (Hino, Lupker & Pexman, 2002) in which effects of ambiguity and synonymy were examined. The authors justify this on the basis of findings by Klein and Murphy (2001) indicating that polysemous items primed sensicality judgements only when the same sense was denoted by prime and target (e.g., shredded paper did not prime a sensicality judgement of daily paper). The authors took this to indicate that two separate senses are stored in the lexicon. However, these findings do not rule out the possibility that polysemous lexical items possess a central sense which is stored in the lexicon, and two or more sense extensions which are generated on-line in context. They could also be attributable to suppression of the semantic features associated with the contextually inappropriate sense once a given sense extension has been generated.

In the present study, we investigate the recognition of high and low frequency mass, count and dual nouns by younger and older adults, using a visual lexical decision paradigm, with the goal of examining (a) the effect of processing of mass/count information has on lexical access; (b) whether mass/count ambiguity affects processing in the same way as other types of ambiguity; and (c) whether any alterations in this processing are seen in healthy older adults. The frequency manipulation was included since, as discussed above, frequency has been shown to exert differential effects on processing in younger and older adults (Spieler and Balota, 2000). Furthermore, we wished to determine whether similar frequency effects are seen for dual nouns as for the homonymous and polysemous items used in the Hino & Lupker (1996) study.

A number of predictions are generated with respect to the RTs to dual nouns. If the two senses of dual nouns are stored separately (as suggested by, e.g., Pustejovsky, 1995) then their behaviour should be identical to that of homonyms; that is, an equivalent ambiguity effect should be seen in high and low frequency items in the LDT task reported here. If, on the other hand dual nouns are simply count nouns which can undergo mass/count conversion via a lexical rule, as suggested by Copestake & Briscoe (1995), their RTs and those to count nouns should be equivalent across the two frequency conditions. A frequency by noun class interaction would suggest differences in processing and representation of dual nouns and homonymous items. Furthermore, given that frequency effects have been demonstrated to be greater in older than in younger adults, any washing out of effects due to the rapid lexical access that occurs with high frequency items is more likely to be seen in older adults; thus, it is predicted that such an interaction is more likely in the older adult group than in the younger adult group.

With respect to the question of how healthy aging will affect processing in the current study, a number of predictions are generated by the theories of cognitive aging outlined above, depending on whether we take dual nouns to be similar to other ambiguous lexical items, as claimed by Klein & Murphy (2001), underspecified with respect to mass/count information, as postulated by Klepousniotou (2002), or simply count nouns which may undergo conversion, as suggested by Copestake & Briscoe (1995).

First, if it is the case that older adults' reduced processing speed underlies their cognitive changes (Salthouse, 1991, 1996), it follows that the cost of processing additional structure (e.g., the feature [mass] or a plural morpheme) may slow recognition of mass and plural nouns more than it does for younger adults. If dual nouns are underlyingly count nouns, no difference is expected between these two categories in either subject group. If they are underspecified with respect to mass/count information, then they should be processed more quickly by older and younger adults, since no mass/count information needs to be accessed. However, older adults may benefit more from the reduced structure to be processed; that is, given that additional structure may slow processing, it follows that faster performance should be seen in items whose lexical entries contain less structure. If they are represented and processed in the same way as homonyms, then they should show a processing advantage across age groups.

A reduction in working memory (WM) resources available to older adults, which Craik and Byrd (1982) hold to be responsible for the changes seen across the lifespan, may also result in relatively longer RTs to nouns that require more processing (i.e., mass and plural nouns), and hence greater WM resources. WM capacity is also related to the ability to inhibit alternative meanings of ambiguous lexical items, which predicts a greater cost in inhibiting the mass reading of dual nouns when seen in their plural form, if dual nouns are processed in the same way as other ambiguous lexical items. If, on the other hand, dual nouns are underspecified, then they may be recognized more quickly than nouns which are specified for mass/count information. Finally, if dual nouns are simply count nouns which may undergo a conversion rule to generate a mass reading, then these items should be processed in the same way as count nouns in both the singular and the plural forms.

Hasher and Zacks's (1988) claim that a reduction in inhibitory function is the central deficit in cognitive aging predicts no alteration in processing of singular nouns, since no inhibition is required in these cases. However, if it is the case that both senses of a dual noun are activated in visual word recognition, this theory predicts that plural dual nouns will be processed more slowly than plural count nouns by older adults, since these individuals will have difficulty inhibiting the inappropriate reading when presented with a plural dual noun. If dual nouns are underspecified, or if they are in fact count nouns that must undergo a conversion rule to have a mass reading, then these plural dual and count nouns should be processed in the same way across subject groups, since no inhibition is required.

Finally, the sensory acuity hypothesis postulated by Lindenberger and Baltes (1994) predicts no differences in the pattern of performance of younger and older adults, since the same sensory demands are made by the different noun classes. These hypotheses are summarized in Table X below.

Table X: Predictions of effect of aging

| | |
|---|---|
| Processing Speed hypothesis | · greater slowing to plural and mass nouns in older than younger adults<br>· IF dual nouns are like homonyms/count nouns, THEN no difference in processing pattern across subject groups<br>· IF dual nouns are underspecified, THEN greater relative advantage in processing singulars but not plurals |
| Working Memory hypothesis | · greater slowing to plural and mass nouns in older than younger adults<br>· IF dual nouns are like homonyms, THEN plural dual nouns slower in older adults due to requirement to inhibit mass reading<br>· IF dual nouns are underspecified, THEN shorter RTs relative to count nouns in singular but not plural<br>· IF dual nouns are like count nouns, THEN no difference in processing pattern across subject groups |
| Inhibitory dysfunction hypothesis | · no difference between groups in singular nouns<br>· IF dual nouns are like homonyms, THEN plural dual nouns slower in older adults due to requirement to inhibit mass reading<br>· IF dual nouns are like count nouns or underspecified, THEN no difference in processing pattern across subject groups |
| Sensory Acuity hypothesis | · no difference between noun categories |

Given that a lexical decision task is used in the current study, one question which arises is whether this task taps semantic processing. It has been pointed out by several researchers (e.g., Balota, 1990, Balota & Chumbley, 1984, 1985, Besner, 1983, Pexman & Lupker, 1999, Seidenberg & McClelland, 1989) that the primary component of an LDT is the decision process itself, which is largely driven by stimulus familiarity, and that semantic coding may not play a large role in this task. However, the level of processing has been demonstrated to alter depending on the type of nonwords used in the experiment: phonotactically legal pseudowords, such as those used in the present study, engender deeper processing than do phonotactically illegal non-words (Borowsky & Masson, 1996, Pexman & Lupker, 1999). Visual lexical decision has been shown to be sensitive to semantic information, such as ambiguity, as discussed above, as well as concreteness and imageability (Cortese, Simpson & Woolsey, 1997; de Groot, 1989; James, 1975; Strain & Herdman, 1999; Zevin & Balota, 2000) and number of semantic features (Pexman, Lupker & Hino, 2002). PET and fMRI studies have also indicated that visual lexical decision activates all brain regions associated with semantic processing (Perani, Cappa, Schnur, Tettamanti, et al., 1999). Thus, given that the stimuli used in the current experiment were controlled for a number of lexical and sublexical variables, and that only phonotactically legal non-words were utilized, it seems likely that any reported effects may have a semantic locus.

Materials and Methods

Participants

Eleven non-demented and independently living older adults (mean age = 75, SD = 10.2; mean education = 14.5 years, SD = 3.3) and ten younger adults (mean age = 26.8, SD =

4.7; mean education = 14.8 years, SD = 1.1) participated in the experiment. Younger adults were recruited via an announcement in an undergraduate class or through word-of-mouth. Older participants were recruited through the Memory Clinic at the Jewish General Hospital in Montreal, Canada, and through newspaper advertisements. Control participants recruited from the Memory Clinic (four of eleven) underwent a complete neuropsychological battery in order to exclude dementia. Participants recruited through newspaper advertisements (seven of eleven) completed the Mini-Mental State Examination (MMSE, Folstein, Folstein & McHugh, 1975) and the Montreal Cognitive Assessment (MOCA, Nasreddine, Chertkow, Phillips, Whitehead, Collin, & Cummings, in press). The MOCA is a rapid screening tool designed to detect mild cognitive dysfunction; it assesses attention, concentration, executive function, memory, language, visuoconstructional skills, conceptual thinking, calculations and orientation.

All participants were native speakers of English with no history of neurological or psychiatric disease and had normal or corrected-to-normal vision. Subjects were remunerated for their participation.

Materials and design

The materials and design used in the current experiment are a replication of those used in Taler and Jarema (in press)[9]. Critical stimuli comprised 50 count (C) nouns, 50 mass (M) nouns and 50 dual (DL) nouns. Each group of nouns was evenly divided into low frequency and high frequency groups. Frequency was included as a factor due to previous research indicating that frequency and lexical ambiguity may interact in the

[9] Note that the older participants whose results are reported here served as a control group for individuals diagnosed with Alzheimer's disease or mild cognitive impairment in the Taler & Jarema (in press) study.

process of lexical selection (see Hino & Lupker, 1996; Hino, Lupker & Pexman, 2002; Lichacz et al., 1999), and that older adults show stronger frequency effects than younger adults (Spieler & Balota, 2000). Stimulus groups were matched for length, number of syllables and frequency using the Celex database (Baayen, Piepenbrock & van Rijn, 1993), and for neighbourhood density, neighbourhood frequency, bigram frequency and bigram frequency by position, using data from the English lexicon project of Washington University in St. Louis (Balota et al., 2002). Familiarity, concreteness and imageability were controlled using the MRC Psycholinguistic database (Coltheart, 1981).[10] Count and dual nouns were presented in both the singular (CS and DLS) and plural (CP and DLP) forms. Mass nouns were only presented in the singular, since plural mass nouns are ungrammatical in English. Stimuli are provided in Appendix 1, and stimuli characteristics in Appendix 2.

In order to avoid repetition priming effects as a result of participants seeing the same stimulus in both the singular and plural forms in the same experimental session, the critical stimuli were divided into two lists, such that no item appeared in both its singular and its plural forms in the same list. Each list contained 25 singular count nouns, 25 different plural count nouns, 25 singular dual nouns, 25 different plural dual nouns, and 25 mass nouns; that is, each list contained 125 critical stimuli. Either 12 or 13 of each group of 25 were of low frequency and the remaining 12 or 13 were of high frequency; that is, high and low frequency stimuli were distributed across both lists. Each list also

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10 Note that 1 of the 150 stimuli were not present in the English lexicon project database, and 17 of 150 were not present in the MRC psycholinguistic database. High-frequency and low-frequency nouns were compared separately; no differences were found between the different groups, with the exception that high-frequency dual nouns were found to be significantly more concrete than high-frequency count nouns. Since effects were stronger in low frequency nouns, it seems unlikely that this difference can account for the observed results.

included 125 filler items, in order to avoid participants' realizing that the study was examining their responses to nouns, and 250 pseudowords. Filler items comprised uninflected verbs and verbs with a third person singular inflection, as well as adjectives. Pseudowords were phonotactically legal and were not neighbours of the critical stimuli, since research has demonstrated priming of real words by neighbouring pseudowords (Forster, 1998). In order to avoid strategic effects, pseudoword items included the suffix '-s' in 40% of cases, as did the critical stimuli and fillers. Subjects participated in two experimental sessions, which were separated by at least three weeks.

Procedure

The experiment was run on a Macintosh i-Book computer using the application Psyscope 1.2.5. Stimuli were presented in random order at the centre of a computer screen in black font on a white background. The random order was different for each participant. Each item was preceded by a row of hashmarks that remained on the screen for 200 ms, and a pause of 150 ms. Participants were asked to perform a lexical decision on each stimulus. The experiment used a go/no-go paradigm; that is, subjects responded to word stimuli but not non-word stimuli. The target word disappeared when the subject responded, and timeout was set to 2000 ms. The go/no-go paradigm was selected as it offers a number of advantages over a standard yes/no lexical decision task: responses are faster and more accurate, and processing demands are reduced relative to a yes/no decision task (Perea, Rosa & Gomez, 2002). Each experimental session was preceded by 24 practice trials (12 real words and 12 pseudo-words).

Results

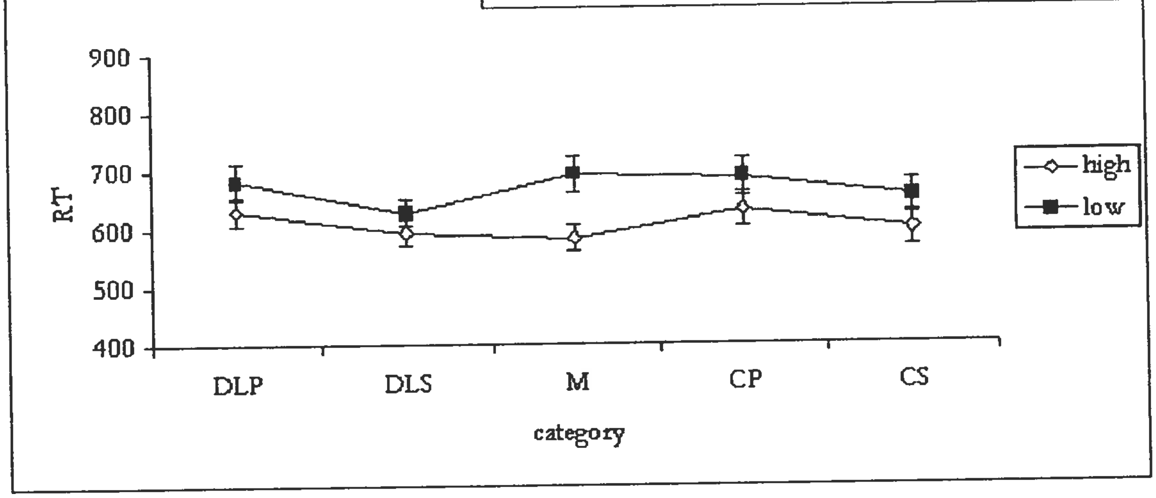
Outliers, defined as responses greater than 2.5 standard deviations above or below the mean, by subject and by category, were removed from the data prior to analysis. Errors (i.e., incorrect "yes" response to a non-word or incorrect null response to a word) constituted 2.0% of total responses for older adults, and 1.6% of total responses for younger adults (chi-square = 4.78, $p<0.05$). Outliers constituted 2.5% of total responses for older adults and 2.9% of total responses for younger adults (chi-square(1) = 0.86, $p<1$). An ANOVA was conducted to determine whether category and/or frequency played a role in error rates, but no such effect was found ($p>0.3$ for all variables).

We conducted a 2x2x5 ANOVA on the RT data, with group (older and younger) as a between-subject variable and frequency (high vs low) and category (DLP vs DLS vs M vs CP vs CS) as within-subject variables. Average RTs and significant effects (by subject and by item) are presented in Figure 3.1 below.

Figure 3.1: Average RTs by category and frequency

ANOVA

| Source | df | MS (Ss) | F (Ss) | MS (Is) | F (Is) |
|---|---|---|---|---|---|
| cat | 4 | 19237.487 | 11.152 | 41967.144 | 12.354 |
| freq | 1 | 209389.165 | 85.028 | 463341.009 | 70.188 |
| group | 1 | 262855.759 | 6.824 | 584882.042 | 602.512 |
| cat x freq | 4 | 8591.069 | 7.900 | 20346.276 | 6.288 |




Is – item analysis

Ss – subject analysis

DLP – dual plural

DLS – dual singular

M – mass

CP – count plural

CS – count singular

RT – reaction time

error bars represent 95% confidence intervals.

The analyses revealed that high frequency items were responded to more quickly than low frequency items overall, and that older adults responded more slowly overall than did younger adults. Both these results are as expected. With respect to the effect of noun category, it was found that there was a significant difference between categories, and that this category effect interacted with frequency (by subjects and by items). Least significant difference (LSD) post-hocs were conducted to determine the locus of the category effect as well as the category x frequency interaction. Of specific interest are differences between singular nouns and their respective plurals (i.e., CS vs CP and DLS vs DLP), differences between the three singular noun categories (DLS, M and CS), and differences between the two plural noun categories (DLP vs CP). These comparisons are shown in Table XI below.

Table XI: Post-hoc tests, overall

| | CATEGORY | | | | | | CATEGORY X FREQUENCY | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BY SUBJECT | | | BY ITEM | | | BY SUBJECT | | | BY ITEM | | |
| | MSE | F | p | MSE | F | p | MSE | F | p | MSE | F | p |
| CP vs CS | 61458.48 | 43.05 | 0.00 | 57605.38 | 16.50 | 0.00 | 279.57 | 0.10 | 0.76 | 11.11 | 0.00 | 0.97 |
| DLP vs CP | 2367.83 | 0.64 | 0.43 | 508.10 | 0.11 | 0.74 | 110.32 | 0.05 | 0.83 | 880.25 | 0.06 | 0.81 |
| DLP vs DLS | 82976.00 | 18.71 | 0.00 | 102434.42 | 65.95 | 0.00 | 5024.51 | 3.93 | 0.06 | 14730.37 | 2.14 | 0.15 |
| DLS vs CS | 7886.80 | 2.97 | 0.10 | 10523.40 | 4.26 | 0.04 | 9625.05 | 11.38 | 0.00 | 21816.84 | 2.14 | 0.15 |
| M vs CS | 7457.54 | 2.57 | 0.13 | 7756.13 | 2.26 | 0.14 | 23747.58 | 8.42 | 0.01 | 149584.35 | 12.09 | 0.00 |
| M vs DLS | 969.51 | 0.40 | 0.53 | 937.93 | 0.33 | 0.57 | 46988.34 | 25.25 | 0.00 | 224469.61 | 14.41 | 0.00 |

With respect to the issue of plurality, it can be seen that, as might be expected, singular nouns were recognized more quickly than plural nouns. This is consistent with the well-established finding that multimorphemic items are recognized more slowly than monomorphemic items (first reported by Taft & Forster, 1975). With respect to the effect of noun class in uninflected (i.e., singular) nouns, the results are slightly more complex. RTs to mass were longer than those to count and dual nouns, but only in low frequency stimuli; no difference was seen in high frequency stimuli. In the item analysis, dual nouns were found to be recognized more quickly than count nouns; this effect was found to be stronger in low frequency stimuli, but only in the subject analysis. No difference was seen between plural count and dual nouns.

Subsequent analyses examining the effect of category and frequency within each participant group were then conducted. In order to reduce the risk of Type I error, a Bonferroni correction was applied, such that $p<0.0167$ was taken to be significant. Results for younger and older adults are presented in Figures 3.2 and 3.3 below.

Figure 3.2: Average RTs, younger adults

ANOVA

| Source | df | MS (Ss) | F (Ss) | MS (Is) | F (Is) |
|---|---|---|---|---|---|
| cat | 4 | 6012.174 | 7.346 | 34019.177 | 8.108 |
| freq | 1 | 84391.189 | 76.878 | 256965.579 | 30.325 |
| cat x freq | 4 | 4996.807 | 5.133 | | |

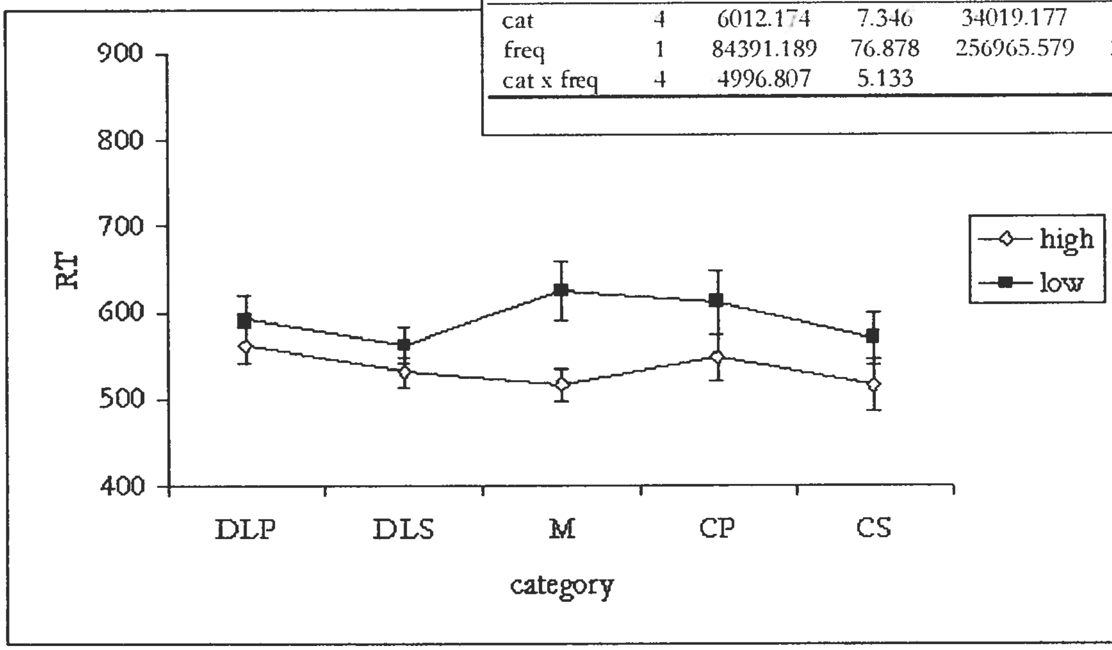
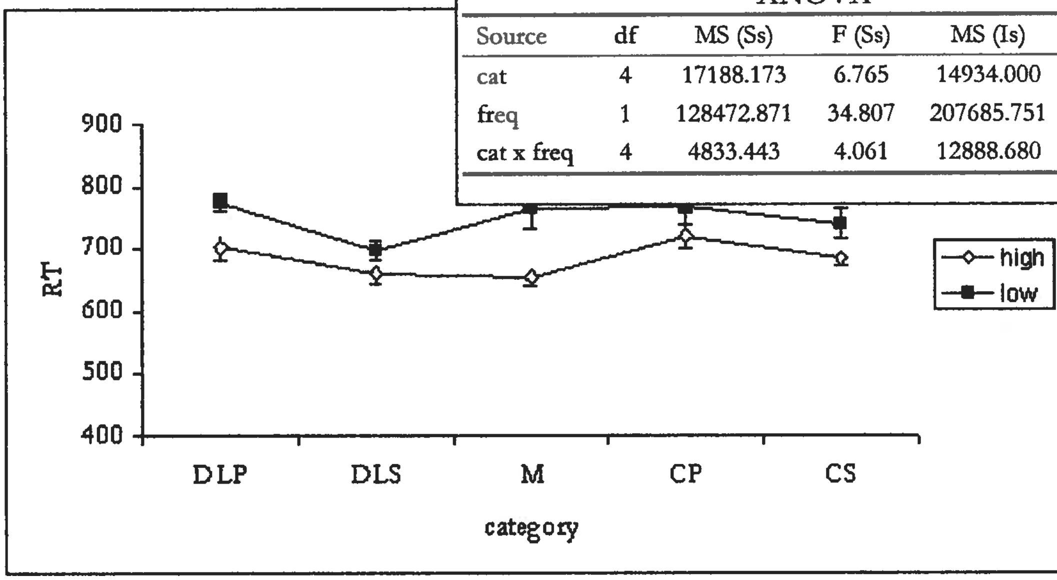


Figure 3.3: Average RTs, older adults




| ANOVA | | | | | |
|---|---|---|---|---|---|
| Source | df | MS (Ss) | F (Ss) | MS (Is) | F (Is) |
| cat | 4 | 17188.173 | 6.765 | 14934.000 | 5.747 |
| freq | 1 | 128472.871 | 34.807 | 207685.751 | 44.152 |
| cat x freq | 4 | 4833.443 | 4.061 | 12888.680 | 5.577 |

Significant effects of frequency, category and frequency x category were seen in both item and subject analyses for younger adults. In the case of older adults, frequency and category were significant in both subject and item analyses, and the interaction was found to be significant in the subject analysis but not the item analysis ($p<0.046$). LSD post-hoc analyses for each of these groups are presented in Tables XII and XIII below.

Table XII: Post-hoc tests, younger adults

| | CATEGORY | | | | | | CATEGORY X FREQUENCY | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BY SUBJECT | | | BY ITEM | | | BY SUBJECT | | | BY ITEM | | |
| | MSE | F | p | MSE | F | p | MSE | F | p | MSE | F | p |
| CP vs CS | 27091.18 | 18.27 | 0.00 | 33887.29 | 12.73 | 0.00 | 642.52 | 0.33 | 0.58 | 2216.74 | 0.36 | 0.55 |
| DLP vs CP | 113.99 | 0.10 | 0.76 | 192.43 | 0.06 | 0.80 | 5349.24 | 4.17 | 0.07 | 29368.25 | 2.71 | 0.11 |
| DLP vs DLS | 17916.85 | 12.66 | 0.01 | 22472.34 | 23.92 | 0.00 | 17.21 | 0.03 | 0.88 | 50.54 | 0.01 | 0.92 |
| DLS vs CS | 402.55 | 0.28 | 0.61 | 412.30 | 0.18 | 0.68 | 2697.61 | 6.34 | 0.03 | 13731.28 | 1.39 | 0.25 |
| M vs CS | 16453.39 | 8.51 | 0.02 | 19445.49 | 7.79 | 0.01 | 14811.00 | 6.15 | 0.03 | 72854.45 | 10.33 | 0.00 |
| M vs DLS | 1704.06 | 2.19 | 0.17 | 152607.92 | 15.40 | 0.00 | 29434.52 | 12.97 | 0.01 | 1952.57 | 1.09 | 0.31 |

Table XIII: Post-hoc tests, older adults

| | CATEGORY | | | | | |
|---|---|---|---|---|---|---|
| | BY SUBJECT | | | BY ITEM | | |
| | MSE | F | p | MSE | F | p |
| CP vs CS | 34829.08 | 25.27 | 0.00 | 48262.33 | 5.58 | 0.03 |
| DLP vs CP | 3518.62 | 0.58 | 0.46 | 648.43 | 0.05 | 0.82 |
| DLP vs DLS | 76753.96 | 10.73 | 0.01 | 183274.70 | 42.28 | 0.00 |
| DLS vs CS | 22421.31 | 5.98 | 0.03 | 54701.37 | 10.34 | 0.00 |
| M vs CS | 88.14 | 0.02 | 0.88 | 443.96 | 0.05 | 0.82 |
| M vs DLS | 3.34 | 0.00 | 0.98 | 1.54 | 0.00 | 0.99 |

Plural nouns were responded to more slowly than singular nouns, across both groups; this effect did not interact with frequency. No difference was seen between dual and count plural nouns. Again, the results with respect to singular nouns are a little more complex. Younger adults show significant differences between mass and count nouns, which are stronger in low frequency items. Dual and count nouns are recognized at the same speed, although an interaction between frequency and category was seen in the subject analysis, suggesting that low frequency dual nouns are recognized more quickly than low frequency count nouns. Finally, mass nouns were recognized more quickly than dual nouns (significant only in subject analysis), especially in low frequency stimuli (significant only in item analysis). Older adults, on the other hand, recognize dual nouns more quickly across frequency ranges, although this effect is slightly stronger in low frequency items (significant only in subject analysis). Low frequency mass nouns are recognized more quickly than low frequency dual nouns (significant interaction in subject analysis, borderline in item analysis), and mass and count nouns are recognized at the same speed.

The interpretation of these results will be discussed in the section below dealing with age differences. However, we begin with a discussion of the overall effects of mass/count status and mass/count ambiguity, across subject groups, as revealed by the main ANOVAs.

Discussion

The present experiment examined the effect of noun class on response times in a lexical decision task. The goal was to determine (a) what effect mass/count status had on lexical access, as measured by RT: (b) what effect mass/count ambiguity had on lexical access; (c) whether differences would be seen between younger and older adults. The ramifications of the present findings for each of these issues are discussed below.

Mass/count status and lexical access

As attested in previous literature (e.g., Gillon et al., 1999), the present study found that mass nouns were recognized more slowly than count (and dual) nouns by both younger and older adults. However, this was the case only for low frequency stimuli; no significant difference was found between mass and count nouns of high frequency. These results support that claim put forward by Gillon et al. (1999) that access to mass nouns requires computation of the feature [mass], and that this computation slow processing of mass nouns relative to count nouns. We suggest that in the case of high frequency exemplars, the rapid rate at which lexical access proceeds washes out any differences between these categories.

The question thus arises of what precisely is meant by the feature [mass]. Although the data presented in the current paper does not speak directly to this issue, we nonetheless offer some speculation as to what the function and composition of this feature may be (see Taler & Jarema, submitted, for further discussion of this issue). In theoretical linguistic terms, this feature can be seen as indexing those nouns which may appear in a mass context, preventing pluralization, etc. From a psycholinguistic viewpoint, the question is slightly more complex. We note that it appears to have a syntactic component, as suggested by Gillon et al.'s (1999) finding that both mass and count nouns are primed by a determiner with which they form a grammatical combination. However, it is unclear why a syntactic feature, which is presumably necessary for both mass and count nouns, should slow processing of mass nouns more than that of count nouns. We further suggest that the feature must also comprise semantic information (i.e., whether the referent of the noun is "stuff" or "things"), which is accessed whenever a mass or count noun is recognized. Thus, the feature [mass] is convenient shorthand for a complex of semantic and syntactic information associated with the lexical entry of a given mass noun. A similar complex of information is activated when a count noun is recognized, although the greater cost of recognizing mass nouns than count nouns is perhaps due to the greater difficulty in activating an unindividuated referent. This claim is of course speculative, although it is supported by the finding that individuals with semantic impairments have difficulty accessing the mass reading of a dual noun (Taler & Jarema, 2004, submitted; Taler, Jarema & Saumier, 2004).

The effect of mass/count ambiguity on lexical access

A second question addressed by the present research is whether lexical items that are ambiguous with respect to mass/count information (dual nouns) are processed similarly to other ambiguous items (as suggested by Klein & Murphy, 2001, and assumed by a number of researchers, including Hino & Lupker, 1996; Hino et al., 2002). According to this account, these items should behave in the same way as other ambiguous items, specifically homonyms, which manifest an ambiguity advantage across frequency ranges in a LDT (Hino & Lupker, 1996). Thus, dual nouns should be recognized more quickly than count nouns in both the high- and the low-frequency conditions. This advantage is presumed to be due to activation of multiple lexical entries and should thus remain stable across the two participant groups, and be seen in plural as well as singular dual nouns.

A second account put forward in the literature (Copestake & Briscoe, 1995; Gillon, 1996) holds that these items are treated as count nouns and must undergo a lexical rule when seen in a mass context. This account predicts that dual nouns will be processed in the same way as count nouns when seen out of context, whether they are in the singular or the plural form. . Again, no effect of age or frequency would be predicted in processing of these lexical items.

In the present study, dual nouns do not behave like count nouns; significant differences were seen between these two categories. In the item analysis, dual nouns were found to be recognized significantly more quickly than count nouns, and an interaction between frequency and category was seen in the subject analysis, whereby low frequency dual nouns were recognized more quickly than low frequency count nouns[11]. These results are inconsistent with the claim that dual nouns are simply count nouns which may undergo a lexical rule to generate a mass reading (Copestake & Briscoe, 1995; Gillon, 1996).

The first conclusion that can be drawn from these results is that, since dual nouns do not behave like mass nouns nor like count nouns, a two-way distinction between mass and count nouns is inadequate. Rather, a three-way distinction between mass, count and dual nouns appears to be necessary. One possible solution to this is to posit that dual nouns are marked both for masshood and for counthood. This is in line with the claim that the processing advantage enjoyed by dual nouns is due to their being lexically ambiguous (since the ambiguity advantage seen in homonymous lexical items is taken to be reflective of activation of multiple meanings). However, this account is not supported by prior research on polysemy which has demonstrated a greater processing advantage for polysemous than homonymous nouns (e.g., Frazier & Rayner, 1990; Azuma & Van Orden, 1997; Klepousniotou, 2002, Rodd, Gaskell & Marslen-Wilson, 2002). Furthermore, the finding that low frequency dual nouns show a greater processing advantage is inconsistent with research demonstrating a processing advantage in both high- and low-frequency ambiguous items in an LDT (Hino & Lupker, 1996). Finally, such an account would predict that the duality advantage should obtain for both plural and singular dual nouns, which was not the case.

[11] The finding that such an interaction obtains in the subject but not the item analysis suggests that a subset of dual nouns are responsible for this effect. In the subsequent analyses by subject group, it was found that this effect is stronger in the younger adults. This issue is thus discussed further in the section addressing age differences in lexical processing.

Thus, we claim that dual nouns do not pattern with mass or count nouns, nor with homonymous nouns like bank, but rather are represented differently than any of these items. One possible account for the processing advantage seen for these lexical items is that they are underspecified with respect to mass/count information. Thus, they are recognized more quickly than count or mass nouns, which are specified for this information. According to this account, when these items are seen in context, a lexical rule of the variety postulated by Klepousniotou (2002) applies. This accounts for the finding that differences are seen between singular but not plural dual and count nouns: when a plural dual noun is seen, the count reading is forced, since plural mass nouns are ungrammatical. Therefore, mass/count information may be inserted, and the insertion of this information takes time, resulting in a loss of processing advantage.

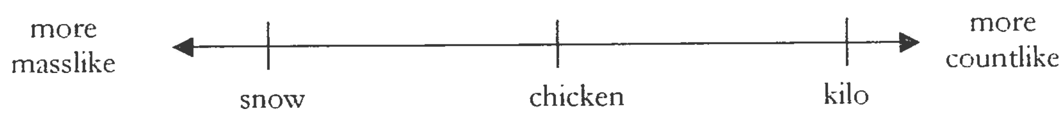
Age differences in lexical processing

Differences were seen in older adults' performance in three areas. First, older adults responded more slowly overall, as has been found in previous literature (e.g., Tainturier, Tremblay & Lecours, 1989; Allen, Madden & Crozier 1991; Allen, Madden, Weber & Groth, 1993). Second, older adults committed significantly more errors than younger adults on critical stimuli. No significant differences were seen with respect to category or frequency, suggesting that this effect does not reflect a greater processing cost in any particular category, but rather is reflective of the generalized cognitive deficit seen in older adults. Third, differences in response patterns were seen across the two groups. Specifically, pluralization of both count and dual nouns was found to exert the same effect across subject groups. In singular nouns, older adults show no significant difference between mass and count nouns, while younger adults do, especially in low frequency stimuli. Finally, dual nouns are recognized significantly more quickly than count nouns by older adults, whereas younger adults do not show such an effect, although a frequency by category interaction was seen in the subject analysis, suggesting that this advantage is seen in a subset of low frequency items.

We suggest that the results of the present experiment point toward a representation of dual nouns which differs from that which is often assumed, whereby dual nouns are seen as patterning with other ambiguous lexical items. As mentioned above, one possible account for the processing advantage seen with singular dual nouns is that they are underspecified with respect to mass/count information. However, this begs the question of why this processing advantage is seen across all dual nouns for older adults, but only in a subset of low frequency items for younger adults. If dual nouns constitute a discrete category which does not contain mass/count information, then they should be processed in a similar fashion across the two age groups.

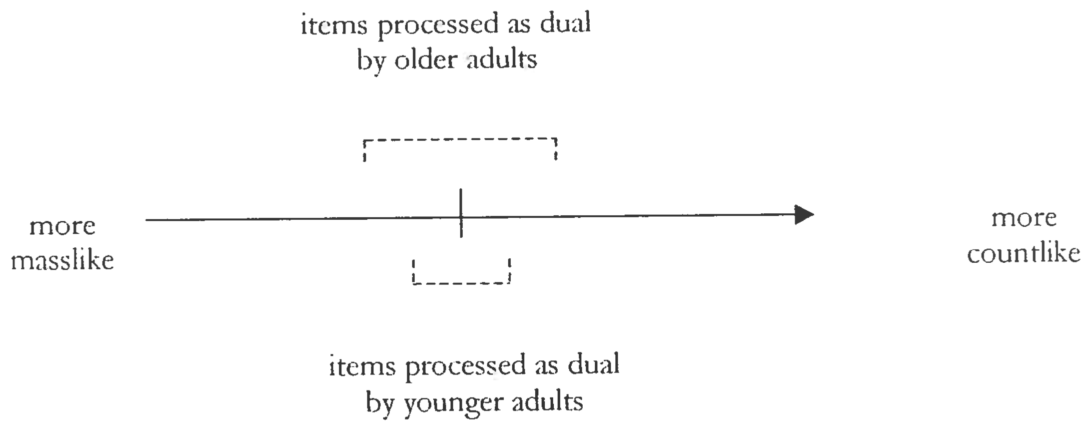
The present findings suggest that older adults treat dual nouns as somehow "more underspecified" than do younger adults. In order to account for this intriguing finding, we appeal to a notion that has been alluded to in the theoretical linguistic literature: the notion that the mass/count status of a noun may be strongly influenced by context (e.g., Pelletier, 1979). We refine this claim, positing that nouns may vary along a continuum in their relative masshood or counthood. Some nouns, such as kilo,. for example, are very unlikely to appear in a mass context, whereas others, such as snow, are unlikely to appear in a count context. Dual nouns are simply those which are likely to appear in either context. This is represented in Figure 3.4 below (for further discussion of this reconceptualization of the mass/count distinction, see Taler & Jarema, submitted).

Figure 3.4: The mass/count distinction




Within this framework, the relatively greater advantage for dual nouns in older adults can be accounted for in a fairly straightforward manner. If the lexical entries of nouns near the centre of this continuum are underspecified in terms of mass/count information, they will be recognized more quickly than count or mass nouns, which require access to mass/count information. If older adults have fewer resources available for on-line lexicosemantic processing, then they may select to "withhold judgement" with respect to mass/count status on a larger set of items than do younger adults, who select a default (count) reading for most lexical items which allow mass and count readings. Thus, the "duality advantage" will be greater in older than younger adults; the latter group will process many of these lexical items as if they were count. This also accounts for the fact that younger adults were found to manifest faster processing of low frequency dual noun in the subject but not the item analysis. This result suggests that the "duality advantage" was present in only a subset of dual nouns for younger adults. Older and younger adults' processing of these lexical items is represented in Figure 3.5 below.

Figure 3.5: Older and younger adults' processing of dual nouns




The framework presented in Figures 3.4 and 3.5 can thus account for the different processing of singular dual and count nouns, as well as the fact that this difference is greater in older than in younger adults. To represent nouns along a continuum of "most mass" to "most count" is also both intuitively appealing and consistent with the observation in the theoretical linguistic literature that nouns manifest varying levels of ease of conversion from mass to count. Previous attempts to characterize these differing levels have relied on probabilistic conversion rules (e.g., Copestake & Briscoe, 1995). However, the present data is inconsistent with such a framework, since this would predict that singular dual nouns (i.e., nouns in the centre of the continuum proposed here) should be processed in the same fashion as singular count nouns, which does not appear to be the case.

We now consider the present results within the framework of the four hypotheses regarding the central deficits postulated to underlie performance alterations in older adults. First, the finding that there were alterations in processing of these categories across the lifespan is inconsistent with the sensory acuity hypothesis, since such a hypothesis would predict that differing noun classes presented in a visually identical fashion should all show the same effect (presumably, generalized slowing). The inhibitory dysfunction hypothesis predicts that, if dual nouns are underspecified, which we suggest they are, then there should be no difference in the processing of dual and count nouns across the lifespan, since inhibition is not required in processing of either of these noun types. However, we found an advantage in processing singular but not plural dual nouns in older adults relative to younger adults. This result is consistent with the predictions of the processing speed theory (Salthouse, 1991, 1996). It is also consistent with the WM hypothesis put forward by Craik and Byrd (1982). Both of these theories predict that the reduced structure of singular dual nouns should result in a relative advantage in older versus younger adults.

However, these theories also predict that mass and plural nouns will exert a greater processing cost in older adults than in younger adults. Neither of these predictions was borne out. In the case of plural nouns, we suggest that this is potentially due to rapid access to these lexical items, resulting in a washing-out of effects, similar to that seen with high frequency mass and count nouns. This is supported by the fact that Gillon et al. (1999) in fact found no effect of plurality at all in dual and regular count nouns, a finding which these authors interpreted as indicating very rapid lexical access.

With respect to the prediction that mass nouns would exert a greater processing load for older than younger adults, we found that the reverse was true: mass nouns in fact resulted in slower processing in younger but not older adults. While we note that this effect may be a result of the small sample size used in the present study[12], and should thus be viewed with caution, it is possible that it indicates a higher relative cost of accessing count or mass information in older adults. This finding is best accounted for within the processing speed theory: younger adults may be able to retrieve an individuated referent rapidly but take longer to access an unindividuated referent, whereas in older adults, retrieval of any referent takes longer.

Conclusions

In the present paper we have examined processing of nouns of different classes (mass, count and mass/count ambiguous, or dual) by younger and older adults. It was found that mass nouns are recognized more slowly overall than are count nouns. Gillon et al. (1999) found a similar result and attributed this to the presence of a feature [mass] in the lexical entry of mass nouns, computation of which slows lexical access. We speculate that this feature may represent a complex of syntactic and semantic information about the lexical item, which must be accessed when the noun is recognized. Such information is also present in the lexical entries of count nouns, but appears to be more easily accessed, possibly due to the fact that referents of count nouns are individuated.

The second major finding in the current study is that older adults recognize singular dual nouns more quickly than singular count nouns across frequency ranges, whereas younger adults manifest only a weak effect in low frequency dual nouns; plural count and dual nouns, on the other hand, manifest similar processing times in both participant groups.

[12]While the category x frequency interaction missed significance in the item analysis for older participants' results, it was borderline ($p<0.046$), and an LSD post-hoc test showed significant interaction for mass vs singular count nouns, whereby low frequency mass nouns were slower than low frequency count nouns ($p<0.05$).

We argue that singular dual nouns may be underspecified with respect to mass/count information, and are thus recognized more quickly. However, when they are seen in the plural form the count reading must be activated (since mass nouns cannot be pluralized), possibly via a lexical rule, as proposed by Klepousniotou (2002) and Taler & Jarema (in press). Thus, plural count and plural dual nouns manifest similar RTs. The finding that older adults experience a greater "duality advantage", manifested in faster responses to dual nouns in comparison to younger adults, is argued to be a result of these individuals not activating mass/count information with a larger range of nouns when they are seen out of context. We argue that common nouns fall along a continuum of more "mass-like" to more "count-like", with dual nouns being those nouns that are in the centre of this continuum. This notion is both intuitively appealing and supported by the theoretical linguistic literature (e.g., Pelletier, 1979, Bale & Barner, submitted; for a more extensive discussion, see Taler & Jarema, submitted). We suggest that older adults treat a larger spectrum of nouns as dual, whereas younger adults activate a default (count) reading of these items even in the absence of context.

In terms of the aforementioned theories regarding the central deficit underlying performance alterations in healthy adults, we suggest that this may be due to reduced processing speed (Salthouse, 1991, 1996) and/or a reduction in resources in older adults (Craik & Byrd, 1982). We postulate that older adults adopt a strategy of not activating mass/count information in the case of dual nouns, unless they are forced to do so by context. This would account for the seeming paradox of a reduction in processing abilities resulting in <u>faster</u> access to dual nouns in older adults when compared to younger adults.

One issue which remains to be addressed through further research is whether the claim that duality is processed differently than homonymy may be extended to other polysemous lexical items. The current study focused on the mass/count distinction, and thus restricted its examination of lexical ambiguity to the case of mass/count ambiguity. However, it seems likely that other cases of polysemy may be amenable to a similar account, whereby the precise referent of the lexical item can be underspecified until it is determined by context, and a polysemous item may be used in a more or less metaphorical fashion, for example. In the case of homonymous items such as "bank", however, no such continuum may be proposed, since the two meanings of the lexical item are discrete.

Appendix 1: Critical stimuli

| | dual nouns | mass nouns | count nouns |
|---|---|---|---|
| high frequency | brick | beauty | basket |
| | cake | butter | bell |
| | carpet | clay | belt |
| | chicken | cloth | blanket |
| | cloud | corn | bowl |
| | coal | cotton | button |
| | crime | cream | cabin |
| | debt | damage | castle[c,i] |
| | fibre[i]† | dirt | cat |
| | fur | dust | clock |
| | lamb | flesh | cousin |
| | lawn | fruit | cow |
| | pipe | honey | crowd |
| | prayer | metal | daisy |
| | rope | paint | doll |
| | salad | plastic† | elbow |
| | shadow | rice | engine |
| | shell | sand | fence |
| | stone | silk | fist† |
| | string | snow | lake |
| | talent | soap | lamp |
| | taste | spite | planet |
| | virtue | sugar | skirt |
| | wire | sweat | sofa |
| | wonder | traffic | ticket |
| low frequency | beet | beef | apron[c] |
| | cabbage | carbon | badge |
| | cable | cement | barn |
| | candy | chalk | beetle |
| | cane | copper | blouse |
| | cedar | denim† | couch |
| | cork | diesel† | cradle |
| | dessert† | fabric | crater† |
| | elm | filth | dime |
| | fog | fluid† | ditch |
| | ham | garlic | donkey† |
| | lobster | gravel | dragon[c,i] |
| | maple | grease† | eagle |
| | onion | ink | flag |
| | pastry† | liquor | fountain |
| | pasture | manure | guitar[c,i] |
| | pepper | mustard | helmet |
| | pumpkin† | parsley† | medal |
| | ribbon | plaster† | needle |

| | | | |
|---|---|---|---|
| | steak<br>thread<br>treasure†<br>turkey†<br>verse<br>walnut | pollen<br>pork<br>satin<br>sulphur<br>veal<br>wax | pebble[c]<br>pony<br>swan†<br>tractor<br>wand<br>wolf |

*indicates that the item was not present in the English Lexicon Database norms.

†indicates that the item was not present in the MRC psycholinguistic database.

[c]indicates that concreteness norms were not available for this item.

[i]indicates that imageability norms were not available for this item.

Appendix 2: Stimulus characteristics (averaged by category)

| | length | syllables | neighbourhood density | neighbourhood frequency | bigram frequency | bigram frequency by position | concreteness | imageability | familiarity |
|---|---|---|---|---|---|---|---|---|---|
| dual high | 4.96 | 1.64 | 5.25 | 7.81 | 1743 | 1448 | 521 | 535 | 539 |
| mass high | 4.96 | 1.36 | 4.64 | 8.07 | 1654 | 1400 | 560 | 546 | 554 |
| count high | 4.88 | 1.48 | 5.76 | 7.88 | 1570 | 1360.4 | 594 | 539 | 580 |
| dual low | 5.36 | 1.64 | 4.08 | 7.49 | 1842 | 1506 | 590 | 502 | 572 |
| mass low | 5.48 | 1.68 | 2.56 | 7.12 | 1857 | 1662 | 587 | 507 | 554 |
| count low | 5.28 | 1.6 | 3.4 | 7.69 | 1698 | 1527 | 594 | 503 | 5812 |

References

Allen, P.A, Madden, D.J, Weber, T.A. & Groth .KE. (1993) Influence of age and processing stage on visual word recognition. Psychology and Aging 8:274-282.

Allen, P.A., Madden, D.J.,& Crozier L.C. (1991) Adult age differences in letter-level and word-level processing. Psychology and Aging 1991: 6:261-271.

Azuma, T., Van Orden, G. (1997) Why SAFE is better than FAST: The relatedness of a word's meanings affects lexical decision times. Journal of Memory and Language, 36:484-504.

Baayen, R.H., Piepenbrock, R., Rijn, H. van. (1993) The CELEX Lexical Database (Release 1) [CD-ROM]. Philadelphia, PA: Linguistic Data Consortium, University of Pennsylvania [Distributor].

Bale, A. & Barner, D. (submitted) Comparative dimensions and individuation: The semantics of mass and count nouns.

Balota, D. A. (1990). The role of meaning in word recognition. In D. A. Balota, G. B. Flores d'Arcaise, & K. Rayner (Eds.), Comprehension Processes in Reading (pp. 9–32). Hillsdale, NJ: Erlbaum.

Balota, D. A., & Chumbley, J. I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. Journal of Experimental Psychology: Human Perception and Performance, 10, 340-357.

Balota, D. A., & Chumbley, J. I. (1985). The locus of word-frequency effects in the pronunciation task: Lexical access and/or production? Journal of Memory and Language, 24, 89-106.

Balota, D.A., Cortese, M.J., Hutchison, K.A., Neely, J.H., Nelson, D., Simpson, G.B., & Treiman, R. (2002) The English Lexicon Project: A web-based repository of descriptive and behavioral measures for 40,481 English words and nonwords. Available at **http://elexicon.wustl.edu/**, **Washington University**.

Besner, D. (1983). Basic decoding components in reading: Two dissociable feature extraction processes. Canadian Journal of Psychology, 37, 429-438.

Borowsky, R., & Masson, M. E. J. (1996). Semantic ambiguity effects in word identification. Journal of Experimental Psychology: Learning, Memory, and Cognition, 22, 63-85.

Bowles, N.L., Williams, D., Poon, L.W. (1983) On the use of word association norms in aging research. Experimental Aging Research, 9:175-77.

Brosseau, J., & Cohen, H. (1996) The representation of semantic categories in aging. Experimental Aging Research, 22, 381-391.

Burke, D.M., MacKay, D.G., James, L.E. (2000) Theoretical approaches to language and aging. In Perfect, T.J. & Maylor, E.A., (Eds.) Models of Cognitive Aging. Oxford: Oxford University Press, 204-237.

Burke, D.M., MacKay, D., Worthley, J. & Wade, E. (1991) On the tip of the tongue: What causes word finding failures in younger and older adults? Journal of Memory and Language, 1991; 30:542-579.

Burke, D.M. & Peters, L. (1986) Word association in old age: Evidence for consistency in semantic encoding during adulthood. Psychology and Aging 1:283-292.

Cohen, G. & Faulkner, D. (1986) Memory for proper names: Age differences in retrieval. British Journal of Developmental Psychology, 4:187-197.

Coltheart, M. (1981). The MRC Psycholinguistic Database. Quarterly Journal of Experimental Psychology, 33, 497-505.

Copestake, A. & Briscoe, T. (1995) Semi-productive polysemy and sense extension. Journal of Semantics, 12:15-67.

Cortese, M.J., Simpson, G.B., & Woolsey, S. (1997) Effects of association and imageability on phonological mapping. Psychonomic Bulletin and Review, 4, 226-231.

Craik, F.I.M. (2000) Age-related changes in human memory. In Park, D. & Schwartz, N. (Eds.) Cognitive Aging: A Primer. Philadelphia: Psychology Press, 75-92.

Craik, F.I.M. & Byrd, M. (1982) Aging and cognitive deficits: The role of attentional resources. In Craik FIM, Trehub S, eds. Aging and cognitive processes. New York: Plenum Press, 191-211.

Craik, F.I.M., Morris, R.G., & Gick, M.L. (1990). Adult age differences in working memory. In G. Vallar & T. Shallice (Eds.) Neuropsychological Impairments of Short-Term Memory. Cambridge, England: Cambridge University Press. 247-267.

de Groot, A.M. (1989). Representational aspects of word imageability and word frequency as assessed through word association. Journal of Experimental Psychology: Learning, Memory and Cognition, 15, 824-845.

Dobbs, A.R., & Rule, B.G. (1989). Adult age differences in working memory. Psychology and Aging, 4, 500-503.

Dommes, A., & Le Rouzo, M.-L. (2004) Vieillisement cognitif et compréhension d'ambigüités lexicales: effect d'amorcage sémantique et familiarité du sens de paires homophoniques. Proceedings of the Cognitio 2004 conference, 60-72.

Folstein, M. J., Folstein, S.E., & McHugh, P.R. (1975). Mini-mental state: a practical method for grading the cognitive state of the patients for the clinician. Journal of Psychiatric Research, 12, 189-198.

Forster, K. (1998). The pros and cons of masked priming. Journal of Psycholinguistic Research, 27(2), 203-233.

Frazier, L. & Rayner, K. (1990) Taking on semantic commitments: Processing multiple meanings vs. multiple senses. Journal of Memory and Language, 28:181-200.

Frisson, S. & Frazier, L. (in press) Carving up word meanings: Portioning and grinding. Journal of Memory and Language.

Gillon, B. (1996) The lexical semantics of English mass and count nouns. In E Viegas (ed.) Breadth and Depth of Semantic Lexicons. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Gillon, B.S., Kehayia, E. & Taler, V. (1999) The mass/count distinction: Evidence from on-line psycholinguistic performance. Brain and Language, 68:205-211.

Gottlob, L. R., Goldinger, S. D., Stone, G. O., & Van Orden, G. C. (1999). Reading homographs: Orthographic, phonologic, and semantic dynamics. Journal of Experimental Psychology: Human Perception and Performance, 25, 561-574.

Grossman, M., Carvell, S. and Peltzer, L. (1993) The sum and substance of it: The appreciation of mass and count quantifiers in Parkinson's Disease. Brain and Language 44: 351-384.

Hasher, L. & Zacks, R.T. (1988) Working memory, comprehension and aging: A review and a new view. In Bower, G.H. (Ed.) The Psychology of Learning and Motivation: Advances in Research and Theory. San Diego, CA: Academic Press.

Hino, Y., & Lupker, S.J. (1996). The effects of polysemy in lexical decision and naming: An alternative to lexical access accounts. Journal of Experimental Psychology Human Perception and Performance, 22, 1331-1356.

Hino, Y., Lupker, S.J., & Pexman, P. (2002). Ambiguity and synonymy effects in lexical decision, naming and semantic categorization tasks: Interactions between orthography, phonology and semantics. Journal of Experimental Psychology: Learning, Memory and Cognition, 28, 686-713.

Howard, D.V. (1980) Category norms: A comparison of the Battig and Montague (1969) norms with the responses of adults between the ages of 20 and 80. Journal of Gerontology, 35:225-231

James, C.T. (1975). The role of semantic information in lexical decisions. Journal of Experimental Psychology: Human Perception and Performance, 1, 130-136.

Jastrzembski, J. E. (1981). Multiple meanings, number of related meanings, frequency of occurrence, and the lexicon. *Cognitive Psychology, 13*, 278-305.

Jastrzembski, J. E., & Stanners, R.F. (1975) Multiple word meanings and lexical search speed. Journal of Verbal Learning and Verbal Behavior, 14, 534-537.

Joosten, F. (2003). Accounts of the count-mass distinction: A critical survey. Nordlyd, 31(1), 216-229.

Kellas, G., Ferraro, F. R., & Simpson, G. B. (1988). Lexical ambiguity and the timecourse of attentional allocation in word recognition. Journal of Experimental Psychology: Human Perception and Performance, 14, 601-609.

Kempson, R.M. (1977) Semantic theory. Cambridge, U.K.: Cambridge University Press.

Klein, D. E., & Murphy, G. L. (2001). The representation of polysemous words. Journal of Memory and Language, 45, 259-282.

Klepousniotou, E. (2002) The processing of lexical ambiguity: Homonymy and polysemy in the mental lexicon. Brain and Language, 81:205-223.

Lichacz, F.M., Herdman, C.M., LeFevre, J., Baird, B. (1999) Polysemy effects in word naming. Canadian Journal of Experimental Psychology, 53, 189-193.

Light, L.L. (1996) Memory and aging. In Bjork EL, Bjork RA, eds. Memory. San Diego, CA: Academic Press, 1996; 443-490.

Lindenberger, U. & Baltes, P.B. (1994) Sensory function and intelligence in old age: A strong connection. Psychology and Aging, 9, 339-355.

Lovelace, E.A. & Cooley, S. (1982) Free associations of older adults to single words and conceptually related word triads. Journal of Gerontology, 1982; 37:432-437.

Madden, D.J., Langley, L.K., Denny, L.L., Turkington, T,G., Provenzale, J.M., Hawk, T.C. & Coleman, R.E. (2002) Adult age differences in visual word identification: Functional neuroanatomy by positron emission tomography. Brain and Cognition, 49:297-321.

Madden, D.J., Turkington, T.G., Coleman, R.E., Provenzale, J.M., DeGrado, T.R. & Hoffman, J.M. (1996) Adult age differences in regional cerebral blood flow during visual word identification: Evidence from $H_2^{15}O$ PET. Neuroimage, 3:127-142.

Maylor, E.A. (1990) Age and prospective memory. Quarterly Journal of Experimental Psychology, 42A:471-493.

Millis, M. L., & Button, S. B. (1989). The effect of polysemy on lexical decision time: Now you see it, now you don't. Memory & Cognition, 17, 141-147.

Nasreddine, Z.S., Chertkow, H., Phillips, N.A., Whitehead, V., Collin, I., & Cummings, J.L. (in press). The Montreal Cognitive Assessment (MoCA): A brief screening tool for mild cognitive impairment. Journal of the American Geriatric Society.

Park, D.C. (2000) The basic mechanisms accounting for age-related decline in cognitive function. In Park, D,C. & Schwartz, N, eds. Cognitive Aging: A Primer. Philadelphia: Psychology Press, 2000; 3-21.

Pelletier, F.J. (1979). Non-singular reference: Some preliminaries. In F.J. Pelletier (Ed.), Mass terms: Some philosophical problems. Dordrecht: Reidel.

Perani, D., Cappa, S.F., Schnur, T., Tettamanti, M., Collina, S., Rosa, M.M., & Fazio, F. (1999) The neural correlates of verb and noun processing. A PET study. Brain, 122, 2337-2344.

Perea, M., Rosa, E., & Gómez, C. (2002). Is the go/no-go lexical decision task an alternative to the yes/no lexical decision task? Memory and Cognition, 30:34-45.

Pexman, P. M., & Lupker, S. J. (1999). Ambiguity and visual word recognition: Can feedback explain both homophone and polysemy effects? Canadian Journal of Experimental Psychology, 53, 323-334.

Pexman, P.M., Lupker, S.J., & Hino, Y. (2002) The impact of semantics in visual word recognition: Number of features effects in lexical decision and naming tasks. Psychonomic Bulletin and Review, 9, 542-549.

Pustejovsky, J. (1995) The generative lexicon. Cambridge, MA: MIT Press.

Rodd, J.M., Gaskell, G. & Marslen-Wilson, W. (2002) Making sense of semantic ambiguity: Semantic competition in lexical access. Journal of Memory and Language, 46, 245-266.

Rubenstein, H., Lewis, S. S., & Rubenstein, M. A. (1971). Evidence for phonemic recoding in visual word recognition. Journal of Verbal Learning and Verbal Behavior, 10, 645-657.

Salthouse TA. (1991) Theoretical Perspectives on Cognitive Aging. Hillsdale, NJ: Erlbaum.

Salthouse, T.A. (1996) The processing-speed theory of adult-age differences in cognition. Psychological Review, 103:403-428.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. Psychological Review, 96, 521-568.

Semenza, C., Mondini, S. and Cappelletti, M. (1997) The grammatical properties of mass nouns: An aphasia case study. Neuropsychologia 35(5): 669-675.

Spieler, D.H. & Balota, D.A. (2000) Factors influencing word naming in younger and older adults. Psychology and Aging, 15:225-231.

Steinhauer, K., Pancheva, R., Newman, A.J., Gennari, S. & Ullman, M.T. (2001) How the mass counts: an electrophysiological approach to the processing of lexical features. Neuroreport, 12: 999-1005.

Steriade, D. (1995) Markedness and underspecification in the study of segments. In J. Goldsmith, (Ed.). A Handbook of Phonological Theory. Cambridge, MA and Oxford, UK: Blackwell: 114-175.

Strain, E. & Herdman, C.M. (1999) Imageability effects in word naming: An individual differences analysis. Canadian Journal of Experimental Psychology, 53, 347-359.

Taft, M., & Forster, K. (1975). Lexical storage and retrieval of prefixed words. Journal of Verbal Learning and Verbal Behaviour, 14, 638–647.

Tainturier, M.J., Tremblay, M. & Lecours, A.R. (1989) Aging and the word frequency effect: A lexical decision investigation. Neuropsychologia, 27:1197-1203.

Taler, V., Chertkow, H. & Saumier, D. (in press) The effect of Alzheimer's disease and aging on conceptual combination. Brain and Cognition.

Taler, V. & Jarema, G. (in press) On-line lexical processing in AD and MCI: An early measure of cognitive impairment? Journal of Neurolinguistics.

Taler, V. & Jarema, G. (submitted) Underspecification in the lexicon: the case of mass/count sense extensions.

Taler, V., Jarema, G. & Saumier, D. (2004) Processing of mass/count information in semantic dementia and agrammatic aphasia. Brain and Language 91: 160-161.

Whiting, W.L., Madden, D.J., Langley, L.K., Denny, L.L., Turkington, T.G., Provenzale, J.M., Hawk, T.C. & Coleman, R.E. (2003) Lexical and sublexical components of age-related changes in neural activation during visual word identification. Journal of Cognitive Neuroscience, 15:475-487.

Wingfield, A., Stine, E.A., Lahar, C.J., & Aberdeen, J.S. (1988) Does the capacity of working memory change with age? Experimental Aging Research, 14, 103-107.

Wingfield, A. & Stine-Morrow, E.A. (2000) Language and speech. In Craik, F.I.M. & Salthouse, T.A. (Eds.) The Handbook of Aging and Cognition. Mahwah, NJ: Erlbaum, 359-416.

Zevin, J.D.& Balota, D. (2000) Priming and attentional control of lexical and sublexical pathways during naming. Journal of Experimental Psychology: Learning, Memory and Cognition, 26, 121-135.

Chapter 4 (Study 3): On-line lexical processing in AD and MCI: An early measure of cognitive impairment?

Vanessa Taler[1,2,*] and Gonia Jarema[1,2,3]

[1]Research Centre, Institut Universitaire de Gériatrie de Montréal, Montreal, Quebec, Canada

[2]Department of Biomedical Sciences, Université de Montréal, Montreal, Quebec, Canada

[3]Department of Linguistics, Université de Montréal, Montreal, Quebec, Canada

*corresponding author

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Abstract

The present study examines on-line processing of mass nouns (e.g., honey), count nouns (e.g., table) and dual (metonymic) nouns (e.g., chicken) in healthy elderly controls with no evidence of cognitive impairment, patients suffering from probable Alzheimer's disease (pAD), and patients diagnosed with mild cognitive impairment (MCI). Participants performed a lexical decision task using a go/no-go paradigm, where they responded to words but not non-words. Within-group comparisons revealed that elderly controls manifested longer reaction times to mass nouns and count nouns than to dual nouns, while pAD and MCI patients manifested longer latencies to mass nouns, but no significant difference between count and dual nouns. The way in which lexicosemantic knowledge breaks down in the case of memory impairment is discussed, and it is argued that breakdown in lexical representations may provide a sensitive early measure of cognitive impairment.

(125 words)

Keywords: Alzheimer's disease, mild cognitive impairment, lexicosemantic processing, mass/count distinction

Introduction

Alzheimer's disease (AD) is a progressive neurodegenerative disease, the primary symptom of which is an impairment in memory, particularly semantic memory. Patients suffering from AD have also been demonstrated to exhibit impairments in language processing; typically, patients manifest anomia (word-finding difficulty) and impairment in verbal fluency early in the disease course (for a review, see Caramelli, Mansur & Nitrini, 1998); subtle processing deficits, such as an impairment in accessing the past tense form of irregular verbs (Ullman, Corkin, Coppola, Hickok, Growdon, Koroshetz, & Pinker, 1997) have also been demonstrated. Syntactic abilities are typically found to be intact, although Grossman, Mickanin, Onishi and Hughes (1995) have suggested that these patients manifest an impairment in the processing of grammatical features. Taken together, these results suggest that AD patients' linguistic impairment is a result of either damage to semantic knowledge or difficulty accessing the information stored there, whereas the patients' grammar is relatively intact (Caramelli et al., 1998). The question of the nature of the deficit, that is, whether these patients' linguistic performance reflects impaired access or impaired representation, has been extensively debated in the literature (see, e.g., Hodges, Salmon & Butters, 1992; Nebes & Brady, 1991).

In order for a patient to be diagnosed as having AD, memory impairments must be accompanied by a dementia; that is, the patient must experience a significant impairment in daily functioning. In the case where a subject exhibits a memory impairment but no dementia, and where no other cause (such as depression) is found to be responsible for the memory impairment, the subject may be diagnosed with mild cognitive impairment (MCI). MCI is a relatively new term, introduced by the World Health Organization (see also Petersen, Smith, Waring, Ivnik, Tangalos and Kokmen, 1999), which is designed to capture the point on the continuum of cognitive states between normal aging and dementia (see Chertkow, 2002 for a discussion). Diagnostic criteria for MCI are as follows: the patient must experience a subjective memory complaint as well as objective memory impairment, in the context of largely intact general cognitive function and preserved activities of daily living. Furthermore, the patient must not meet the criteria for dementia and there must be no other obvious medical neurologic or psychiatric explanation for the memory problems (Chertkow, 2002; Petersen, 2003).

When considering these criteria, it must be noted that a great deal of heterogeneity is seen amongst MCI individuals. Individuals with MCI most commonly manifest a significant short- or long-term memory impairment in the absence of dementia (the amnestic form of MCI), although the syndrome may also present as mild deficits across a number of cognitive domains (multiple-domain MCI) or as a significant deficit in a single non-memory domain (single non-memory-domain MCI; for a review, see Petersen, 2003). In amnestic MCI, indivduals show significant impairment in memory performance (approximately 1.5 standard deviations below unimpaired age- and education-matched individuals) while performance in other cognitive domains in mildly impaired (up to 0.5 standard deviations below age- and education-matched individuals; Petersen et al., 1999). Individuals with multiple-domain MCI, in contrast do not exhibit an impairment in any one domain that is out of proportion to other cognitive domains; rather, performance may be at 0.5 to 1.0 standard deviations below the norm (Petersen, 2003). It should be noted that the ranges given here are descriptive rather than diagnostic. Individuals with single non-memory-domain MCI show a significant impairment in just one non-memory domain, such as language or executive function.

One of the primary research questions that arises with respect to MCI is whether it represents an early stage of AD. Most clinical studies show that approximately 44% of MCI individuals will have converted to AD over a 3-year follow-up, for an annual conversion rate of about 15% (Chertkow, 2002, Petersen et al., 1999; for a review of the principal studies reported in the literature, see Laurent & Thomas Antérion, 2002). This is in contrast to an annual conversion rate of about 1-2% in the general population (Petersen et al., 1999). However, there exists a subgroup of MCI patients who do not convert to AD even ten years after the onset of memory problems (Chertkow, 2002; Petersen, 2003). In the former author's cohort, this subgroup appears to comprise approximately 25% of the total group of MCI patients.

It has been suggested MCI individuals who do not convert to AD may simply be individuals who "sit for their whole lives at the bottom of any Gaussian curve of neuropsychological results" (Chertkow, 2002). Furthermore, individuals may sometimes progress to other forms of dementia, such as vascular dementia in the case of multiple-domain and single non-memory-domain MCI, and primary progressive aphasia (Mesulam, 2001), frontotemporal dementia (Rosen, Lengenfelder & Miller, 2000) or Lewy body dementia (Ferman et al., 1999) in the case of single non-memory-domain MCI. Thus, MCI is best viewed as a "prodromal, at-risk condition for AD" (Peterson, 2003).

On a neuropathological level, some autopsy studies reveal the same pattern in AD and MCI patients: neurofibrillary tangles in the hippocampus and entorhinal cortex (Chertkow, 2002) and decreased hippocampal volume (Jack, Petersen, Xu, O'Brien, Smith, Ivnik, Boeve, Waring, Tangalos and Kokmen, 1999). Alterations in the cholinergic system, a hallmark of AD, have also been found in MCI (for a review, see Sarter & Bruno, 2004). Following an extensive literature review, Laurent and Thomas Antérion (2002) conclude that MCI represents a pre-clinical stage of AD in 70-80% of cases.

The present study examines the on-line processing of differing noun types in these two patient groups, with the goal of establishing more precisely the nature of the linguistic deficits seen in these groups. Our previous research (Taler & Jarema, 2004) examined processing of nouns in two off-line tasks, a sentence-picture matching task and a sentence grammaticality judgement task. While almost all AD and MCI participants showed control-like performance in the latter task, the majority of these participants exhibited a deficit in the sentence-picture matching task. Interestingly, the nature of the deficit appeared identical in the two patient groups; the present experiment aims to determine whether a chronometrised task reveals a distinction between the two groups, or whether the nature of the cognitive impairment in MCI is seen to mirror that in AD even when using this more sensitive measure.

Three categories of nouns were included in the experiment reported here: mass nouns, count nouns and dual nouns. The distinction between mass and count nouns exists in many languages, and is best captured in terms of syntactic distribution, although conceptually it falls approximately along the lines of "stuff" (mass nouns) and "things" (count nouns). There also exist a category of nouns which may take a mass or a count reading (e.g., chicken). In the present study, these nouns will be referred to as dual nouns. In English, mass, count and dual nouns pattern as seen in Table XIV (see Gillon, 1999 for a discussion of the mass/count distinction in English).

Table XIV: Distribution of mass, count and dual nouns in English

| MASS NOUNS | COUNT NOUNS | DUAL (METONYMIC) NOUNS – take both a mass and a count reading |
|---|---|---|
| cannot be pluralised (*two honeys) | can be pluralised (two trees) | can be pluralised (two chickens) |
| do not take the indefinite article (*a honey) | take the indefinite article (a tree) | take the indefinite article (a chicken) |
| take only quantifiers that do not denumerate (*many honey, much honey) | take only quantifiers that denumerate ( many trees, *much tree) | take both quantifiers that denumerate and those that do not denumerate (many chickens, much chicken) |

Duality may be considered a type of polysemy. That is, these nouns possess multiple related senses. This type of lexical ambiguity may be contrasted with homonymy. Homonymous nouns, such as bank possess multiple unrelated meanings (i.e., a financial institution, the side of a river). Polysemy may be metonymic (as in the case of dual nouns), if the two senses are both literal, or it may be metaphorical, in the case where one sense of the word is literal and one is metaphorical (e.g., eye meaning an organ of the body or the opening at the top of a needle).

On-line processing of these differing noun types has been examined in unimpaired populations, and category differences have been found. Gillon, Kehayia & Taler (1999) found that mass nouns were processed more slowly than count nouns in a simple lexical decision task, and that both noun types yielded faster reaction times (RTs) when primed by a determiner with which they formed a grammatical combination. These results were taken to indicate that there exists a semantic feature [mass] ([M]), which is accessed when the word is recognised. Because mass nouns were recognised more slowly than count nouns, the feature was taken to be monovalent; that is, count nouns carry no such feature. Note that, under this hypothesis, there is no difference in the mass/count information contained in the lexical entries of count and dual nouns; only mass nouns are specified for mass/count information.

In a recent study of on-line processing of lexical ambiguity using a cross-modal sentence priming task, Klepousniotou (2002) found that metonymic nouns actually yielded shorter RTs and greater priming than was elicited by homonymous nouns. This was taken as evidence that homonymy relies on a process of sense selection, and that an exhaustive listing of the word's different senses is stored in the lexicon. On the other hand, in the case of polysemy (particularly metonymy), a lexical rule operates on the basic sense, which is stored in the lexicon, to create the extended senses. That is, Klepousniotou claims that dual nouns possess one central sense, and extensions to this sense are generated on-line, as proposed by Copestake and Briscoe (1995) and Pustejovsky (1995). This is in contrast to the position that a list of potential senses are stored in the lexicon, a view espoused by Kempson (1977), among others. This interpretation is supported by previous studies reported in the literature: Azuma and Van Orden (1997) found that related ambiguous words were accessed faster than unrelated ambiguous words, and Frazier and Rayner (1990) demonstrated that words with multiple senses showed shorter fixation times in a reading task than words with multiple meanings.

Processing of the mass/count distinction has also been examined in individuals with neurological disorders, albeit primarily using off-line (untimed) paradigms. Shapiro, Zurif, Carey and Grossman (1989) examined whether aphasic patients were able to access mass and count readings of ambiguous nouns using a sentence-picture matching task, and found that both fluent and non-fluent aphasic patients were impaired in this task. Unfortunately, however, stimuli included both polysemous and homonymous nouns, and results were not reported for these subgroups of stimuli. Taler and Jarema (2004) replicated this study with pAD and MCI patients, using only dual nouns, and found an impairment in a majority of patients in both groups, as mentioned above. Grossman, Carvell & Peltzer (1993) and Grossman et al. (1995) examined the mass/count distinction in patients suffering from Parkinson's disease and AD respectively. The same tasks were used in these two studies: a sentence-picture matching task, a grammaticality judgement task and a sentence completion task. These tasks were designed to separate the semantic and syntactic information contained in the determiners much and many. Both patient groups were found to exhibit some difficulty with quantifiers: in the case of AD patients, the authors report that the patients were able to access the semantic information contained in these quantifiers, but not the syntactic (mass/count) information. Finally, Semenza, Mondini and Cappelletti (1997) reported on the case of an aphasic patient who exhibits a selective impairment for mass but not count nouns across a variety of off-line tasks, in the absence of other grammatical deficits. The authors interpret this as an impairment at the lemma level of lexical retrieval (Kempen & Huijbers, 1983), indicating that specific grammatical rules stored at this level are independently represented and accessible.

Recently, Klepousniotou & Baum (2003) reported an on-line study of processing of metaphorical polysemy, metonymy and homonymy in right-hemisphere and left-hemisphere damaged populations as well as an age-matched control group. Polysemous, metonymic and homonymous nouns were used as primes in a lexical decision task which varied interstimulus interval (ISI), with the goal of determining the time course of activation and suppression of alternate meanings of the different noun types. The results suggest activation of both primary and secondary meanings in the metonymy condition in all three subject groups. That is, focal brain damage does not impair the capacity to access both meanings of metonymic nouns on-line.

The experiment reported here examines the effect of pAD and MCI on processing of mass, count and dual nouns, with the aim of determining whether these diseases affect the way in which these noun types are processed on-line, and whether any processing differences are exacerbated in pAD relative to MCI. A lexical decision paradigm is used, with RT as the dependent variable.. Longer RTs may be taken to reflect additional processing in accessing the item in question, either as a result of additional information made available when the item is accessed, or of additional morphological operations (e.g., Taft & Forster, 1975; Ahrens & Swinney, 1995; Laudanna, Badecker & Caramazza, 1992). As mentioned above, Gillon et al. (1999) used a lexical decision paradigm to examine the mass/count distinction, taking longer RTs to reflect additional structure. A similar approach is adopted in the current paper.

## Method

### Participants.

Eleven subjects meeting the criteria for probable Alzheimer's disease (pAD) (McKhann, Drachman, Folstein, Katzman, Price and Stadlan, 1984), 9 subjects diagnosed with mild cognitive impairment (MCI), and 11 healthy elderly control subjects participated in the study. Three pAD participants and one MCI participant were subsequently excluded from the study, either because of an inability to successfully complete the practice session (2 pAD participants) or an error rate above 15% in the first session of the experiment (1 pAD and 1 MCI participant) The participant details given below refer to the participants who successfully completed both sessions of the experiment.

All subjects were native speakers of English, and subjects with a prior history of neurological or psychiatric disease were excluded. pAD and MCI subjects were recruited from the Memory Clinic of the Jewish General Hospital in Montreal, a tertiary referral centre, and were diagnosed by a neurologist or neuropsychologist at the Memory Clinic. Control participants were recruited through the Memory Clinic and through newspaper advertisements. Control participants recruited from the Memory Clinic (four of eleven) underwent a complete neuropsychological battery in order to exclude dementia. Participants recruited through newspaper advertisements (seven of eleven) completed the Mini-Mental State Examination (MMSE, Folstein, Folstein & McHugh, 1975) and the Montreal Cognitive Assessment (MOCA, Nasreddine, Chertkow, Phillips, Whitehead, Collin, & Cummings, in press). The MOCA is a rapid screening tool designed to detect mild cognitive dysfunction; it assesses attention, concentration, executive function memory, language, visuoconstructional skills, conceptual thinking, calculations and orientation. All participants had normal or corrected-to-normal vision.

Control participants ranged in age from 60 to 85; their average age was 72 years. Their level of education ranged between 11 and 19 years; the average was 15 years. pAD participants ranged in age between 74 and 93; their average age was 81 years. Their level of education ranged between 7and 22 years; the average was 14 years. All pAD participants were taking acetylcholinesterase inhibitors at the time of testing (Aricept, Reminyl or Exelon). Dementia severity ranged from mild to moderate, and average score on the MMSE was 23. MCI participants ranged in age from 70 to 85; their average age was 76.5 years. Their level of education ranged between 7 and 17 years; the average was 11 years. Average MMSE score was 28. These participants were not being treated for their cognitive impairment at the time of testing. The pattern of impairments seen in each of the MCI participants is provided in Table XV. No type 3 (single non-memory domain) individuals with MCI were included in the participant pool; all but one had an objective memory impairment. With respect to language impairment, naming performance was below age- and education-matched norms in 3 of the 8 MCI participants. Given that a naming impairment is often seen early in the course of AD, it is unsurprising that MCI inidividuals would also exhibit such an impairment. Thus, impaired naming ability was not used as an exclusionary criterion for the study.

Table XV: Impairments in MCI participants

| | memory | visuospatial | executive function | naming |
|---|---|---|---|---|
| MCI1 | 2* | | | |
| MCI2 | 1 | | 2 | 2 |
| MCI3 | no objective deficit | | | |
| MCI4 | 2 | 1 | 1 | |
| MCI5 | 2 | | 2 | 2 |
| MCI6 | 2 | | | |
| MCI7 | 2 | | 2 | |
| MCI8 | 2 | | | 1.5 |

*numbers indicate standard deviations below the mean of age- and education-matched controls

Materials and Design.

Sets of 25 high-frequency and 25 low-frequency mass, count and dual nouns were matched for length, number of syllables and frequency using the Celex database (Baayen, Piepenbrock & Rijn, 1993), and for neighbourhood density, neighbourhood frequency, bigram frequency and bigram frequency by position, using data from the English lexicon project of Washington University in St. Louis (Balota et al., 2002). Ratings of familiarity, concreteness and imageability were taken from the MRC psycholinguistic database (Coltheart, 1981)[13]. High-frequency and low-frequency nouns were compared separately: no differences were found between the different groups, with the exception that high-

[13] 1 item was not present in the English lexicon database, and 17 items were not present in the MRC database. These items are indicated in the stimuli list in Appendix 2.

frequency dual nouns were found to be significantly more concrete than high-frequency count nouns.

Count and dual nouns were presented in both the singular and the plural. In order to avoid repetition priming effects, stimuli were divided into two lists, each of which contained either 12 or 13 critical stimuli from each category. Each list thus contained 125 critical stimuli, as well as 125 distractor stimuli (verbs and adjectives) and 250 phonotactically legal pseudowords. Critical stimuli and pseudowords were matched for length and number of syllables. Pseudowords were designed such that they were not neighbours of critical stimuli, in order to avoid priming effects, as have been demonstrated to occur by Forster (1998). Forty percent of pseudowords also contained a plural morpheme. This was designed to minimize strategic effects due to the plural morpheme being present on critical stimuli. Critical stimuli are provided in Appendix 1.

Procedure.

The experiment was run on a Macintosh i-Book computer using the application Psyscope 1.2.5. Stimuli were presented at the centre of a computer screen in black font on a white background and were randomized for each participant. Each item was preceded by a row of hashmarks that remained on the screen for 200 ms, and a pause of 150 ms. Participants were asked to perform a lexical decision on each stimulus. The experiment used a go/no-go paradigm; that is, subjects responded to word stimuli but not non-word stimuli. The purpose of using this paradigm was to render the task easier for pAD patients. The target word disappeared when the subject responded by pressing the space bar, and timeout was set to 2000 ms.

Each experimental session began with 24 practice trials, of which 12 were words and 12 were pseudowords. Verbal feedback was provided when necessary, and the practice trials were repeated up to three times, to ensure comprehension of the task. The instructions given to the participants are presented in Appendix 2.

Results

Erroneous responses were removed from data analysis, as were outliers, defined as any response more than 2.5 standard deviations above or below the mean, by subject and by category. Errors consituted 2.5% of total responses, and outliers constituted 3.3% of total responses. Average reaction times (RTs) and standard deviations by subject and by category are shown in Figures 4.1-4.3.

Figure 4.1: Control participants' results

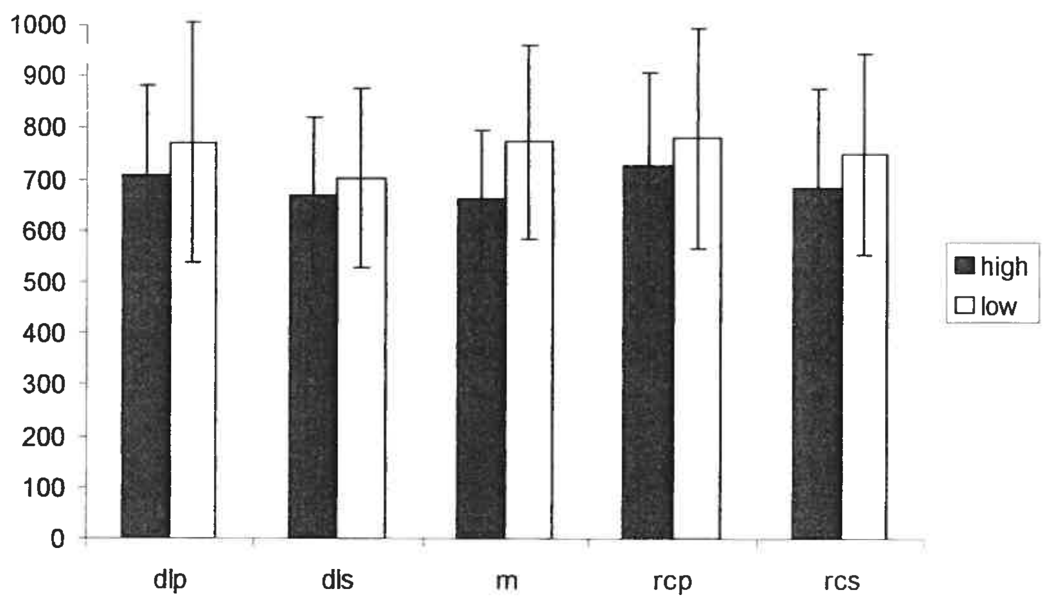


Figure 4.2: MCI participants' results

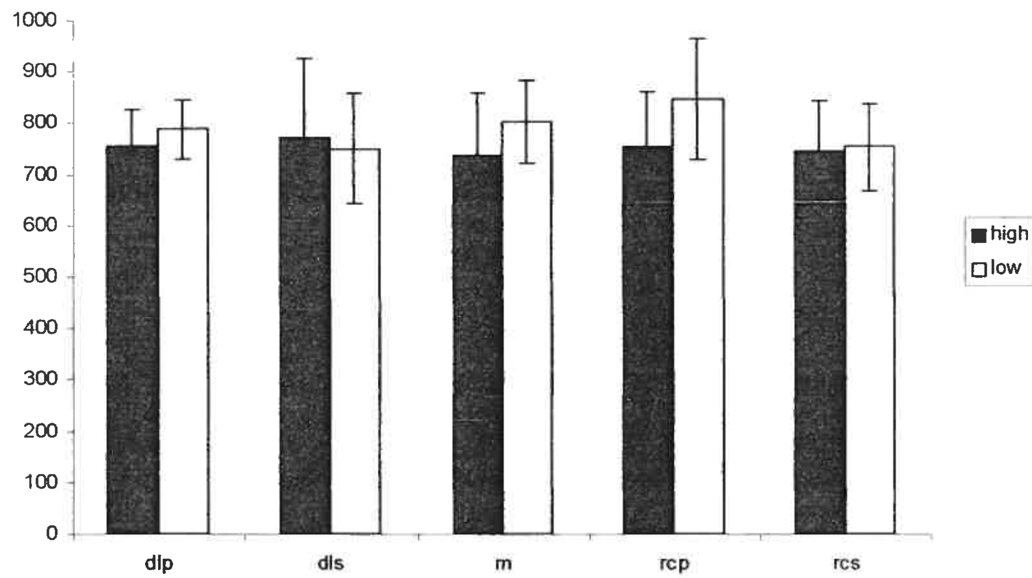
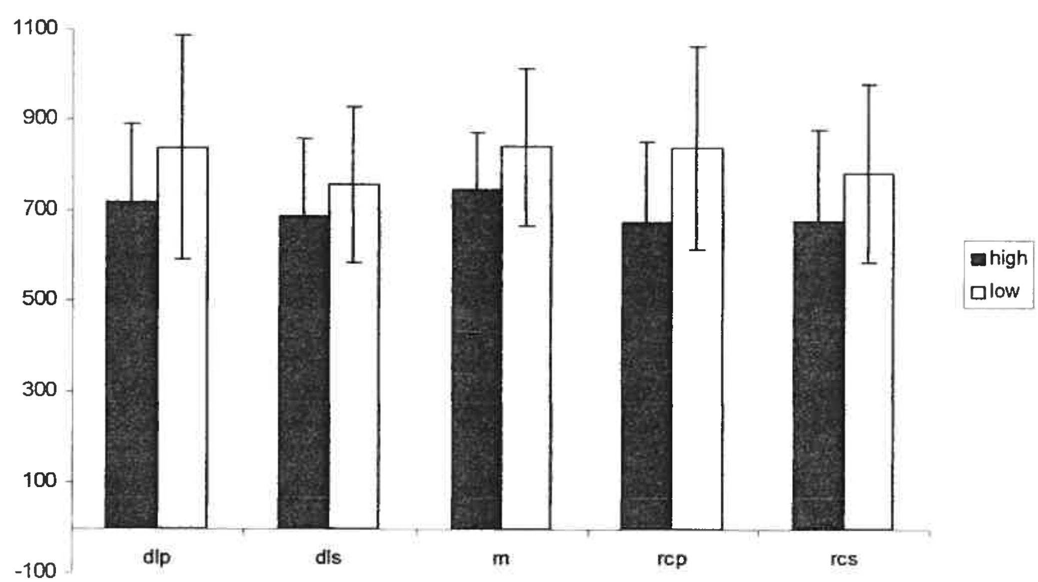



Figure 4.3: pAD participants' results




A 3x2x5 mixed model ANOVA with group (control vs MCI vs pAD) as a between-subject variable and frequency (high vs. low) and category (DLS vs DLP vs M vs RCS vs

RCP) as within-subject variables revealed significant effects of frequency ($F = 59.231$, $p<0.001$), where high frequency items were recognised more quickly than low frequency items and category ($F = 9.686$, $p<0.001$). An interaction between frequency and category ($F = 8.416$, $p<0.001$) was also observed. A series of least squares difference (LSD) post-hocs were conducted; significant effects in the category analysis and the frequency x category analysis are reported in Table XVI.

Table XVI: Significant post-hoc analyses, all stimuli

| | CATEGORY | | CATEGORY x FREQUENCY | |
|---|---|---|---|---|
| | F | p | F | p |
| dual plural vs. dual singular | 10.524 | ** | 5.164 | * |
| count plural vs count singular | 27.849 | *** | 4.419 | * |
| dual plural vs. count singular | 11.006 | ** | | |
| count plural vs dual singular | 26.738 | *** | 18.571 | *** |
| count plural vs. mass | 6.155 | * | 7.001 | * |
| dual singular vs mass | 15.582 | *** | 28.441 | *** |
| mass vs. count singular | | | 13.368 | *** |

* significant at <0.05 level

** significant at <0.01 level

*** significant at <0.001 level

Given that category effects were stronger in low-frequency items, a separate analysis of low frequency items was conducted. This analysis revealed a main effect of category (F =

18.446, $p<0.001$). Overall category effects for low frequency items are reported in Table XVII below; only significant effects are reported. As can be seen, singular nouns differed from plural nouns in all cases (RCS vs. RCP, DLS vs. DLP, RCS vs. DLP, DLS vs. RCP). In all cases, singular nouns were recognized more quickly than plural nouns. This is as expected, and indicates the increased cost of recognizing a plural morpheme. Furthermore, all three singular noun categories differed from one another: singular dual nouns were recognized more quickly than singular count nouns, which were recognized more quickly than mass nouns.

Table XVII: Significant post-hoc analyses, low-frequency stimuli

| | OVERALL | |
|---|---|---|
| | F | p |
| dual plural vs. dual singular | 16.607 | *** |
| count plural vs count singular | 29.675 | *** |
| dual plural vs. count singular | 8.397 | ** |
| count plural vs dual singular | 35.591 | *** |
| dual singular vs mass | 47.175 | *** |
| dual singular vs count singular | 5.150 | * |
| mass vs count singular | 27.976 | *** |

* significant at <0.05 level

** significant at <0.01 level

*** significant at <0.001 level

We then examined each subject group's performance on low frequency items individually. Given that three planned comparisons were conducted (one for each subject group), a Bonferroni correction was applied, meaning that $p<0.0167$ in order for an effect to be considered significant. One-way ANOVAs with category as a within-subject variable (DLS vs DLP vs M vs RCS vs RCP) revealed a main effect of category in all three subject groups (OCs: $F = 7.411$, $p<0.001$; MCIs: $F = 5.694$, $p < 0.01$; pADs: $F = 4.285$, $p < 0.01$). LSD post-hoc comparisons of each category are reported in Table XVIII.

Table XVIII: Significant post-hoc analyses, low frequency stimuli, by subject group

| | OCs | | MCIs | | ADs | |
|---|---|---|---|---|---|---|
| | F | p | F | p | F | p |
| dual plural vs. dual singular | 11.128 | ** | 2.105 | 0.19 | 5.718 | * |
| count plural vs count singular | 8.060 | * | 22.606 | ** | 4.179 | 0.08 |
| count plural vs dual singular | 29.706 | *** | 9.575 | * | 6.954 | * |
| dual singular vs mass | 36.819 | *** | 4.715 | 0.066 | 23.540 | ** |
| dual singular vs count singular | 10.297 | ** | 0.007 | 0.935 | 1.153 | 0.318 |
| mass vs count singular | 5.874 | * | 19.962 | ** | 7.282 | * |

* significant at <0.05 level

** significant at <0.01 level

*** significant at <0.001 level

As can be seen, control subjects manifested an effect of plurality, whereby they responded more slowly to plural than to singular nouns. They also manifested significantly different response times to singular nouns of different categories; specifically, they responded most quickly to dual nouns, then count nouns, and most slowly to mass nouns. pAD and MCI participants, on the other hand, manifested a different response pattern. The pAD group responded more quickly to count singular than to count plural nouns; this was also the case for dual nouns, where plurals were 82ms slower than singulars, although the effect missed significance (p=0.08). In the singular nouns, mass nouns were responded to more slowly than count or dual nouns, but no difference was seen between the latter two categories. MCI participants responded significantly more quickly to singular than to plural dual nouns. Again, this was also the case for count nouns, where plurals were 94ms slower than singulars, although this effect was also not significant. In the singular nouns, the MCI and pAD groups showed the same profile, where mass nouns were significantly slower than count or dual nouns, response times to which were almost identical (a difference of 2ms in the MCI group and 11ms in the pAD group).

Discussion

The results reported here shed light both on normal lexical processing of mass, count and dual nouns, and on the way in which this processing is affected in the case of pAD and MCI. Although overall latency is slightly longer in the pAD group than in the MCI group, and longer in the MCI than in the elderly control group, these effects did not reach significance, and the response patterns manifested by the two patient groups are almost identical. Furthermore, the results seen in pAD and MCI are informative with regard to the pattern of cognitive deficits seen in these patients.

Processing of noun categories in unimpaired speakers

Healthy elderly controls manifest a pattern that is consistent with the studies reported up to now in the literature. Stronger effects were found in low frequency than in high frequency nouns; this may be taken to reflect the fact that some effects may be attenuated or even washed out completely when lexical access proceeds extremely rapidly, as is the case for high frequency nouns. We turn now to a discussion of the effects found for low frequency stimuli.

The current study found that healthy elderly subjects recognized dual nouns more quickly than count nouns. This result is consistent with previous studies in the literature (Frazier & Rayner, 1990; Azuma and Van Orden, 1997; Klepousniotou, 2002) which have found faster RTs for polysemous nouns, of which dual nouns form a subgroup, although these have focused primarily on the comparison between polysemous and homonymous nouns (i.e., those with multiple senses and those with multiple meanings). These results suggest that, for healthy elderly speakers, only the basic sense of dual nouns is stored in the lexicon, and extended (mass and count) senses are computed on-line, when context is present. In the case of plural dual nouns, the count interpretation must be selected, due to the presence of a plural morpheme. Thus the plural morpheme may be taken to represent context, albeit within a single word, as opposed to sentential context.

The fact that count nouns and dual nouns manifest different RTs is problematic for Gillon et al's (1999) claim that mass nouns contain a feature [M] which slows recognition for mass but not count nouns. This claim implies that no mass/count information is contained in the lexical entry for count nouns, and as such, no significant difference would be predicted for dual and count nouns, both of which require no computation of mass/count information. That access to dual nouns is faster than access to count nouns for healthy elderly controls suggests that some extra information is accessed when a count noun is recognised. One possible way to account for this result would be to follow underspecification theory (Steriade, 1995). Although this theory was developed to account for phonological effects, the principles translate elegantly to other featural accounts, such as the one put forward here.

The effects observed here can be accounted for as follows. We posit that mass nouns have a node [countability] ([C]) which is specified as mass ([M]). Count nouns also possess the node [C], but the node is underspecified (i.e., bare). In the case of plural count nouns, the [C] node is specified for plural: that is, the feature [plural] is dominated by the [C] node. Dual nouns have no [C] node; since this results in an ill-formed surface structure, this node and all its dependents are specified at the surface level (that is, in context) according to a rule which we term countability by context. This rule allows for the mass and count readings of dual nouns, since the determiner specifying the noun as mass or count must have a [C] node, which is spread to the dual noun's representation. The countability by context rule can be seen as a specification of the lexical rule postulated by Klepousniotou (2002) that operates on the dual noun when its sense is computed on-line.

Since count and mass nouns do not meet the specifications for the countability by context rule, they do not undergo this rule. Crucially, according to standard underspecification theory, such rules are feature-filling but not feature-changing. That is, features can be filled in through spreading, as in the case of a dual noun being specified as mass or count, but they cannot be changed if already present, so, for example, the countability node from the determiner much cannot be spread to a count noun. Representations of the different noun categories under this analysis are shown in Figure 4.4; the rule countability by context is illustrated in Figure 4.5.

Figure 4.4: Lexical representations of mass, count and dual nouns

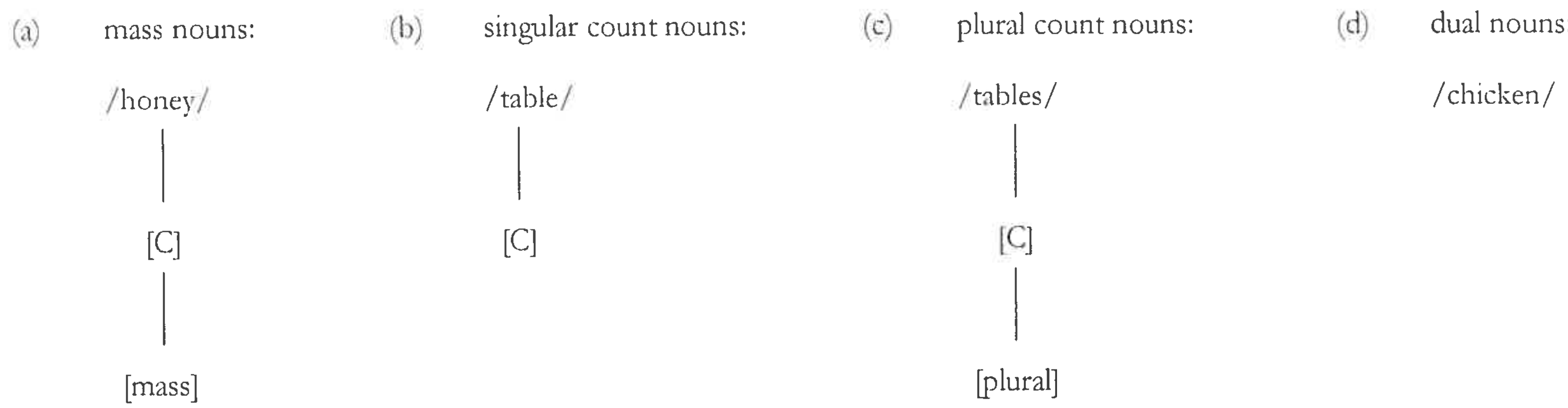
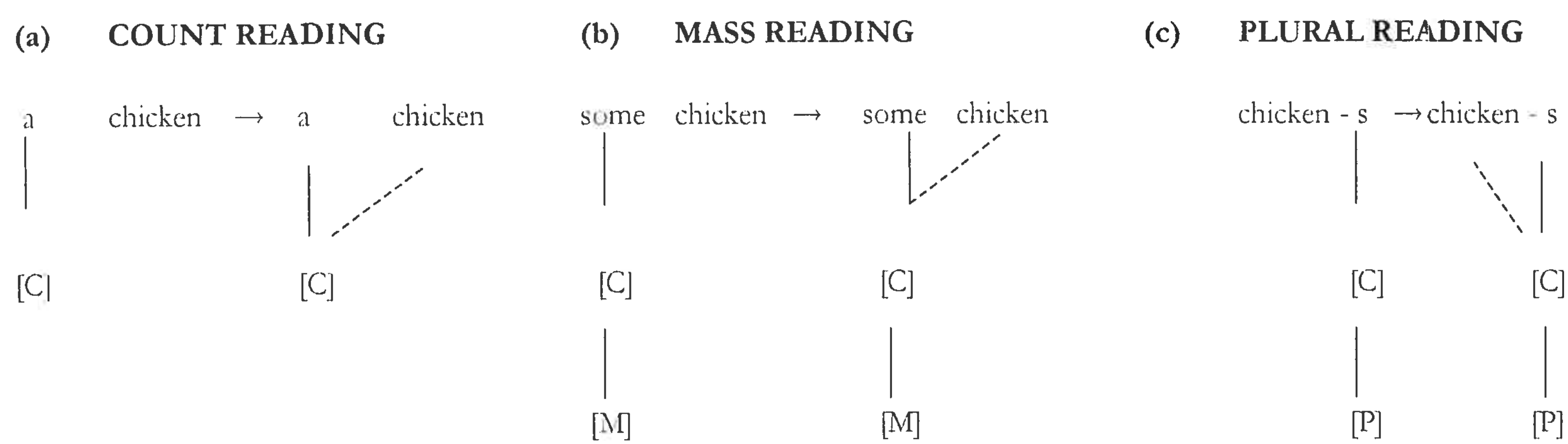


Figure 4.5: Application of the lexical rule <u>countability by context</u>



For example, consider the sentences below:

1a. John saw a chicken.

1b. John ate some chicken.

1c. John chased the chickens.

As illustrated in Figure 4.5, the lexical rule countability by context will apply in all these cases. In the sentence illustrated in 1(a), the determiner a contains the information that the noun is a count noun; that is, the countability node is present in the lexical entry of this item. When the sentence is processed on-line, the reader/listener extracts this information from the determiner in order to identify the noun chicken as a count noun. This is expressed formally as spreading of the countability node from the determiner to the noun. Similarly, the countability node in sentence 1(b) is spread from the determiner some, which is specified as mass, to the noun chicken. Finally, in sentence 1(c), the plural morpheme "s" contains a countability node which is specified as plural; spreading of this node allows identification of the noun chicken as count plural.

This account is in contrast to that espoused by Copestake and Briscoe (1995), who posit a series of probabilistic lexical rules which convert count nouns to mass nouns or vice versa. For example, the "grinding" rule converts animals to meat, so the count reading is taken to be the default reading of these items. The "portioning" rule, on the other hand, converts substances to portions thereof, so the mass reading is taken to be the default. Under this account, all nouns are either mass or count, and may be converted on-line. This cannot account for the finding that dual nouns are recognized more quickly than mass or count nouns: those with a default count reading should be treated as count out of context, and those with a default mass reading should be treated as mass out of context.

Breakdown in AD

In the case of the pAD patients, a different pattern of results is seen. In low frequency stimuli, these participants manifest shorter RTs to count nouns than to mass nouns, whereas no significant difference is seen between count and dual nouns. That is, it appears that pAD patients are processing dual nouns in the same fashion as count nouns. As argued in section 4.1, the healthy elderly control subjects' results suggest that access to the lexical entries for both mass and count nouns require the computation of the node [C], whereas the lexical entries for dual nouns do not require such computation. Straightforward processing of dual nouns as count nouns, which would require the addition of the node [C] to dual nouns' lexical entry, seems unlikely in this case.

Another possibility is that the [C] node is lost from the count nouns' lexical entry, meaning that count nouns are being processed as dual rather than vice versa. However, in our previous research (Taler & Jarema, 2004), we found that pAD and MCI patients had difficulty interpreting the mass reading of a dual noun in an off-line sentence-picture matching task. Errors consisted almost exclusively of selecting the count reading when the mass reading was correct. It appears that this pattern was not due to higher frequency of count nouns than of mass nouns, since in an off-line rating task unimpaired speakers rated the mass reading as being more frequent than the count reading for all but one of the exemplars. Furthermore, the majority of patients exhibited no impairment in a sentence grammaticality judgement task in which sentences ended with determiner-noun pairs that varied in terms of grammaticality, where the sentence-final noun was either mass or count. That is, they did not have difficulty processing the mass/count information contained in a given determiner and performing feature-matching between determiners and nouns in the case of mass and count nouns.

The results found by Taler & Jarema (2004) discount the possibility that pAD subjects process dual nouns as count. First, if the results seen in the present experiment reflected a disruption in the lexical entries for count nouns, then one would expect normal performance in dual nouns; thus, the performance seen in our previous research would have to be taken as reflecting a separate deficit. Second, if pAD patients exhibit disrupted processing of count nouns in a lexical decision task, it seems unlikely that they would exhibit control-like performance in a sentence grammaticality task using the same type of stimuli. Thus, a disruption in representation of information about count nouns is not the most parsimonious account for the data.

It seems clear, therefore, that the problem lies at the level of dual nouns, and that the representation of the feature [M] is intact in the lexical entries for mass and count nouns. The results from both previous off-line studies and the on-line study reported here indicate that pAD patients are interpreting dual nouns as count. We suggest that pAD patients are lacking the <u>countability by context</u> rule. Thus, they cannot fully specify underlying duals (that is, representations with no [C] node) in the normal way. The illicit representation is thus repaired by adding the minimal structure necessary to render the representation licit. This minimal structure takes the form of a bare [C] node; the noun is thus interpreted as count because, as proposed in section 4.1, it is precisely the (singular) count nouns that possess an underspecified, or bare [C] node. This interpretation proceeds regardless of context, accounting for pAD patients' interpretation of dual nouns as count even when they were seen in a context that forced a mass reading, as was the case in the sentence-picture matching task reported in Taler & Jarema (2004).

Breakdown in MCI

The pattern of results seen in the MCI group is strikingly similar to that of the pAD group. While no significant effects are seen in the high frequency stimuli, performance on the low frequency stimuli parallels closely that of pAD patients. That is, mass nouns are recognised more slowly than both count and dual nouns, and no significant differences are seen between these two categories. Although average latency is 23ms shorter in the low frequency stimuli for MCI than for pAD participants, this effect did not reach significance. This pattern of results mirrors the results found in our previous research (Taler & Jarema, 2004), where pAD and MCI patients were found to manifest qualitatively and quantitatively identical impairments in the interpretation of dual nouns. We thus postulate that the impairment seen in this patient group is the same as that seen in the pAD group; that is, these patients lack the countability by context rule and assign minimal structure (a countability node) to dual nouns when processing them. Thus, at least in the case of the task and stimuli used here, the cognitive impairment seen in MCI is identical to that seen in pAD.

One caveat to the claim that the impairment on the current task seen in MCI is identical to that seen in pAD is that the sample sizes are small (n = 8 in both groups). Given that the average latency to low frequency items was 23ms shorter in the MCI group than in the pAD group, it seems likely that larger sample sizes would indeed yield a significant difference in overall latency between the two groups. This result would mean that the task described in the present paper provides both a qualitative measure of impairment (response pattern) and a quantitative measure of impairment (overall latency).[14]

Conclusions

The present study has focused on one particular aspect of lexical processing, the processing of mass, count and metonymic (dual) nouns, and has demonstrated alterations in processing in the presence of pAD and MCI. We have shown that these alterations occur even in the case of mild cognitive deficits. That is, pAD and MCI subjects exhibit the same pattern of results. Thus, while these subtle impairments in processing may not provide insight into the progress of the disease, they do provide an early index of the presence of cognitive impairment.

The contribution of the present study is thus twofold. First, on a theoretical psycholinguistic level, it provides insight into the way in which the lexicon is structured and how it may break down in neurodegenerative disease. The results reported here provide evidence for a three-way distinction between mass, count and dual nouns in terms of representation. The representation and/or processing of dual nouns has been demonstrated to be altered in pAD and MCI, in contrast to other patient groups, such as those who have suffered focal left or right hemisphere damage (Klepousniotou & Baum, 2003). The lexical rule which allows specification of dual nouns as mass or count in

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[14] Note, however, that the 23ms difference may be related to variability in transmission time from the key response.

postulated in the case of pAD and MCI. Thus, a psycholinguistic model of the processing and representation of these noun types is provided, both in the case of unimpaired speakers and in the case of neurodegenerative disease.

Second, on a clinical level, the present study allows elucidation of the nature of the linguistic deficit in MCI. The fact that MCI and pAD patients manifest similar response patterns in the task reported here lends support to the theory that in many cases MCI represents an early stage of AD. Furthermore, the identification of subtle processing deficits that are detectable in behavioural measures and that manifest early in the disease course provides a step towards the development of a tool for early diagnosis of AD, one of the major goals of research on AD and MCI.

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References

Ahrens, K. & Swinney, D. (1995). Participant roles and the processing of verbs during sentence comprehension. Journal of Psycholinguistic Research, 23, 534-547.

Azuma, T., & Van Orden, G. (1997). Why SAFE is better than FAST: The relatedness of a word's meanings affects lexical decision times. Journal of Memory and Language, 36, 484-504.

Baayen, R.H., Piepenbrock, R., & Rijn, H. van (1993). The CELEX Lexical Database (Release 1) [CD-ROM]. Philadelphia, PA: Linguistic Data Consortium, University of Pennsylvania [Distributor].

Balota, D.A., Cortese, M.J., Hutchison, K.A., Neely, J.H., Nelson, D., Simpson, G.B., & Treiman, R. (2002). The English Lexicon Project: A web-based repository of descriptive and behavioral measures for 40,481 English words and nonwords [Electronic database]. Washington University.

Bayles, K. (1982). Language function in senile dementia. Brain and Language, 16, 265-280.

Caramelli, P, Mansur, L.L., & Nitrini, R. (1998). Language and communication disorders in dementia of the Alzheimer's type. In Stemmer, B. and Whitaker, H. (Eds.) Handbook of Neurolinguistics (pp.463-473) San Diego: Academic Press.

Chan, A., Salmon, D., & De La Pena, J. (2001). Abnormal semantic network for "animals" but not "tools" in patients with AD. Cortex, 37(2), 197-217.

Chenery, H., Ingram, J., & Murdoch, B. (1998). The resolution of lexical ambiguity with reference to context in dementia of the Alzheimer's type. International Journal of Language and Communication Disorders, 33(4), 393-412.

Chertkow, H. (2002). Mild cognitive impairment. Current Opinion in Neurology, 15, 401-407.

Coltheart, M. (1981). The MRC Psycholinguistic Database. Quarterly Journal of Experimental Psychology, 33, 497-505.

Copestake, A. & Briscoe, T. (1995). Semi-productive polysemy and sense extension. Journal of Semantics, 12, 15-67.

Cruse, D.A. (1986) Lexical Semantics. Cambridge, U.K.: Cambridge University Press.

Cummings, J., Benson, D., Hill, M., & Read, S. (1985). Aphasia in dementia of the Alzheimer's type. Neurology, 35, 394-397.

Emery, V. (1996). Language Functioning. In R. Morris (Ed.) The Cognitive Neuropsychology of Alzheimer-Type Dementia (pp. 166-192) Oxford: Oxford University Press.

Folstein, M. J., Folstein, S.E., & McHugh, P.R. (1975). Mini-mental state: a practical method for grading the cognitive state of the patients for the clinician. Journal of Psychiatric Research, 12, 189-198.

Forster, K. (1998). The pros and cons of masked priming. Journal of Psycholinguistic Research, 27(2), 203-233.

Frazier, L., & Rayner, K. (1990). Taking on semantic commitments: Processing multiple meanings vs. multiple senses. Journal of Memory and Language, 28, 181-200.

Fung, T., Chertkow, H., Murtha, S., Whatmough, C., Peloquin, L., Whitehead, V., & Templeman, F. (2001). The spectrum of category effects in object and action knowledge in dementia of the Alzheimer's type. Neuropsychology, 15(3), 371-379.

Gillon, B. (1999). The lexical semantics of English mass and count nouns. In E. Viegas (Ed.) Breadth and Depth of Semantic Lexicons. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Gillon, B., Kehayia, E., & Taler, V. (1999). The mass/count distinction: Evidence from on-line psycholinguistic performance. Brain and Language, 68(1-2), 205-211.

Grossman, M., Carvell, S., & Peltzer, L. (1993). The sum and substance of it: The appreciation of mass and count quantifiers in Parkinson's disease. Brain and Language, 44, 351-384.

Grossman, M., Mickanin, J., Onishi, K., & Hughes, E. (1995). An aspect of sentence processing in Alzheimer's disease: Quantifier-noun agreement. Neurology, 45, 85-91.

Hodges, J.R., Salmon, D.P., & Butters, N. (1992). Semantic memory impairment in Alzheimer's disease: Failure of access or degraded knowledge? Neuropsychologia, 30, 301-314.

Irigaray, L. (1973). Le langage des dements. The Hague: Mouton.

Jack, C., Petersen, R., Xu, Y., O'Brien, P., Smith, G., Ivnik, R., Boeve, B., Waring, S., Tangalos, E., & Kokmen, E. (1999). Prediction of AD with MRI-based hippocampal volume in mild cognitive impairment. Neurology, 52, 1397-1403.

Kempen, G., & Huijbers, P. (1983). The lexicalization process in sentence production and naming: Indirect election of words. Cognition, 14, 185-209.

Kempson, R.M. (1977). Semantic theory. Cambridge, U.K.: Cambridge University Press.

Klepousniotou, E. (2002). The processing of lexical ambiguity: Homonymy and polysemy in the mental lexicon. Brain and Language, 81, 205-223.

Klepousniotou, E., & Baum, S. (2003). Processing homonymous and polysemous words: The effects of focal left- and right-hemisphere damage. Presented at the Academy of Aphasia annual meeting, Vienna, Austria.

Laudanna, A., Badecker, W., & Caramazza, A. (1992). Processing inflectional and derivational morphology. Journal of Memory and Language, 31, 333–348.

Laurent, B., & Thomas Antérion, C. (2002). Incertitudes et limites du MCI: apport de la neuropsychologie. Revue Neurologique, 158(10), 5S11-5S20.

Lyons, J. (1977). Semantics (Vol.2). Cambridge, U.K.: Cambridge University Press.

McKhann, G., Drachman, D., Folstein, M., Katzman, R., Price D., & Stadlan, E.M. (1984). Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRDA work group under the auspices of Health and Human Services Task Force on Alzheimer's Disease. Neurology, 34, 939-944.

Montanes, P., Goldblum, M., & Boller, F. (1995). The naming impairment in living and non-living items in AD. Journal of the International Neuropsychological Society, 1(1), 39-48.

Murdoch, B., Chenery, H., Wilks, V., & Boyle, R. (1987). Language disorders in dementia of the Alzheimer type. Brain and Language, 31, 122-137.

Nasreddine, Z.S., Chertkow, H., Phillips, N.A., Whitehead, V., Collin, I., & Cummings, J.L. (in press). The Montreal Cognitive Assessment (MoCA): A brief screening tool for mild cognitive impairment. Journal of the American Geriatric Society.

Nebes, R.D., & Brady, C.B. (1991). The effect of contextual constraint on semantic judgments by Alzheimer patients. Cortex, 27, 237-246.

Petersen, R. (2003). Mild Cognitive Impairment: Aging to Alzheimer's Disease. New York: Oxford University Press.

Petersen, R., Smith, G., Waring, S., Ivnik, R., Tangalos, E., & Kokmen, E. (1999). Mild cognitive impairment: Conceptual basis and current nosological status. Lancet, 355, 225-228.

Pustejovsky, J. (1995). The generative lexicon. Cambridge, MA: MIT Press.

Sarter, M., & Bruno, J.P. (2004). Developmental origins of the age-related decline in cortical cholinergic function and associated cognitive abilities. Neurobiology of Aging, 25(9), 1137-1149.

Semenza, C., Mondini, S., & Cappelletti, M. (1997). The grammatical properties of mass nouns: An aphasia case study. Neuropsychologia, 35(5), 669-675.

Shapiro, L., Zurif, E., Carey, S., & Grossman, M. (1989). Comprehension of lexical subcategory distinctions by aphasic patients: Proper/common and mass/count nouns. Journal of Speech and Hearing Research, 32, 481-488.

Smith, S., Chenery, H., & Murdoch, B. (1989). Semantic abilities in dementia of the Alzheimer type. 2. Grammatical semantics. Brain and Language, 36, 533-542.

Smith, S., Murdoch, B., & Chenery, H. (1989). Semantic abilities in dementia of the Alzheimer type. 1. Lexical semantics. Brain and Language, 36, 314-324.

Steriade, D. (1995). Markedness and underspecification in the study of segments. In J. Goldsmith (Ed.) A Handbook of Phonological Theory. Cambridge, MA and Oxford, UK: Blackwell.

Taft, M., & Forster, K. (1975). Lexical storage and retrieval of prefixed words. Journal of Verbal Learning and Verbal Behaviour, 14, 638–647.

Taler, V., & Jarema, G. (2004). Processing of mass/count information in Alzheimer's disease and mild cognitive impairment. Brain and Language, 90(1-3), 262-275.

Ullman, M., Corkin, S., Coppola, M., Hickok, G., Growdon, J., Koroshetz, W., & Pinker, S., (1997). A neural dissociation within language: Evidence that the mental dictionary is part of declarative memory, and that grammatical rules are processed by the procedural system. Journal of Cognitive Neuroscience, 9(2), 266-276.

Appendix 1: Critical stimuli

| | dual nouns | mass nouns | count nouns |
|---|---|---|---|
| high frequency | brick | beauty | basket |
| | cake | butter | bell |
| | carpet | clay | belt |
| | chicken | cloth | blanket |
| | cloud | corn | bowl |
| | coal | cotton | button |
| | crime | cream | cabin |
| | debt | damage | castle[c,i] |
| | fibre[*]† | dirt | cat |
| | fur | dust | clock |
| | lamb | flesh | cousin |
| | lawn | fruit | cow |
| | pipe | honey | crowd |
| | prayer | metal | daisy |
| | rope | paint | doll |
| | salad | plastic† | elbow |
| | shadow | rice | engine |
| | shell | sand | fence |
| | stone | silk | fist† |
| | string | snow | lake |
| | talent | soap | lamp |
| | taste | spite | planet |
| | virtue | sugar | skirt |
| | wire | sweat | sofa |
| | wonder | traffic | ticket |
| low frequency | beet | beef | apron[c] |
| | cabbage | carbon | badge |
| | cable | cement | barn |
| | candy | chalk | beetle |
| | cane | copper | blouse |
| | cedar | denim† | couch |
| | cork | diesel† | cradle |
| | dessert† | fabric | crater† |
| | elm | filth | dime |
| | fog | fluid† | ditch |
| | ham | garlic | donkey† |
| | lobster | gravel | dragon[c,i] |
| | maple | grease† | eagle |
| | onion | ink | flag |
| | pastry† | liquor | fountain |
| | pasture | manure | guitar[c,i] |
| | pepper | mustard | helmet |
| | pumpkin† | parsley† | medal |
| | ribbon | plaster† | needle |

| | | | |
|---|---|---|---|
| | steak | pollen | pebble[c] |
| | thread | pork | pony |
| | treasure† | satin | swan† |
| | turkey† | sulphur | tractor |
| | verse | veal | wand |
| | walnut | wax | wolf |

[*] indicates that the item was not present in the English Lexicon Database norms.

†indicates that the item was not present in the MRC psycholinguistic database.

[c] indicates that concreteness norms were not available for this item.

[i] indicates that imageability norms were not available for this item.

Appendix 2: Instructions to participants

The following instructions were provided to participants prior to the practice session of the experiment:

A string of letters will appear on the screen. If this string of letters is a word in English, press the space bar. If it is not, wait for the string to disappear. You will have a practice session, after you which you can ask the tester any questions you may have.

# Chapter 5 (Study 4): Semantic and syntactic aspects of the mass/count distinction

Vanessa Taler[1,2] and Gonia Jarema[1,2,3]

[1]Research Centre, Institut Universitaire de Gériatrie de Montréal, Montreal, Canada

[2]Department of Biomedical Sciences, University of Montreal, Montreal, Canada

[3]Department of Linguistics, University of Montreal, Montreal, Canada

(currently under revision)

Abstract

One participant diagnosed with semantic dementia, one participant diagnosed with agrammatic aphasia and a group of healthy elderly control participants performed a sentence grammaticality judgement task and a sentence-picture matching task, aimed at assessing their processing of the syntactic and semantic information contained in the lexical entries of nouns varying in terms of their mass/count status. The agrammatic participant was impaired in both tasks, while the semantic dementia patient was impaired only in the latter task. It is postulated that semantic processing of these nouns requires access to syntactic information, and that both types of information must be available for successful on-line processing.

(103 words)

Keywords: semantic dementia, agrammatism, metonymy, mass/count distinction

Nouns in the English language may be classified as common nouns, proper names or pronouns. Common nouns may be further subdivided into two categories: mass nouns (e.g., sand) and count nouns (e.g., table). These nouns can be distinguished according to syntactic criteria: count nouns can be pluralized (tables), they may take the indefinite article (a table), they take quantifiers that denumerate (many tables), but not quantifiers that do not denumerate (*much table), and they may be modified by a cardinal numeral (four tables). Mass nouns, on the other hand, cannot be pluralized (*sands), cannot take the indefinite article (*a sand), take quantifiers that do not denumerate, but not those that do (much sand, *many sands), and may not be modified by cardinal numerals (*four sands).

There also exist nouns in English which may take either a mass or a count reading (e.g., chicken). These nouns may be pluralized (chickens), may take the indefinite article (a chicken), may take both quantifiers that denumerate and those that do not (much chicken, many chickens) and may be modified by a cardinal numeral (four chickens). Following Gillon (1999), we refer to these nouns as "dual". Duality constitutes a variety of polysemy, whereby a lexical item possesses multiple related senses. This is in contrast to homonymy, a variety of lexical ambiguity where the lexical item possesses multiple unrelated meanings (e.g., bank meaning 'the side of a river' or 'a financial institution'). Polysemy may be either metaphorical, where the two senses of the word are metaphorically related (e.g. eye meaning 'an organ of the body' or 'the opening at the top of a needle'), or metonymic, if the two senses are both literal. This latter distinction applies in the case of dual nouns, which are metonymic polysemous items with a mass/count extension.

Although mass and count nouns can be distinguished on the basis of syntactic criteria, they also vary according to semantic criteria; that is, mass nouns represent 'stuff', whereas count nouns represent 'things'. It has been claimed that the distinction between mass and count nouns is determined by the way in which language users conceptualize the outside world (e.g., Wierzbicka, 1991; Jackendoff, 1992). Under this view, count nouns are conceptualized in an 'individuated' fashion; that is, they are perceived as individual entities. Mass nouns, on the other hand, are conceptualized in an 'unindividuated' manner. Thus, the mass/count distinction is seen as a conceptual-semantic distinction, rather than a grammatical one.

Joosten (2003) points out some difficulties with this account of the mass-count distinction. First, this account appears in some instances to be somewhat ad hoc. There is no a priori reason that spaghetti should be a mass noun in English and a plural count noun in Italian, for example. Second, this view does not account for the alternation between mass and count that is seen in many nouns, in English as well as other languages. It is clear that such an alternation occurs in the case of dual nouns; however, it may also occur for nouns that are considered purely mass or count. This phenomenon is well illustrated by Pelletier's (1979) thought experiment, referred to as the "universal grinder". This machine could grind any object such that an individual entity (such as 'man') could become an unindividuated mass. Thus, a sentence such as "There's man all over the floor" could become grammatical.

This leads to a third possible account of the mass/count distinction: the contextual view. Under this view, countability is a feature not of nouns, but of noun phrases (Allan, 1980). While this elegantly accounts for the mass/count alterations of many nouns, certain objections may nonetheless be raised (Joosten, 2003). First, not all nouns can be used in mass noun phrases (NPs). Second, certain NPs are neutral with regard to countability (e.g., that chicken). And third, the contextual view cannot account for the fact that most nouns favour either a mass or a count reading.

In view of the evident problems with the different accounts of the mass/count distinction put forward in the literature, Joosten (2003) posits that this distinction must be viewed as a multidimensional phenomenon, and that a number of criteria must be taken into account when analyzing it. First, it must be recognized that there is a connection between countability and reality: for example, entities such as porridge and rain are harder to individuate than other entities such as tree. One must take into account language users' conceptualization of this reality. Second, countability must be recognized as primarily a feature of NPs rather that the nouns themselves, although nouns may favour (i.e., be more likely to appear in) a mass or a count NP. Third, any mismatch between reality and conceptualization may or may not be motivated. It must be recalled that arbitrariness is a feature of all languages.

A number of studies of processing of mass, count and dual nouns, with both impaired and unimpaired populations, are reported in the literature. Gillon, Kehayia & Taler (1999) examined processing of a number of noun types in a healthy young population, using a simple and a primed lexical decision task. Category differences were found between mass and count nouns. Specifically, mass nouns were found to yield longer reaction times (RTs) than did count nouns in the simple lexical decision task. In the primed lexical decision task, participants were asked to make a decision on nouns which were preceded by a determiner with which they formed a grammatical or an ungrammatical combination (e.g., that table, *those table). Nouns which were primed with a determiner with which they formed a grammatical combination yielded shorter RTs than did nouns which were primed with a determiner with which they formed an ungrammatical combination. These results were interpreted to reflect the fact that the lexical entries of mass nouns contain a feature [mass], which must be accessed when the lexical item is recognized, thus slowing recognition. When a noun is preceded by a determiner, grammaticality is ascertained through a process of feature-matching. In the case of a mismatch, recognition is slowed.

Klepousniotou (2002) conducted a cross-modal sentence priming task with healthy young controls; targets were nouns exhibiting various types of lexical ambiguity. She found that metonymic nouns (e.g., turkey) exhibited shorter RTs and greater priming than did homonymous nouns (e.g., pen). This was taken to support the view that only the basic sense of metonymic nouns is stored in the lexicon, and that sense extensions are processed on-line using a lexical rule, as proposed by Copestake and Briscoe (1995) and Pustejovsky (1995). Similar results in previous studies support this claim: Frazier and Rayner (1990) found in a reading task that words with multiple senses yield shorter fixation times than do words with multiple meanings. Likewise, Azuma and Van Orden (1997) found that related ambiguous words were accessed faster than unrelated ambiguous words.

A number of studies with brain-damaged populations, both on-line and off-line, have also shed light on the processing and representation of mass and count nouns, as well as the breakdown in this processing. Shapiro, Zurif, Carey and Grossman (1989) used a sentence-picture matching task to examine whether fluent and non-fluent aphasic participants were able to distinguish between mass and count readings of ambiguous nouns, and found impaired performance in both participant groups. Stimuli included both homonymous items such as corn (meaning 'a type of vegetable' or 'a local hardening of epidermis') and metonymic items such as lamb (meaning the animal, or the meat of that animal). Taler and Jarema (2004) replicated the design of the Shapiro et al. (1989) study, but used only metonymic terms. They examined performance by participants suffering from Alzheimer's disease (AD) and mild cognitive impairment (MCI), and found impaired performance on this task in both populations, although these participants were able to correctly judge the grammaticality of sentences containing mass and count nouns. Grossman, Carvell and Peltzer (1993) and Grossman, Mickanin, Onishi and Hughes (1995) examined processing of mass and count terms in patients suffering from Parkinson's disease and AD, respectively. They used the same three tasks in the two studies: a sentence-picture matching task, a grammaticality judgement task and a sentence completion task. The goal of these tasks was to assess processing of the semantic and syntactic information contained in the determiners much and many; impairments were found in both populations. Finally, Semenza, Mondini and Cappelletti (1997) report on the case of an aphasic patient who exhibits a selective impairment for mass nouns across a variety of off-line tasks. Processing of count nouns was intact, and no other grammatical deficits were seen in this patient. This was interpreted as an impairment at the lemma level of lexical retrieval, indicating that specific grammatical rules stored at this level are independently represented and accessible.

On-line experiments examining processing of different noun categories in various populations have also revealed deficits. Taler and Jarema (submitted) had patients suffering from AD or MCI, as well as healthy elderly controls, participate in a simple lexical decision task using mass, count and dual nouns as targets. Differing patterns of results were seen in the patient and control populations. Specifically, healthy elderly controls manifested significantly longer RTs to count nouns than to dual nouns, whereas both patient populations manifested no significant difference in RT between these two categories, although longer RTs to mass nouns were seen in these groups. In combination with the results found in the off-line study described above (Taler & Jarema, 2004), this response pattern was taken to mean that AD and MCI patients treat dual nouns as count; that is, they have lost the mass reading of these items. This was claimed to be a result of the loss of the lexical rule attributing a mass or count reading to dual nouns in context, resulting in selection of the default (count) reading. The representations of mass, count and dual nouns, as well as the form of the lexical rule postulated by Taler & Jarema (2004) are illustrated in Figures 5.1 and 5.2.

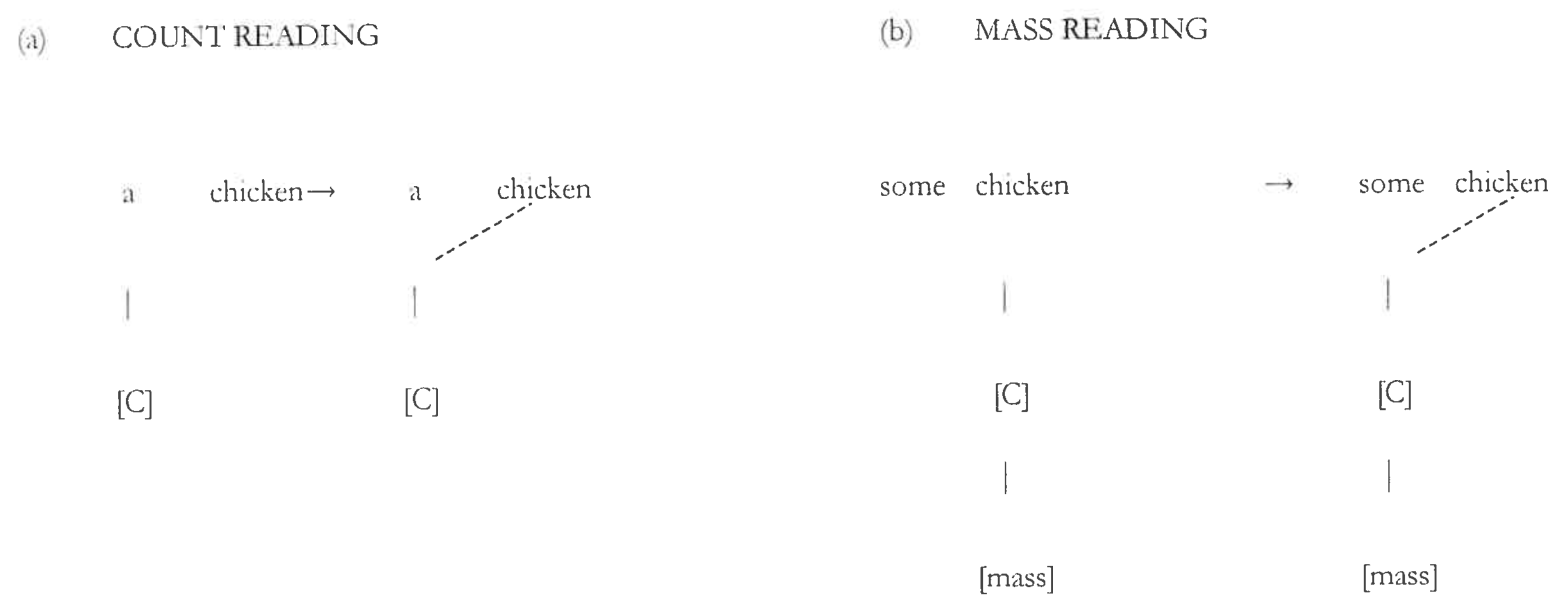
Figure 5.1: Representations of mass, count and dual nouns

(from Taler & Jarema, in press)

| (a) mass nouns | (b) singular count nouns | (c) plural count nouns | (d) dual nouns |
| --- | --- | --- | --- |
| /honey/ | /table/ | /tables/ | /chicken/ |
| \| | \| | \| | |
| [C] | [C] | [C] | |
| \| | | \| | |
| [mass] | | [plural] | |

Figure 5.2: Operation of the lexical rule <u>countability by context</u>

(from Taler & Jarema, in press)



Recently, Klepousniotou and Baum (2003) examined on-line processing of lexical ambiguity in left- and right-hemisphere damaged populations. They conducted a primed lexical decision task with homonymous items (e.g., pen), metonymic items (e.g., turkey) and items exhibiting metaphorical polysemy (e.g., eye) as primes, and varied inter-stimulus interval. The objective of this study was to examine the timecourse of activation of the different meanings of these ambiguous lexical items. They found that both primary and secondary meanings of metonymic lexical items were activated, and that this activation occurred irrespective of focal left or right hemisphere damage.

In sum, the results in the literature up to now lead to the following conclusions:

- mass/count information is represented in the lexicon and is processed on-line (Gillon et al., 1999);
- semantic and syntactic aspects of this information are separable (Grossman et al., 1993, 1995)
- focal brain damage may cause category-specific impairments, that is, loss of knowledge about mass nouns (Semenza et al., 1997);
- the lexical entries of dual (metonymic) nouns do not contain mass/count information (Klepousniotou, 2002);
- mass-count information is inserted on-line, according to context, by means of a lexical rule (Copestake & Briscoe, 1995; Pustejovsky, 1995, Klepousniotou, 2002);
- diffuse brain damage, as seen in AD, may alter processing of metonymic lexical items (Taler & Jarema, 2004, submitted); and

focal brain damage, whether in the right or the left hemisphere, does not appear to alter processing of these items (Klepousniotou & Baum, 2003; however, see Shapiro et al., 1989).

In the current paper we report an exploratory-descriptive study of performance on tasks designed to tap syntactic and semantic processing of mass and count nouns by one patient diagnosed with a pure semantic deficit and another diagnosed with a pure syntactic deficit (semantic dementia and agrammatic aphasia, respectively). The purpose of this study is to attempt to tease apart semantic and syntactic contributions to processing of mass, count and dual nouns. Given the diverse accounts in the theoretical linguistic literature claiming to capture the mass/count distinction, we believe that neurolinguistic evidence is crucial to disentangle this issue. The reasoning is as follows: if the mass/count distinction is represented in semantic terms (as claimed by, e.g,, Wierzbicka, 1991; Jackendoff, 1992), then a semantic deficit will have a greater impact on processing of these items than will a syntactic deficit. If, on the other hand, this distinction is in fact represented in syntactic terms (as claimed by, e.g., Bloomfield, 1933), then a syntactic deficit should have a greater impact on processing of these terms. If, as suggested by Joosten (2003), both semantic and syntactic factors play a role in the representation of mass/count information, then both deficits should affect processing of mass and count nouns.

Before turning to the experiments these individuals participated in, we offer a brief description of semantic dementia and agrammatic aphasia.

Semantic dementia (SD) is a recently described clinical syndrome, also known as fluent primary progressive aphasia[15]. Primary progressive aphasia (PPA) was first described by Mesulam (1982), who published a series of case descriptions of six patients who exhibited a progressive language impairment in the absence of other cognitive dysfunction. Patients exhibiting this disorder were universally found to suffer from anomia (word-finding difficulty); however, considerable variation was seen in terms of phonological, semantic and syntactic impairments. It was realized that a division into fluent and non-fluent subtypes yielded a more coherent picture of the disorder. Patients suffering from non-fluent PPA exhibit laboured, telegraphic speech, grammatical errors, phonological paraphasias, and impaired comprehension of syntax but spared comprehension of single words. That is, the profile of linguistic deficits is similar to that of Broca's aphasia. Atrophy is found to occur in the left perisylvian region, and disease progression is typically slow.

In the case of fluent PPA, on the other hand, fluent, grammatically correct speech is seen, but language tends to be empty of content words, and generic terms such as "stuff" may be inserted. Errors occasionally take the form of semantic paraphasias, and patients exhibit a progressive loss not only of the meaning of words, but also of the meaning of objects. This can be characterized as a specific impairment in semantic memory, or our shared world knowledge (Tulving, 1972). Episodic memory, or our store of knowledge about personally experienced events, is generally intact. Thus, the term

[15] Note that the term "semantic dementia" is defined by many researchers as referring to individuals with visual agnosia (for faces and objects) in combination with impaired word comprehension (Mummery, Pattersen, Wise, Vandenbergh et al., 1999; Snowden, 1999). Pronounced visual agnosia is incompatible with a diagnosis of PPA. However, in clinical practice individuals with fluent aphasia and impaired word comprehension are often diagnosed as suffering from SD (Mesulam, 2003).

"semantic dementia" was coined to describe this syndrome (Snowden, Goulding & Neary, 1989). Atrophy is found in the polar and infero-lateral temporal lobe; the left hemisphere is often more affected than the right (Garrard & Hodges, 1999).

Agrammatic aphasia is an acquired language disorder in which patients' speech is essentially devoid of free-standing and bound closed-class items. These patients typically speak slowly and effortfully; they exhibit difficulty in naming and in repetition, although comprehension can be relatively spared. This syndrome occurs after a focal brain injury such as a cerebrovascular accident, and left anterior lesions are typically seen, although there does exist variability in lesion localization (Vanier & Caplan, 1990).

A description of the participants in the present study is provided below.

Case descriptions

Semantic dementia patient.

J.H. is a 73-year-old English-speaking man with 18 years of education. He reported memory problems beginning in 1996, and was initially diagnosed with Alzheimer's disease in 1999. This diagnosis was subsequently modified to semantic dementia in 2001. Prior to onset of memory problems, he worked as a journalist and in publishing. J.H.'s performance in the current experiments has been reported previously (Taler, Jarema & Saumier, in press-a, in press-b).

Upon neuropsychological testing, J.H. was found to have intact working memory and executive function (attention/concentration, sequencing, shift of mental set, cognitive flexibility under pressure, non-verbal reasoning, figural and verbal fluency and verbal abstract reasoning). Likewise, reading, spelling and oral comprehension of instructions were found to be intact. However, naming was abnormal and a test of receptive language suggested semantic loss. Scores on standardized neuropsychological tests are given in Table XIX below.

Table XIX: J.H.'s scores on standardized neuropsychological tests.

| Test | Score | Percentile |
|---|---|---|
| Western Aphasia Battery – aphasia quotient (Kertesz, 1982) | 48.7/50 | |
| Boston Naming Test (Kaplan, Goodglass & Weintraub, 1983) | 29/60 | <10th |
| Controlled Oral Word Association (COWA), FAS (Benton & Hamsher, 1976) | 38 | 40th |
| COWA (animals) | 12 | <10th |
| Wide Range Achievement Test (WRAT), reading (Jastak & Wilkinson, 1984) | | 90th |
| WRAT (spelling) | | 91st |
| Wechsler Adult Intelligence Scale (WAIS), vocabulary (Wechsler, 1981) | | 63rd |
| WAIS, comprehension | | 63rd |
| letter/number sequencing | | 99th |
| spatial & digit spans | | 99th |

<u>Agrammatic aphasic patient.</u>

H.A[16]. is a 64-year-old ambidextrous English-speaking male with a master's degree in Education who, on October 10th, 1993, at the age of 53, suffered a left ischemic cerebrovascular accident. The lesion is localized in the left superior carotid artery. Initial testing revealed severe mixed aphasia with verbal apraxia. The subject demonstrated

[16] Note that H.A.'s performance in the current experiments has been reported previously (Taler, Jarema & Saumier, in press-b).

some yes-no responses to simple questions, but experienced difficulty with more complex material. Reading was impossible, and while the patient could perform letter matching, errors occurred due to impulsivity. Naming could not be done spontaneously, although the subject did demonstrate some naming capacity with maximal verbal cueing (i.e., both contextual and phonemic cueing). Generative naming (animals and FAS) could not be done, and resulted in hesitant behaviours and stereotyped words ("no", "and"). Automatic speech (e.g., counting to ten, reciting the days of the week) could only be done in unison, using rhythm. Communication was essentially gestural and non-verbal.

At the time of testing, H.A. exhibited functional auditory comprehension with simple familiar material, and partially functional auditory comprehension with complex information. He could follow 3 step instructions easily. Breakdown occurs with the increment on memory demands as well as with the morphosyntactic complexity of the commands. He was unable to complete the last 4 step command of the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1972), and obtained an overall score of 10/15 ($50^{th}$ percentile). H.A. exhibited severely impaired oral expression, with spontaneous speech limited to highly automatic responses such as "Hi, How are you, yes, no, fine, and I don't know". With maximal cueing (e.g., sentence completion or phonemic cueing), he could provide a one to two word answer to an open-ended question. He exhibited verbal and phonemic paraphasias. His reading comprehension was partially functional; he could read single words (30/30) and simple sentences (10/10), but exhibited difficulty with more complex written material (4/10). In functional terms, he was capable of understanding written information such as the headlines of a newspaper, a short note, or simple instructions. Finally, with respect to written expression, he exhibited severe agraphia, and was unable to write even material of a highly automatic nature (e.g., his name, age, alphabet etc.). H.A. was diagnosed with severe Broca's aphasia with severe verbal apraxia.

Control participants.

Ten healthy elderly participants served as controls in Experiment 1 (average age = 66.4, average education = 15.6), and twenty healthy elderly participants (average age = 61.4, average education = 14.5 years) served as controls in Experiment 2. All participants were native speakers of English with no history of neurological or psychiatric illness.

Experiment 1

In the first experiment, participants were required to categorize sentences as grammatical or ungrammatical. The purpose of this task was to determine whether J.H. and H.A. were able to process the mass/count information contained in the determiner and noun, and to perform feature matching between the two.

Stimuli.

Stimuli comprised seven sets of ten sentences, each ending in a determiner-noun combination. The seven groups of sentences were constructed as follows: ten grammatical and ten ungrammatical sentences ending in a count noun (e.g., grammatical: 'The little boy fed a swan', ungrammatical: *'The millionaire doesn't own much swan'); ten grammatical and ten ungrammatical sentences ending in a mass noun (e.g., grammatical: 'Florida doesn't get much snow', ungrammatical: *'James is clearing a snow'); ten ungrammatical sentences ending in a dual noun (e.g., * 'The sheep gave birth to two lamb'); ten grammatical sentences forcing a count reading of a dual noun (e.g., 'The farmer bought a lamb'); and ten grammatical sentences forcing a mass reading of a dual noun (e.g., 'My favourite food is lamb'). Stimuli are presented in Appendix 1.

Method.

Sentences were presented visually and read aloud by the examiner. Participants were asked to determine whether each sentence was acceptable in English or not. Examples of grammatical and ungrammatical sentences were given, where the ungrammaticality was not a result of determiner-noun mismatch, in order to ensure that participants understood that they were required to determine acceptability on the basis of syntax rather than semantics or plausibility. Participants were then tested on four practice items, two grammatical and two ungrammatical, where again ungrammaticality was not a result of determiner-noun mismatch. Sentences were presented in a pseudo-random order, and no feedback was provided on test sentences.

Results

Control participants performed near ceiling. Confidence intervals were calculated in order to determine whether patients exhibited impaired performance or not ($p<0.05$). J.H., the semantic dementia patient, exhibited ceiling performance in 5 of the seven categories and committed only one error in the remaining 2 categories. H.A., the agrammatic patient, exhibited control-like performance in four of the seven categories, and impaired performance in three categories: sentences ending in a grammatical determiner-mass noun combination, sentences ending in an ungrammatical determiner-mass noun combination, and sentences ending in an ungrammatical determiner-dual noun combination. In the mass grammatical category, he committed only one error. Results for control participants, J.H. and H.A. are shown in Table XX.

Table XX: Results, experiment 1

| Stimulus Type | count gram. | count ungram. | mass gram. | mass ungram. | dual (count reading) | dual (mass reading) | dual ungram. |
|---|---|---|---|---|---|---|---|
| Control mean | 9.8/10 | 9.7/10 | 10/10 | 8.8/10 | 10/10 | 9.9/10 | 9.4/10 |
| Control standard deviation | 0.42 | 0.42 | 0 | 1.14 | 0 | 0.32 | 0.97 |
| J.H | 10/10 | 9/10 | 9/10* | 7/10 | 9/10* | 9/10 | 9/10 |
| H.A. | 9/10 | 10/10 | 9/10* | 6/10* | 10/10 | 9/10 | 7/10* |

* indicates the score falls outside the 5% confidence interval for control subjects

Discussion

Both J.H. and H.A. committed one error in the mass grammatical condition, and J.H. committed one error in the dual grammatical (count reading) condition. Although these scores fall outside the confidence interval for control-like performance, this is due to the fact that controls committed no errors at all in these conditions. Nonetheless, a score of 9/10 is significantly better than chance performance and cannot be taken to reflect a deficit in this condition.

At first glance, H.A. and J.H's performances in the mass ungrammatical condition appears to reflect a grammatical deficit. However, it is clear upon examination that both patients as well as healthy elderly control participants are likely to sometimes accept these ungrammatical sentences; H.A. scored 6/10 in this category, J.H. 7/10 and elderly control participants scored only 8.8/10 on average.

In order to account for this result, one must consider the way in which the ungrammatical determiner-mass noun combinations were constructed. The mass noun was paired with a determiner which is grammatical in combination with a singular count noun (a, each, or every). Thus the sentence would be grammatical if the mass noun were interpreted as count. There are two factors that may render participants more likely to accept sentences of this type. First, mass nouns in English are interpretable as countable if the noun refers to a type of the mass noun (e.g., a cereal meaning a type of cereal) or a unit thereof (e.g., a sugar to mean a packet of sugar). Thus, participants may interpret sentences such as "The child was eating a cereal" to mean "The child was eating a type of cereal". Second, as noted above, the boundary between mass and count nouns is fluid, and nouns may move back and forth between these two categories. Thus, given a sentence where a mass noun must be interpreted as count if the sentence is to make sense, participants may force a count reading of the mass noun.

The remaining category in which H.A. showed an impairment is the dual ungrammatical category. In this category both J.H. and the elderly controls scored at or near ceiling (10/10 and 9.4/10, respectively). This suggests that H.A.'s impaired performance is not due to some property or characteristic of the noun category itself, but rather to a grammatical impairment. In order to account for this, we appeal to the representation of dual nouns postulated by Taler & Jarema (in press). Under this account, the lexical entries of dual nouns are assumed not to contain mass/count information: this information is inserted on-line by means of a lexical rule whereby the countability node of the determiner, containing mass/count and plurality information, is spread to the noun in question. Representations of mass, count and dual nouns as well as of the operation of this rule, termed countability by context, are illustrated in Figures 5.1 and 5.2 above. If the dual noun does not contain a plural morpheme (/s/), then the spreading of a countability node from a plural determiner is blocked, meaning that a combination such as *these turkey is rendered ungrammatical. In the present task, ungrammatical sentences ending in a singular dual noun were constructed in precisely this way, that is, using a determiner that forms a grammatical combination only with a plural noun (e.g., *'This year we didn't buy many turkey.')

Thus, we postulate that H.A.'s performance may be the result of an inability to make use of the lexical rule countability by context. There are two possible deficits that could account for the pattern of results seen here. First, the lexical rule may not be blocked by a mismatch in plurality between determiner and noun, meaning that H.A. accepts sentences with this type of violation as grammatical. Second, the rule may not be operative at all; that is, H.A. may not have access to information about the mass/count status of dual nouns. Thus, he accepts any determiner-dual noun combination as grammatical, since he detects no mismatch between the determiner and the noun. In the former case, one would predict unimpaired performance in interpreting mass and count readings of dual nouns, since the the lexical rule responsible for the spreading of mass/count information is still operative, albeit also in inappropriate contexts. In the latter case, one would expect that H.A. would be unable to distinguish between these two readings, since the rule is no longer operative, meaning that mass/count information cannot be spread to the dual noun. The following task aimed to answer this question, examining J.H. and H.A.'s capacity to match sentences forcing a mass or count reading of a dual noun to semantically appropriate pictures.

Experiment 2

In Experiment 2, participants were required to distinguish between mass and count readings of dual nouns by matching sentences containing dual nouns with a semantically appropriate picture. This task aimed to determine whether J.H. and H.A. were able to use both syntactic and semantic information to interpret dual nouns appropriately.

Stimuli.

Each stimulus comprised two pictures, one of the mass reading of a dual noun and one of the count reading of the same noun. Underneath the two pictures was a sentence of the form "Point to the picture of X" or "Point to the picture of an X". For example, a picture of a live chicken and a picture of chicken pieces on a plate were accompanied either by the sentence "Point to the picture of chicken" (requiring that participants select the mass reading of the dual noun) or "Point to the picture of a chicken" (requiring that participants select the count reading of the dual noun). Twenty-four stimuli were included in the test, and each was presented with both the mass and the count readings, for a total of 48 items. Items on which control participants committed an error were removed from the analysis. All 48 items were nonetheless presented to J.H. and H.A., in the interests of maintaining testing conditions as similar as possible for patients and control participants. A list of items, as well as a brief description of the accompanying pictures, is given in Appendix 2.

Method.

Sentences were presented visually and were also read aloud by the examiner. Participants were not provided with feedback during testing. Both mass and count readings of each noun were presented in the same experimental session; items were presented in a pseudo-random order.

Results

As in Taler and Jarema (2004) and Taler, Jarema and Saumier (in press-a), both readings of any item on which control participants did not perform at ceiling were removed from the analysis. Control participants committed errors on seven items, leaving both the mass and count readings of 17 lexical items remaining in the analysis. Scores were assigned out of 17, and participants had to correctly distinguish the mass and count readings of a given lexical item in order to receive a point for that item. Scoring was done in this way in order to ensure that participants were not simply selecting the picture they felt best represented the item in question, and pointing to that picture regardless of the presence or absence of a determiner.

H.A. scored 1/17 on this task, and J.H. scored 5/17. Paired t-tests revealed a significant difference between the control group's performance and that of both patients ($p<0.01$ in both cases).

Discussion.

Although both J.H. and H.A. exhibit impaired performance on this task, we postulate that the underlying reason for this performance differs for the two participants. Consider the demands of the task in question. First, the participant must process the syntactic information contained in the determiner, which is either a (in the case of a count reading) or a zero determiner (in the case of a mass reading). Second, the lexical rule countability by context must operate, such that this syntactic information is spread from the determiner to the dual noun. Third, the syntactic information now possessed by the dual noun must be processed semantically in order to allow the participant to distinguish between the mass and count interpretations of this noun in terms of real-world entities. Finally, the participant must match this semantic information with the pictures provided.

Recall the two possible deficits suggested above to account for H.A.'s performance. It could be the case that the presence of a plural morpheme does not block the operation of the lexical rule countability by context; if this is true, then one would predict an unimpaired ability to distinguish between the mass and count readings of these nouns. Alternatively, this lexical rule may not be operative at all, meaning that H.A. does not have access to information about the mass/count status of these nouns, and accepts plural determiner-singular dual noun combinations as grammatical simply because no mismatch is detected. In this case, we predict that this participant will be unable to distinguish between the two readings of these nouns. The results of Experiment 2, whereby H.A. was unable to correctly select the alternate readings of dual nouns, supports the latter interpretation. In the absence of mass/count information, we suggest that H.A. invariably selects the default interpretation of the dual noun, which is the count reading. J.H., on the other hand, was able to correctly judge as ungrammatical sentences ending with a plural determiner and a singular dual noun, indicating no syntactic impairment. This is as predicted, given that this participant exhibits a specific impairment in semantic memory. Nonetheless, he also manifested impaired performance in the sentence-picture matching task. This is best interpreted as an impairment in the capacity to access the semantic information contained in the determiner and/or to integrate this information with the syntactic information that is available to the patient.

## General discussion and conclusions

The present paper has aimed to tease apart syntactic and semantic aspects of the mass/count distinction. Although the distribution of mass and count nouns is best captured syntactically, linguists disagree on the best characterization of these items, and have proposed grammatical (syntactic), semantic and contextual accounts. Recently, Joosten (2003) put forward a series of criteria that must be taken into account when dealing with this distinction: countability and reality are connected (semantic aspects), countability is primarily a feature of NPs rather that the nouns themselves (contextual aspects), and any mismatch between reality and conceptualization may or may not be motivated. That is, all language is arbitrary to a certain extent. The goal of the current paper has thus been to examine the multidimensional nature of this distinction in terms of language processing and impairment, rather than from an exclusively theoretical viewpoint. To this end, patients suffering from a specific syntactic impairment (agrammatic aphasia) and a specific semantic impairment (semantic dementia) performed tasks designed to tap semantic and syntactic aspects of the mass/count distinction. It was found that these aspects are indeed dissociable on a performance level, and not just on a purely theoretical level.

The agrammatic patient, H.A., exhibited impaired performance on both the sentence grammaticality judgement task and the sentence-picture matching task. His impaired performance on the latter task was confined to dual nouns, that is, nouns which may take either a mass or a count reading. We postulate that he is unable to make use of the lexical rule countability by context (Taler & Jarema, in press), which spreads mass/count information contained in the sentence context. The mass/count information contained in the lexical entries of mass and count nouns appears to be intact, at least syntactically, although whether his ability to process this information semantically is affected remains an open question.

In the case of J.H., the semantic dementia patient, no impairment is seen in the ability to judge the grammaticality of sentences containing grammatical and ungrammatical determiner-noun combinations. However, this patient is unable to correctly match a sentence forcing the mass or count reading of a dual noun with a semantically appropriate picture. We interpret this as a deficit in the capacity to access the semantic information carried by the mass or count feature and/or an inability to successfully integrate syntactic and semantic information.

In sum, we have demonstrated that, in contrast to traditional linguistic approaches, both semantic and syntactic information are relevant to the characterization of the mass/count distinction. These aspects are dissociable; specific syntactic impairments lead to one pattern of performance, and specific semantic impairments to another. Nonetheless, both syntactic and semantic information are necessary for successful on-line processing of these terms. Specifically, it appears that in order to correctly process nouns in context, speakers must be able to: (a) access the syntactic information contained in the noun and/or the context; (b) apply the lexical rule <u>countability by context</u>, if necessary; (c) access the semantic information conveyed by the feature [mass]; and (d) integrate the semantic and syntactic information in order to correctly interpret the item in question. A deficit in any of these processes will result in language impairment. Furthermore, at least in the tasks described here, the semantics appears to follow from the syntax in the input. This is reflected in the performance of J.H. (specific damage to the semantic component results in impaired performance in semantic but not syntactic tasks) and H.A. (specific damage to the syntactic component results in impaired performance on both semantic and syntactic tasks). Psycholinguistic models must thus distinguish between these levels of representation, rather than focusing exclusively on one or the other.

Appendix 1: Sentences used in Experiment 1

Examples: The man is eating soup.

*The man has eating soup.

Practice: Harvey has a very long beard.

*They are go to the supermarket.

My brother is a policeman.

*Ingrid made spaghetti to dinner.

Trials:

Count grammatical

The cat is stalking a beetle.
The office sold every ticket.
The woman bought a needle.
The neighbour fed each cat.
The woman bought a lamp.
The soldier cleaned each medal.
The embassy is flying a flag.
The shirt is missing a button.
The baby likes every doll.
The little boy fed a swan.

Count ungrammatical

*The lizard kills much beetle.
*They didn't have much ticket.
*The seamstress wants a bit of needle.
*The baby doesn't like much cat.
*The house has a bit of lamp.
*He has earned a bit of medal.
*This shop doesn't have much flag.
*The drycleaner loses much button.
*The girl doesn't love much doll.
*The millionaire owns a bit of swan.

Mass grammatical

The meal included a bit of rice.
The child wants a bit of mustard.
Norman ate a bit of pork.
Kimberley never buys much cereal.
That ring doesn't contain much gold.
He asked for a bit of cheese.

Mass ungrammatical

*The children ate each rice.
*The boy spread every mustard.
*The waitress served a pork.
*The child is eating a cereal.
*The man polished each gold.
*The woman sliced a cheese.

Florida doesn't get much snow.
The store doesn't have much paint.
The tide didn't move much sand.
Jeremy doesn't each much jam.

*James is clearing a snow.
*The dog spilled a paint.
*Harry couldn't weigh every sand.
*He spread his toast with a jam.

Dual (count reading)

She was sitting under a cedar.
The loggers chopped down an oak.
For Thanksgiving my mom cooked a turkey.
Jennifer cut up an avocado.
The girl's ponytail is tied with a ribbon.
That patient really needs a liver.
The father carved a pumpkin.
The farmer bought a lamb.
In his soup he found a hair.
At the beach Kim saw a lobster.

Dual (mass reading)

Dad bought a sideboard made of cedar.
The chair is made of oak.
Beef has more fat than turkey.
Guacamole is made with avocado.
The parcel is tied with ribbon.
Mike hates to eat liver.
The pie is made with pumpkin.
My favourite food is lamb.
Jamie has blond hair.
My favourite seafood is lobster.

Dual ungrammatical

*Last summer she planted three cedar.
*On the trip we saw several oak.
*This year we didn't buy many turkey.
*She made the salad using three avocado.
*In her hair she wore many ribbon.
*No animal has two liver.
*The farmer sold several pumpkin.
*The sheep gave birth to two lamb.
*At the crime scene the police found several hair.
*The fisherman didn't catch many lobster.

Appendix 2: Items used in Experiment 2

| | Count Reading | Mass Reading |
|---|---|---|
| TURKEY | A live turkey | A piece of turkey on a plate |
| PUMPKIN | A whole pumpkin | Pumpkin pieces on a plate |
| OAK | An oak tree | A plank of wood |
| CEDAR | A cedar tree | A plank of wood |
| LAMB | A live lamb | A piece of lamb on a platter |
| LIVER | A liver (the organ) | Pieces of liver on a platter |
| FISH | A live fish | A fish fillet on a platter |
| BRICK | A whole brick | Pieces of brick in a pile |
| PINE | A pine tree | A plank of wood |
| AVOCADO | A whole avocado | A cut up avocado on a chopping board |
| LOBSTER | A live lobster | Lobster pieces on a plate |
| TOMATO | A whole tomato | Chopped up tomato on a plate |
| ONION | A whole onion | Chopped up onion on a plate |
| SAUSAGE | A whole sausage | Pieces of sausage on a platter |
| POTATO | A whole potato | Mashed potato in a bowl |
| RIBBON | A ribbon in a girl's hair | Ribbon on a spool |
| HAIR | A single hair | A girl's head in profile with long hair covering the side of her head |

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References

Allan, K. (1980). Nouns and countability. Language, 56, 541-567.

Azuma, T. and Van Orden, G. (1997). Why SAFE is better than FAST: The relatedness of a word's meanings affects lexical decision times. Journal of Memory and Language, 36, 484-504.

Benton, A.L., & Hamsher, K. (1976) Multilingual Aphasia Examination. Iowa City: AJA Associates.

Bloomfield, L. (1933) Language, New York: Henry Holt.

Copestake, A. and Briscoe, T. (1995). Semi-productive polysemy and sense extension. Journal of Semantics, 12,15-67.

Frazier, L. and Rayner, K. (1990). Taking on semantic commitments: Processing multiple meanings vs. multiple senses. Journal of Memory and Language, 28, 181-200.

Garrard, P. & Hodges, J. (1999). Semantic dementia: Implications for the neural basis of language and meaning. Aphasiology, 13(8), 609-623.

Gillon, B. (1996). The lexical semantics of English mass and count nouns. In E. Viegas (Ed.), Breadth and depth of semantic lexicons. Dordrecht, The Netherlands: Kluwer Academic Publishers, pp. 19-37.

Gillon, B., Kehayia, E. and Taler, V. (1999) The mass/count distinction: Evidence from on-line psycholinguistic performance. Brain and Language 68(1-2): 205-211.

Goodglass, H. & Kaplan, E. (1972) Assessment of Aphasia and Related Disorders. San Diego, CA: Academic Press.

Grossman, M., Carvell, S. and Peltzer, L. (1993). The sum and substance of it: The appreciation of mass and count quantifiers in Parkinson's Disease. Brain and Language, 44, 351-384.

Grossman, M., Mickanin, J., Onishi, K. and Hughes, E. (1995). An aspect of sentence processing in Alzheimer's disease: Quantifier-noun agreement. Neurology, 45, 85-91.

Jackendoff, R. (1992). Parts and boundaries. In B. Levin & S. Pinker (Eds.), Lexical and conceptual semantics (Cognition Special Issues). Cambridge, MA: Blackwell.

Jastak, S. & Wilkinson, G.S. (1984) Wide Range Achievement Test Revised: Administration manual. Wilmington, DE: Jastak Associates.

Joosten, F. (2003). Accounts of the count-mass distinction: A critical survey. Nordlyd, 31(1), 216-229.

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

Kean, M.L. (1995). The elusive character of agrammatism. Brain and Language, 50(3), 369-84.

Kertesz A. Western Aphasia Battery. New York: Grune & Stratton; 1982.

Klepousniotou, E. (2002). The processing of lexical ambiguity: Homonymy and polysemy in the mental lexicon. Brain and Language, 81, 205-223.

Klepousniotou, E. & Baum, S. (2003). Processing homonymous and polysemous words: The effects of focal left- and right-hemisphere damage. Presented at the Academy of Aphasia annual meeting, Vienna, Austria.

Mesulam, M. (1982). Slowly progressive aphasia without generalized dementia. Annals of Neurology, 11, 592-598.

Mesulam, M. (2003). Primary progressive aphasia – a language-based dementia. New England Journal of Medicine, 349, 1535-1542.

Mummery, C.J., Patterson, K., Wise, R.J.S., Vandenbergh, R., Price, C.J., & Hodges, J.R. (1999). Disrupted temporal lobe connections in semantic dementia. Brain, 122, 61-73.

Pelletier, F.J. (1979). Non-singular reference: Some preliminaries. In F.J. Pelletier (Ed.), Mass terms: Some philosophical problems. Dordrecht: Reidel.

Pustejovsky, J. (1995) The generative lexicon. Cambridge, MA: MIT Press.

Semenza, C., Mondini, S. and Cappelletti, M. (1997). The grammatical properties of mass nouns: An aphasia case study. Neuropsychologia, 35(5), 669-675.

Shapiro, L., Zurif, E., Carey, S. and Grossman, M. (1989). Comprehension of lexical subcategory distinctions by aphasic patients: Proper/common and mass/count nouns. Journal of Speech and Hearing Research, 32, 481-488.

Snowden, J.S. (1999). Semantic dysfunction in frontotemporal lobar degeneration. Dementia and Geriatric Cognitive Disorders, 10S, 33-36.

Snowden, J.S., Goulding, P.J. & Neary, D. (1989). Semantic dementia: A form of circumscribed cerebral atrophy. Behavioural Neurology, 2, 167-182.

Taler, V. & Jarema, G. (2004). Processing of mass/count information in Alzheimer's disease and mild cognitive impairment. Brain and Language. 90(1-3):262-75

Taler, V. & Jarema, G. (submitted). On-line lexical processing in AD and MCI: An early measure of cognitive impairment?

Taler, V., Jarema, G. & Saumier, D. (in press-a). Semantic and syntactic aspects of the mass/count distinction: A case study of semantic dementia. Brain and Cognition.

Taler, V., Jarema, G. & Saumier, D. (in press-b) Processing of mass/count information in semantic dementia and agrammatism. Brain and Language.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), Organization of memory. New York: Academic Press.

Vanier, M. & Caplan, D. (1990) CT-scan correlates of agrammatism. In Menn, L., Obler, L. (Eds.), Agrammatic Aphasia. A Cross-Language Narrative Sourcebook, Vol. 1. Amsterdam: John Benjamins, pp. 37-114.

Wechsler, D. (1981) Wechsler Adult Intelligence Scale – Revised Manual. San Antonio: The Psychological Corporation.

Wierzbicka, A. (1991). Semantic rules know no exceptions. Studies in Language, 15, 371-398.

# CHAPTER 6: CONCLUSIONS

This thesis presented the results of four studies examining processing of mass, count and dual nouns in English in a variety of impaired and unimpaired populations. The goal was to shed light on representation and processing of these noun types in unimpaired speakers, as well as to characterize the ways in which such representation and/or processing may break down in the case of neurological impairment.

## 6.1. Summary of results

Study 1 (Chapter 2) examined off-line processing of these noun types in patients diagnosed with AD and MCI, using a sentence grammaticality judgement task and a sentence-picture matching task. In the sentence grammaticality judgement task, all but four of the twenty-four AD and MCI participants included in the study exhibited control-like performance. In the sentence-picture matching task, on the other hand, it was found that a majority of both AD and MCI participants exhibited an impairment. Although in certain cases this impairment appears to be due to attentional factors, in the majority of cases the patients' performance may be due to a linguistic deficit. Specifically, while they appear to have no impairment in accessing syntactic mass/count information, these participants were found to have difficulty processing sense extensions in the case of metonymic (dual) nouns. Thus, dual nouns were interpreted as count, which is taken to be the default reading of these lexical items. Furthermore, the severity of the impairment was found to be identical in AD and MCI subjects.

We conducted an ANOVA with age and education as covariates, and divided the patients into three groups: MCI (n=12), mild pAD (n=12) and moderate/severe pAD (n=2). The results are reported in Table XXI below.

Table XXI: Reanalysis of data from Study 1

| | Experiment 1 | | | | Experiment 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | df | MSE | F | p | df | MSE | F | p |
| age | 1 | 0.328 | 0.11 | 0.74 | 1 | 107.47 | 3.87 | .064 |
| educ | 1 | 19.09 | 6.55 | 0.02 | 1 | 116.98 | 4.22 | 0.054 |
| group | 2 | 34.42 | 11.81 | 0.00 | 2 | 4.69 | 0.17 | 0.846 |
| total | 23 | 2.91 | | | 23 | 27.76 | | |

As can be seen, we found an effect of education in both tasks and an effect of group in Task 1 (sentence grammaticality judgement). There was no effect of group in Task 2 (sentence picture matching; $p = 0.846$). It should be noted, however, that these effects miss significance when the two moderate/severe pAD participants are excluded, as shown in Table XXII below.

Table XXII: Reanalysis of data from Study 1, mod/sev AD excluded

| | Experiment 1 | | | | Experiment 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | df | MSE | F | p | df | MSE | F | p |
| age | 1 | 0.255 | 0.094 | 0.76 | 1 | 103.694 | 3.580 | 0.08 |
| educ | 1 | 10.932 | 4.024 | 0.06 | 1 | 108.74 | 3.755 | 0.07 |
| group | 1 | 0.492 | 0.181 | 0.675 | 2 | 11.682 | 0.403 | 0.533 |
| total | 23 | 2.716 | | | 23 | 27.76 | | |

The group effect in Task 1 in the first analysis is consistent with the idea that any impairment in grammaticality judgement is correlated with a more general cognitive impairment. Furthermore, we can conclude that the deficit in the second task is not affected by degree of impairment, although an effect of education was seen when the two most impaired patients were included in the analysis. This effect raises the intriguing possibility that education may provide a protective effect in lexicosemantic processing, although such a suggestion is clearly highly tentative given the small number of participants.

However, the results of Study 1 must be interpreted with caution for a number of reasons:

(a) It is very possible that the impairments in the sentence-picture matching task are due not to linguistic, but rather to attentional factors (i.e., a misunderstanding of the task being performed). It was postulated that this was the case for a subset of the individuals who appeared to understand the task requirements halfway through, but there is no way to ascertain that the remaining individuals simply never understood the task at hand.

(b) The number of patients and stimuli is rather low.

(c) The control group is younger and more educated than the patient groups. Although an ANOVA with age and education included as covariates did not reveal a significant effect of age or education for the mild AD and MCI groups, it is nonetheless possible that the different demographic characteristics of the control and patient groups accounts for the differing performance.

(d) It is possible that a quantitative difference between language capacities in AD and MCI does exist, but is not revealed by the tasks included in this study: patients may be showing a floor effect in the first task and a ceiling effect in the second.

(e) Finally, it should be noted that visuoconstructive impairments were not controlled for in the patient group. It is thus possible that the results are due not to a linguistic but rather to a visuoconstructive impairment, since the sentence-picture matching tasks relies on participants' ability to recognize the objects/substances represented in the pictures.

In order to address at least some of these issues, AD and MCI individuals took part in a speeded lexical decision task examining recognition of mass, count and dual nouns. A timed task offers greater sensitivity than an off-line task such as that used in Study 1. Thus, if the similar performance manifested by the two patient groups in Study 1 is a result of floor and ceiling effects, it is possible that differences will be found in the lexical decision task. Likewise, since the task does not require the identification of pictures, the issue of visuoconstructive impairments is addressed. Finally, since the noun types are presented under identical circumstances, any differences between noun categories are unlikely to be due to deficits in attention or sensory acuity.

Before assessing the performance of AD and MCI individuals on this task, a baseline study was run examining the performance of healthy older and younger adults. Although lexicosemantic processing is typically found to be intact in normal aging, the experiment reported in this chapter did indeed find processing differences across the two populations, specifically in low-frequency nouns[16]. The major results of this experiment were as follows:

1. Plural nouns were recognized more slowly than singular nouns, across participant groups.
2. Low frequency items were recognized more slowly than high frequency items, across participant groups.
3. Older adults manifested longer reaction times overall than did younger adults.
4. Older adults committed significantly more errors than did younger adults on critical stimuli; no significant difference was seen in errors rates on nouns of different categories or frequencies.
5. Older adults manifested shorter reaction times to singular dual nouns than they did to mass and singular count nouns.

[16] It should be noted that, although stimuli were controlled for a number of lexical and sublexical variables, the age of acquisition of the stimuli could not be assessed, as norms were not available for most of the items (97 of 150).

6. Younger adults exhibited similar reaction times to singular dual and count nouns, and longer reaction times to mass nouns. However, an interaction between frequency and category was seen in the subject analysis, suggesting that low frequency dual nouns were recognized more quickly than low frequency count nouns by this group.

These results are summarized in Figures 6.1 and 6.2 below.

Figure 6.1: Results, older adults

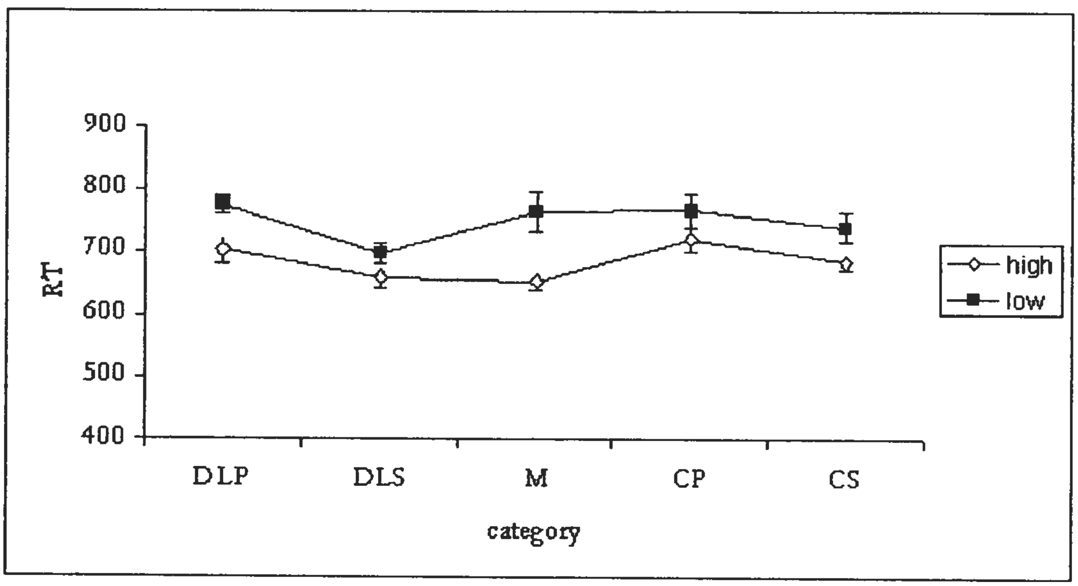
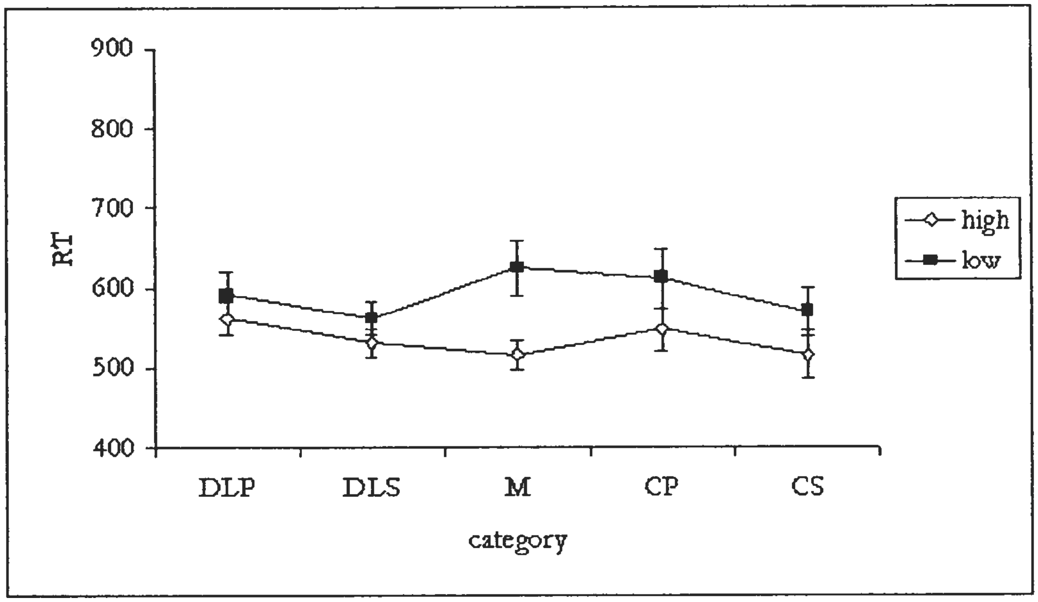


Figure 6.2: Results, younger adults




DLP – dual plural

DLS – dual singular

M – mass

CP – count plural

CS – count singular

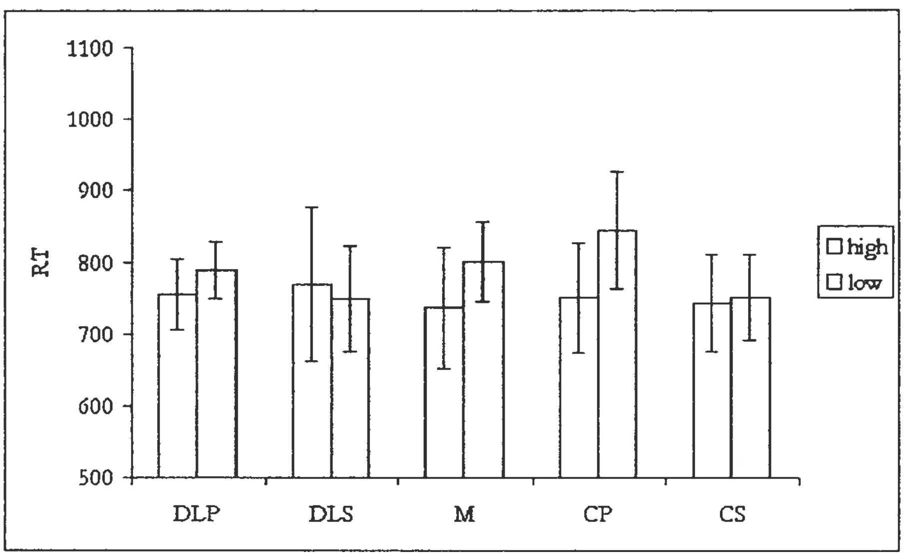
RT – reaction time

error bars represent 95% confidence intervals.

The ramifications of these findings in terms of representation and processing of the various noun types are explored in section 6.2 below. We suggest that one possible account for the differential response pattern in older adults may be that these individuals treat a wider variety of nouns as dual than younger adults: that is, they do not access mass/count information when accessing these lexical items. We suggest that this may be as a result of a reduction in resources available for lexicosemantic processing.

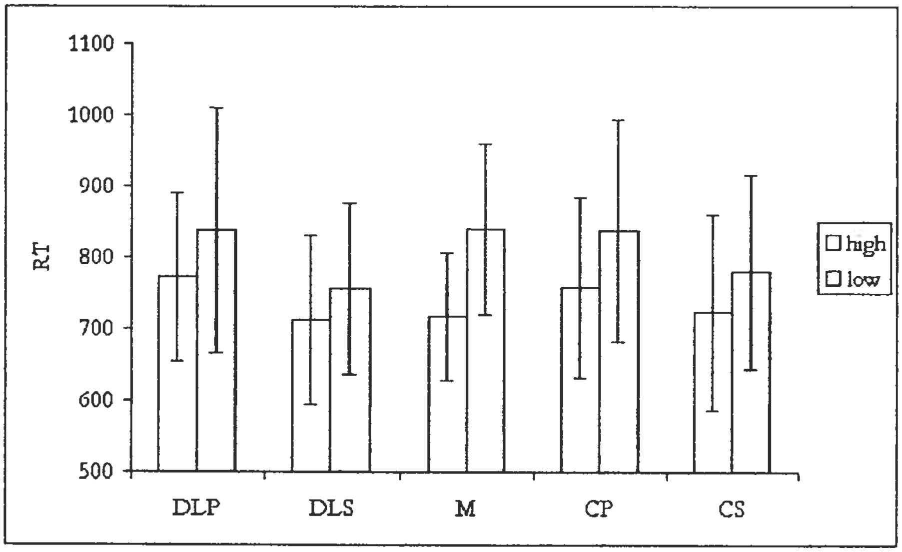
Study 3 (Chapter 4) aimed to further investigate the nature of the impairment seen in AD and MCI subjects in study 1. This study compared the performance of AD and MCI subjects to that of healthy older adults in the lexical decision task reported in Study 2. It was found that, in contrast to elderly control participants, who manifested longer reaction times to mass nouns and count nouns than to dual nouns, AD and MCI participants manifested longer latencies to mass nouns, but no significant difference between count and dual nouns was found. Patients' results are illustrated in Figures 6.3 and 6.4 below[17] (control results are represented in Figure 6.1 above).

Figure 6.3: Results, MCI participants




[17] Note that AD and MCI results are represented in a bar graph, rather than a line graph as was used to represent the data for younger and older adults. This is because the large error bars for the patient groups overlap if a line graph format is used, rendering the graph difficult to read.

Figure 6.4: Results, AD participants




As in Study 1, the AD and MCI groups performed similarly in this task. Both patient groups show similar RTs to count and dual nouns, in contrast with older controls, whose RTs to dual nouns are significantly shorter than their RTs to count nouns. We suggest that one possible explanation for these results is that older adults do not access mass/count information when performing a lexical decision on dual nouns out of context, but that in the appropriate context they are able to assign a mass or count reading to dual nouns. AD and MCI individuals, on the other hand, may have impaired access to and/or representation of the mass readings of dual nouns, simply treating them as if they were count. This is consistent with the finding in Study 1 that, in the majority of cases, AD and MCI individuals selected the count referent of a dual noun even in sentences with mass syntax. Thus, the findings of Study 3 are consistent with those of Study 1. One possible account for these response patterns is presented in Section 6.2 below.

Study 4 (Chapter 5) reports an exploratory study of processing of mass/count information in one individual with a pure semantic deficit (semantic dementia, or SD) and one individual with a pure syntactic deficit (agrammatic aphasia, or AA). The goal of this study was to further specify the precise stages of processing of semantic and syntactic information required for successful comprehension of mass, count and dual nouns. These participants undertook a sentence grammaticality judgement task and a sentence-picture matching task, as in Study 1. It was found that the SD patient was able to perform the grammaticality judgement task but exhibited an impairment in the sentence-picture matching task. The AA participant exhibited an impairment both in the sentence-picture matching task and in the sentence grammaticality judgement task; specifically, he was unable to detect sentences ending in an ungrammatical determiner-dual noun combination. On the basis of these results, we postulate a series of processing stages that must be completed for successful processing of mass and count nouns. We suggest that syntactic information must be successfully computed before semantic information is accessed, at least in the tasks included in this study. These processing stages are outlined in section 6.2, below.

The research presented in this thesis has both clinical and theoretical implications. On a theoretical level, it sheds light upon the representation of mass, count and dual nouns, both through examination of processing in unimpaired populations, and by assessing the ways in which such processing can break down in the case of impairment. It also examines the contributions of different types of knowledge to successful processing of these noun types. On a clinical level, this research suggests a possible direction for future research aimed at developing a tool for early diagnosis of AD. These implications are explored in sections 6.2 and 6.3 below.

## 6.2 Theoretical contributions

The finding that dual nouns are accessed more quickly than count nouns in a normal elderly population (Chapter 3), and that a distinction is seen between the reaction times yielded by regular count and mass nouns in healthy young adults as well as participants suffering from AD and MCI (Chapters 3 and 4) leads us to postulate a three-way distinction in the representation of these noun types in the mental lexicon, whereby the lexical entries for dual nouns do not contain information about their mass/count status. Following Gillon et al. (1999), we suggest that the lexical entries of mass nouns contain a monovalent feature [mass], access to which slows recognition of these items. This leads to the question of how the representations of count and dual nouns differ.

The account that we put forward is based on underspecification theory (see, e.g., Kiparsky, 1982, Steriade, 1995), which was developed within phonological theory but can also account for the mass/count alternations seen in the current case. Below we provide a brief overview of underspecification theory as it pertains to phonological representations, before describing the way in which we apply it to semantic representations.

### 6.2.1 Underspecification theory

The concept of underspecification was introduced to theoretical linguistics by Kiparsky (1982; for a historical review see Steriade, 1995). This theory holds that phonological representations may be underspecified with respect to a given feature; that is, they may contain a subset of the phonological features of a given segment. Those features that are predictable (default features) are not present in the underlying form of the segment. Consider for example, the segment /n/ in the English word *in*. Since [coronal] is the default place for consonants in English, the underlying representation does not need to be specified for this information. It can be predictably filled in when the segment is processed on-line. The underlying representations of /n/ and /m/ (which is labial and is fully specified for place) are thus as shown in Figures 6.5 and 6.6 below (for the sake of simplicity, only place information is included in the figures):

Figure 6.5: Underlying representation of segment /n/ in English

/n/
|
[place]

Figure 6.6: Underlying representation of segment /m/ in English

/m/
|
[place]
|
[labial]

This account predicts variations in the phonetic output as a result of assimilation, which are seen with underlyingly coronal segments, but not with underlyingly labial or dorsal segments:

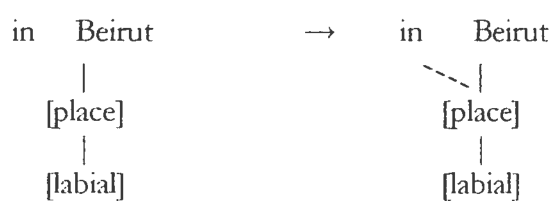
1. in Denmark: /ɪn/ → [ɪn]
2. in Beirut: /ɪn/ → [ɪm]
3. in Cairo: /ɪn/ → [ɪŋ]

but:

4. sing ballads /sɪŋ/ → [sɪŋ]
5. sing ditties /sɪŋ/ → [sɪŋ]

Assimilation occurs as a result of spreading of the place node from the adjacent segment, as shown in figure 6.8 below:

Figure 6.7: Spreading of place node




Thus, the nasal segment is specified as labial in the context where it is followed by a labial segment. Out of context, it is realized as default (i.e., coronal).

It is this basic mechanism that is extended to apply to mass/count information in the current thesis. Below we discuss the possibility that underspecification may play a role in the representation of mass/count information within the lexicon.

### 6.2.2 Representation of mass, count and dual nouns in the lexicon

We postulate a set of representations of mass, count and dual nouns where the complexity of the mass/count information contained in the lexical entry is lowest in dual nouns and highest in mass nouns. This is intended to account for the finding that mass nouns are recognized more slowly than singular count nouns by younger adults as well as AD and MCI participants[19], and that singular count nouns are recognized more slowly than singular dual nouns by healthy elderly individuals.

The representations we postulate are illustrated in Figures 6.8 - 6.11 below. As can be seen, the representation of mass nouns, as well as of singular and plural count nouns, contain a node [countability], or [C][20]. In the case of mass nouns it is specified using a feature [mass], and in the case of plural count nouns it is specified using a feature [plural]. The [C] node of singular count nouns is underspecified (i.e., bare). Dual nouns have no [C] node; we suggest that this ill-formed surface structure is repaired using a lexical rule, which is discussed below.

---

[19] Note that, while the category x frequency interaction missed significance for older adults, it was borderline ($p<0.046$) and this borderline effect was in part attributable to a difference between low frequency singular count and mass nouns.

[20] This countability node is not intended to indicate that the noun is count, but rather that it is specified for mass/count information.

Figure 6.8: Representation of mass nouns

```
/honey/
   |
  [C]
   |
[mass]
```

Figure 6.9: Representation of singular count nouns

```
/table/
   |
  [C]
```

Figure 6.10: Representation of plural count nouns

```
/tables/
   |
  [C]
   |
[plural]
```

Figure 6.11: Representation of dual nouns

```
/chicken/
```

This account is consistent with that put forward by Klepousniotou (2002), who suggests that the lexical entries of polysemous nouns contain only the basic sense, and that specific information about the sense of the item is filled in by means of a lexical rule that operates in context. We suggest a possible form and operation for this lexical rule in section 6.2.3.2 below. However, before describing the form of the lexical rule that we postulate, we will briefly discuss the hypotheses of Copestake & Briscoe (1995), whose seminal work on the operation of lexical rules forms the basis of the present work.

### 6.2.3 Lexical rules

The claim that lexical rules can account for sense extension was originally put forward by Copestake and Briscoe (1995). They posit a series of lexical rules that apply to the basic sense of a lexical item. In the case of mass/count sense extensions (in the terminology of the present thesis, sense extensions applying to dual nouns), they posit the rules "portioning" and "grinding". Their claim is presented below.

#### 6.2.3.1 Portioning and grinding: Using lexical rules to account for sense extensions

Copestake and Briscoe (1995) use a lexical representation language (LRL) to represent lexical entries as feature structures (FS), and suggest that rules may be applied to these entries in order to extend the sense of the lexical item. For example, in the case of "grinding" (cf. Pelletier, 1979), whereby a lexical item referring to an animal may also be used to refer to the meat of that animal (e.g., *lamb*), the rule takes the following form:

Meat-grinding

< > < grinding < >

< 1 QUALIA > = animal

< 0 QUALIA > = c_subst.

Note that 0 and 1 contain information about the item, such as orthographic, semantic and syntactic information, although this has been omitted for the sake of clarity.

the meat-grinding rule, this means that the lexical entry for *lamb* is unified with the meat-grinding rule, resulting in a c_subst. reading, where "c_subst." signifies "normally comestible naturally derived substances", or in the case of *lamb*, "edible stuff derived from lambs".

Application of this rule is taken to be governed by pragmatic, language- or culture-specific factors, and may be blocked by the existence of an alternate lexical item expressing the sense in question. For example, in English, the grinding rule described above may apply to animal meat, but is blocked in the case of "pig" by the existence of the lexical item "pork". In contrast, grinding of meat is ungrammatical in Inuit. Likewise, the use of fruit or nut terms to refer to the liquid produced by their grinding is not conventionalized in English, rendering sentences such as *"I drink orange for breakfast" ungrammatical. Thus the grinding rule may not apply in these cases.

One important feature of this theory is that the count reading of these items is taken to be the default, and the mass reading is derived from the count reading by means of this rule. Note that the reverse may also apply; for example, the lexical rule *portioning* accounts for the sense extension which occurs in cases such as "We would like *three beers*", where a mass noun with a count reading is used to refer to a portion of that substance. This lexical rule is represented as follows:

Portioning

< > < portioning < >

< 1 QUALIA > = lex-count-noun

< 0 QUALIA > = lex-uncount-noun

Thus, lexical items have a default and an extended sense. In the words of Copestake and Briscoe:

> "The effect of the lexical rule is to create from a count noun with the qualia properties appropriate to an individuated physical object, a mass noun with properties appropriate for an unindividuated substance… The meat-grinding rule creates a second extended sense for the mass noun *rabbit* (and other animal-denoting count nouns) but does not result in the full specification of what might usually be taken as the meaning of the meat/flesh sense. The substance is stated to be edible… and to be derived from the animal, but there is no attempt at defining the meaning to exclude, say, stuff derived from bones … we assume that pragmatic effects will ensure further contextual specialization."

While this variety of lexical rule is intuitively appealing at a theoretical linguistic level since it accounts for the preference of certain nouns for mass or count contexts, it requires the specification of a great deal of semantic information within each rule, as well as a proliferation of rules to account for different default and extended senses (e.g., a "fur-grinding" rule to account for the use of *rabbit* to mean rabbit fur), which share the common feature that they undergo a mass/count alternation. Nonetheless, the authors still appeal to pragmatic effects to account for contextual specialization. That is, despite their complexity, the rules alone do not account for the different readings of the items in question.

The account put forward by Copestake and Briscoe can explain the performance of AD and MCI participants in Study 1, since these subjects may simply be unable to apply the lexical rule itself, meaning that they always select the default (count) reading of dual nouns. However, this account cannot explain the three-way distinction in reaction time that was seen between mass, count and dual nouns in Studies 2 and 3. Under Copestake and Briscoe's account, dual nouns are simply count nouns that can undergo a lexical rule to give a mass reading, or a mass noun that can undergo a lexical rule to give a count reading; thus, it would be predicted that dual nouns should yield a performance intermediate between that of mass nouns and that of count nouns in on-line testing, unless they are required to undergo the lexical rule, in which case longer reaction times would be predicted. However, this was not the case; older adults recognized dual nouns more quickly than count nouns, and pluralization was more costly, indicating that the representation of these items differs from that of count nouns.

We put forward an account of mass/count alternations based on the principle that dual nouns are underspecified for mass/count information; that is, a countability node is not present in their lexical entries, as described above. This information is filled in on-line and in context. This is in contrast to Copestake & Briscoe's position that there exist language-specific filters which determine which lexical items may undergo any given rule; our account thus constitutes a theoretically more parsimonious account. The operation of the rule we postulate is described in section 6.2.2.3 below.

6.2.3.2 Countability by context

The lexical rule postulated here, which we term *countability by context* (henceforth CBC), involves the spreading of the countability ([C]) node in order to repair the ill-formed surface structure of a bare dual noun. This spreading may occur from any item in the syntactic context, such as a determiner or a plural morpheme. The item from which the information is spread must contain a [C] node, which may be additionally specified as plural or mass.

It should be noted that such a lexical rule may be feature-spreading but not feature-filling. Thus, since count and mass nouns already possess a [C] node, they do not meet the specifications for the CBC rule which precludes feature-filling. Thus, mass and count nouns do not undergo this rule.

The application of this lexical rule is illustrated in Figures 6.12-6.14.

Figure 6.12: Application of CBC (count reading)


Figure 6.13: Application of CBC (mass reading)

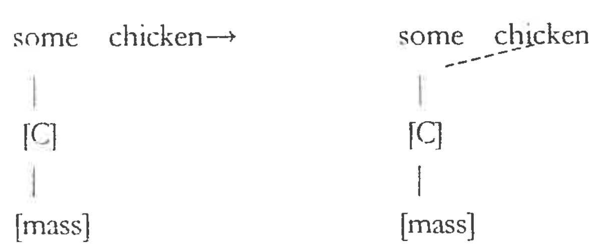
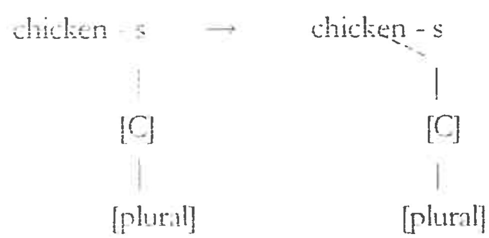


Figure 6.14: Application of CBC (plural reading)




We now turn to a discussion of the way in which this rule applies in the different populations reported upon in the current thesis.

In Study 2 (Chapter 3), we found faster RTs to singular dual than to singular count nouns in healthy older adults, and similar RTs to plural nouns whether they were count or dual. This suggests that count nouns require additional processing and/or that additional information is accessed when singular count nouns are recognized relative to singular dual nouns. One possible account for these findings has been offered above: dual nouns possess less structure (no countability node), thus engendering faster RTs. When a dual noun is seen in the plural, however, CBC must apply. Recognition is thus slowed, such that no difference in seen in RTs to plural count and dual nouns.

Younger participants, on the other hand, show similar RTs to count and dual nouns, both in the plural and in the singular, although a subset of low frequency dual nouns appear to be recognized more quickly than low frequency count nouns in this population. We suggest that this may be because younger adults activate mass/count information only for a certain subset of those nouns which we have classified as "dual", assigning a default (count) reading to these nouns even when they are seen out of context, whereas older adults do not. Thus, they process these lexical items in the same way as count nouns. The question of which nouns are processed as dual by older adults and count by younger adults is discussed further in Section 6.2.4 below. The reasoning behind the assumption that the count reading is taken to be the default reading of dual nouns is twofold. First, the fact that individuals with language impairments select the count referent in a sentence-picture matching task indicates that this meaning may be more "basic" than the mass meaning. Second, in terms of the taxonomy described above, the lexical entries of count nouns possess less structure than those of mass nouns (i.e., a bare countability node).

In sum, we suggest that younger adults activate mass/count information in a subset of dual nouns, whereas older adults do not. Their postulated failure to activate mass/count information in those dual nouns that younger adults treat as count may be due to a reduction in processing speed and/or resources available for lexicosemantic processing. Due to the greater cost of activating this information, older adults may "withhold judgement" with respect to mass/count status for these lexical items, whereas younger adults do not. (See Section 6.2.4 below for further dicussion of this notion.)

In the case of AD and MCI individuals, dual and count nouns engender similar RTs in both the singular and the plural, whereas mass nouns are processed more slowly than other singular nouns. In combination with the findings reported in Study 1 (that many of these patients had difficulty interpreting a null determiner as indicating a mass referent for a dual noun), these results point to the possibility that AD and MCI individuals may have an impairment in processing and/or representation of the mass reading of dual nouns.

We suggest that AD and MCI individuals' performance on the tasks reported here is consistent with an inability to apply CBC. If this were indeed the case, the processing of dual nouns would proceed as follows:

1) If these individuals are unable to spread mass/count information from syntactic context, they are left with an ill-formed surface structure when they encounter a dual noun.
2) This violation must be repaired, and the way that this is done is through the insertion of default mass/count information. As argued above, the count reading, which entails the minimal structure, is taken to be the default.
3) As a result, dual nouns are consistently interpreted as count by these patient groups.

Thus, AD and MCI individuals' inability to apply CBC constitutes a possible account for the pattern of results found in Studies 1 and 3 (Chapters 2 and 4).

Study 4 (Chapter 5) examined the performance on two tasks, grammaticality judgement and sentence-picture matching, of two individuals, one with a pure semantic deficit and one with a pure syntactic deficit. Although the tasks were designed to tap into semantic and syntactic processing of dual nouns, it should be noted that both tasks require the integrity of syntactic information for their successful completion. The study thus aims to clarify the stages required for processing of mass, count and dual nouns when seen in a syntactic context. These stages are outlined below.

(a) Access to the syntactic information contained in the noun and/or the context;

(b) Application of CBC (if applicable);

(c) Access to the semantic information conveyed by the feature [mass], made available by the syntax; and

(d) Integration of the semantic and syntactic information, allowing a correct interpretation of the item in question.

These stages apply in the case where mass/count information has been made available either via the lexical entry itself (in the case of mass or count nouns) or via the syntax (in the case where a dual noun is seen in a syntactic context that disambiguates it). It does not apply in cases where mass/count information about a dual noun is made available through semantic context, as in examples 6 and 7 below:

6. The lamb gamboled in the field. [count reading]

7. The lamb was served with mint sauce. [mass reading]

These examples demonstrate that it is possible to disambiguate dual nouns (i.e, obtain mass/count information) from semantic context. In the case of sentence 6, the verb [gambol] requires an animate agent, forcing the "animal" (count) reading. In the case of sentence 7, the verb [serve] requires a theme which is edible, forcing the "meat" (mass) reading. Thus, the mass and count readings are derived from subcategorization requirements of the verb, rather than directly from a determiner or plural morpheme contained within the DP. It thus seems unlikely that a lexical rule dependent on syntactic information, such as CBC, can apply here. We suggest that disambiguation in these circumstances likely depends upon the integrity of semantic systems, although this remains to be determined.

A summary of the proposed processing stages required in the sentence grammaticality judgement and sentence-picture matching tasks, as well as the deficits we suggest may occur in the various populations tested, is provided in Table XXIII below.

Table XXIII: Impairments in different populations

| Stage | Young controls | Older controls | MCI/AD | Semantic dementia | Agrammatic aphasia |
|---|---|---|---|---|---|
| (a) access to syntactic info contained in noun and/or context | intact* | intact | intact | intact | intact |
| (b) application of lexical rule | intact | intact | impaired | intact | impaired |
| (c) access to semantic info in feature [mass] | intact | intact | intact | impaired | intact |
| (d) integration of semantic and syntactic info | intact | intact | ?** | impaired | ?** |

* younger adults are postulated to assign a default (count) interpretation for many nouns with both a mass and a count reading, even in the absence of context

** In these cases, the capacity to integrate syntactic and semantic information cannot be assessed on the basis of the present data, since these patients exhibited an impairment in the task which sheds light on this processing stage (sentence-picture matching) for independent reasons (impairment in the capacity to apply CBC).

In the following section, we tie our results in with the theoretical models of the mass/count distinction discussed in Chapter 1, as well as with the discussion on recent insights into the neurobiological foundations of language representation and processing.

### 6.2.4 The mass/count distinction reconceptualized

The reader will recall that four proposals regarding the status of the mass/count distinction have been proposed in the theoretical linguistic literature:

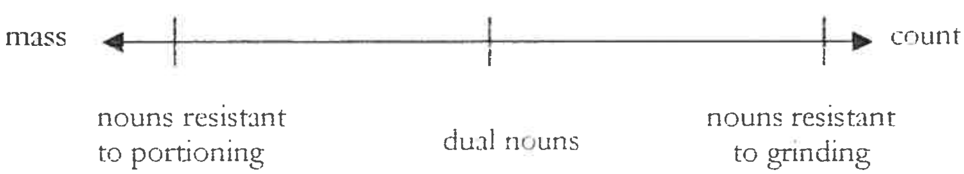
- the syntactic account: mass/count information is encoded in the syntax; semantic factors do not play a role
- the ontological account: mass/count status of items is determined according to whether their real-world referents are objects or substances
- the semantic account: mass/count status of items is determined according to whether speakers conceptualize their referents as objects or substances
- the contextual account: all nouns may be either mass or count, depending on the context in which they are seen

As pointed out by Joosten (2003), objections may be raised to all of these positions: the most plausible account of the mass/count distinction will probably incorporate elements from all of these theories.

We suggest that semantic and syntactic information are intimately linked in the representation of the mass/count distinction. Thus, aspects of processing of mass, count and dual nouns will be affected both by neurological disorders affecting semantic systems and those affecting syntactic systems, as demonstrated by the research presented here.

First, we propose that the mass/count distinction is best viewed not in terms of a two- (or three-) way dichotomy, but rather in terms of the relative "mass-like" or "count-like" nature of the referent of any noun. Nouns will vary from very mass-like (e.g., *snow*) to very count-like (e.g., *man*), with dual nouns falling in the middle. That is, we suggest that mass- and counthood falls on a continuum, as represented in Figure 6.15 below.

Figure 6.15: The mass/count distinction re-conceptualized

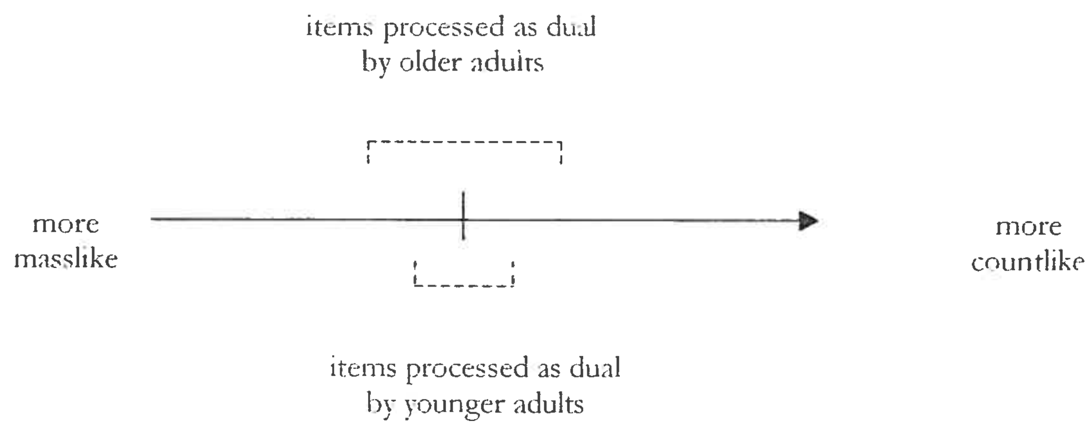



Essentially, the claim is that when a noun falls on the left (mass) side of the spectrum, the reader/listener activates the information that the item is mass; when a noun falls on the right (count) side of the spectrum, the reader/listener activates the information that the item is count. Activating mass information appears to be more demanding, either computationally or in terms of the information accessed, than activating count information, as attested by the fact that longer RTs are seen to these items across populations. However, as pointed out in the theoretical linguistic literature, most nouns may be semantically forced into their non-preferred reading. Frisson and Frazier (in press) have recently demonstrated that this carries a cost in terms of processing time.

This cost may reflect the operation of a process such as portioning or grinding, as claimed by Copestake and Briscoe (1995).

The point on the continuum at which a noun is deemed mass or count seems to be variable across populations (or possibly individuals, although the present research does not address this issue). In the case of younger adults, only nouns which fall close to the midpoint of the spectrum appear to be processed as dual (i.e., no mass/count information is activated) when seen out of context. Older adults appear to "withhold judgement" on a broader spectrum of nouns, that is, on nouns falling more distally from the midpoint than is the case with younger adults. This is represented in Figure 3.5 in Chapter 3, repeated here for convenience as Figure 6.16.

Figure 6.16: Older and younger adults' processing of dual nouns



The mass or count information contained in a lexical representation is taken to be an closely-linked web of semantic/ontological and syntactic information. The placing of mass and count nouns on a continuum captures the contextualists' insight that all nouns are defined as mass and count according to the context in which they are seen, while remaining faithful to the observation that the majority of nouns prefer either a mass or a count context. Thus, this account integrates aspects of all of the theories put forward in the linguistic literature, each of which has its advantages and drawbacks.

The claim that semantic and syntactic information are closely linked in the representation of these noun types suggests that integrity of both of these types of information is necessary for successful processing of mass and count nouns, and that feedback between them likely occurs during processing of mass/count information. Thus, a task such as the sentence-picture matching task presented in Studies 1 and 4, which requires both syntactic and semantic processing, will be difficult for individuals with either a syntactic or a semantic impairment. The sentence grammaticality judgement task, which is more purely syntactic, may be successfully completed by individuals with focal semantic deficits, such as semantic dementia and Alzheimer's disease.

In the following section we will attempt to draw links between the theory proposed here and the recent insights into the neurobiological underpinnings of language processing that were discussed in the introduction to this thesis.

6.2.5 From theory to neurobiology: Some speculations

One important consideration in formulating a comprehensive account of the mass/count distinction is the issue of the neural systems responsible for representation and processing of this information. Although our data are inadequate to make any claims with respect to the precise neural substrates of this representation and processing, we nonetheless sketch out an account which is consistent with current theories of the neurobiological bases of language processing. In so doing, we appeal to the claim put forward by Pulvermüller (2001) that lexical items are represented in cell assemblies (or, in his terms, *word webs*) that have a broad cortical distribution and comprise neurons from diverse cortical areas (e.g., motor cortex, primary sensory cortices, and so on). These word webs are activated when the item is accessed. We postulate that, when a noun is accessed, both semantic and syntactic information about its mass/count status is made available. Under this view, the links between semantic and syntactic information are wired into the brain, as connections between the neurons responsible for processing the two types of information.

This speculation is supported by evidence from ERP and magnetoencephalography (MEG) studies demonstrating early and temporally overlapping activation of lexical (word/non-word) and semantic information in word recognition; this activation may occur as early as 100-200ms after stimulus onset (Pulvermüller, Assadollahi, and Elbert, 2001). We suggest that it is likely that a speaker of a language has been exposed to consistent syntax to semantics mapping, whereby mass syntax co-occurs with mass semantics and count syntax with count semantics. According to the principle of Hebbian learning (Hebb, 1949), the resultant synchronous firing of neurons responsible for the processing of syntactic and semantic information will strengthen the connections between these neurons. Thus, semantic and syntactic information will be processed in parallel and are essentially non-dissociable from one another, temporally speaking.

The reader may at this point be wondering how the countability node, the feature [mass] and the lexical rule CBC can be incorporated within this framework. We argue that these representations may be viewed as shorthand for the broadly distributed cortical networks that underlie mass/count information. These cortical networks may encode a variety of information types, such as visual, conceptual, or grammatical information, amongst others. The rule CBC may be understood at a neurophysiological level as relating to spreading activation within a cortical network as mass or count information is activated from elsewhere in the semantic or syntactic context and spread to the dual noun.

The claim that AD and MCI affects the operation of CBC thus implies that these individuals manifest an impairment in spreading activation at the neurophysiological level. This has in fact been theorized to occur in the case of AD. A primary event in the pathogenesis of AD is the accumulation of β-amyloid protein (Aβ) deposits (Small & MacLean, 1999) which cause the death of mature neurons (Mattson, 2000; Haughey, Nath, Chan, Borchard, et al., 2002). It has been hypothesized that these deposits may delay signal transmission by several milliseconds (Knowles, Wyart, Buldyrev, Cruz et al., 1999). Thus, if a postsynaptic neuron receives an input from a dendrite whose length has been altered by an Aβ deposit, this neuron will fire several milliseconds after a neuron that receives an input from a dendrite that did not traverse such an Aβ deposit (Knowles et al., 1999). These timing alterations appear to be sufficient to interfere with information transfer. Thus, the spreading activation mechanism posited to underlie the lexical rule CBC may be affected by these Aβ deposits.

We now consider the case whereby re-parsing of a lexical item is required once an initially activated reading has been reached and context indicates that another reading is necessary (i.e., portioning or grinding). We suggest that this may occur via activation of the cortical circuits responsible for mass information (in the case of grinding) or count information (in the case of portioning) after initial activation of the networks underlying the other reading. Thus, wider cortical networks are activated overall, since the reader/listener will initally activate the network associated with the default reading of the lexical item, and will then be obligated to activate the network associated with the "ground" or "portioned" item. This accounts for the greater processing cost associated with these rules relative to CBC. Note that this account would predict that, the closer the item to either end of the continuum represented in Figure 6.15, the greater the cost of applying the lexical rule. We leave testing of this prediction for future research.

Finally, we argue that this account is consistent with diverse findings on children's acquisition of the mass/count distinction. There exist some conflicting results in the literature with respect to acquisition of mass/count information. For example, Gordon (1985) found that children rely on syntactic information to a greater extent than perceptual information to determine a novel noun's mass/count status. In contrast, Soja, Carey and Spelke (1991) found that children are able to extend novel words on the basis of object kind prior to mastering the mass/count distinction. It has been suggested

(Bloom, 1999) that children use a bidirectional syntax-semantics mapping to acquire the mass/count distinction, as shown below:

| | | |
|---|---|---|
| count noun | ↔ | individual |
| mass noun | ↔ | non-individual |

We suggest that, during acquisition, the neurons underlying the *syntactic* information regarding mass/count status and those encoding *semantic* information are frequently co-activated. Thus, following the principle of Hebbian learning, the links (i.e., synapses) between these neurons are strengthened, eventually forming a "word web" in the adult brain that is activated when the word is accessed. Since this activation co-occurs with many different word forms (most or all mass and count nouns) it follows that when a novel lexical item is encountered in a mass or count context (be it syntactic or semantic), correct processing of the novel item is unproblematic (see discussion of sequence detectors on page 42 for a brief discussion of how this generalization of syntactic knowledge may occur).

In sum, we suggest that processing and representation of mass/count information may involve wide networks of neurons[21] that are activated to a greater or lesser degree, depending on where on the mass/count spectrum the item appears. The consequence of this possibility for the various theories of the mass/count distinction is profound: since

[21] Note that the results presented here do not speak to the question of the cortical regions responsible for the processing of this information, since autopsy results indicating the areas affected are not available for the patients studied, and the limited number and nature of the tasks used precludes pinpointing the regions responsible for representing and processing each type of information.

this possibility for the various theories of the mass/count distinction is profound: since semantic, syntactic and contextual information all play a role in representation and processing of nouns, the debate essentially boils down to a question of which account best describes the *distribution* of these terms in natural language (i.e., their appearance in a given syntactic context and/or the correlation between a noun's category and the semantic properties of its referent), rather than pertaining to the processing and/or representation of this information per se.

We now turn to a brief discussion of the potential clinical implications of the findings presented in this thesis.

### 6.3. Clinical implications

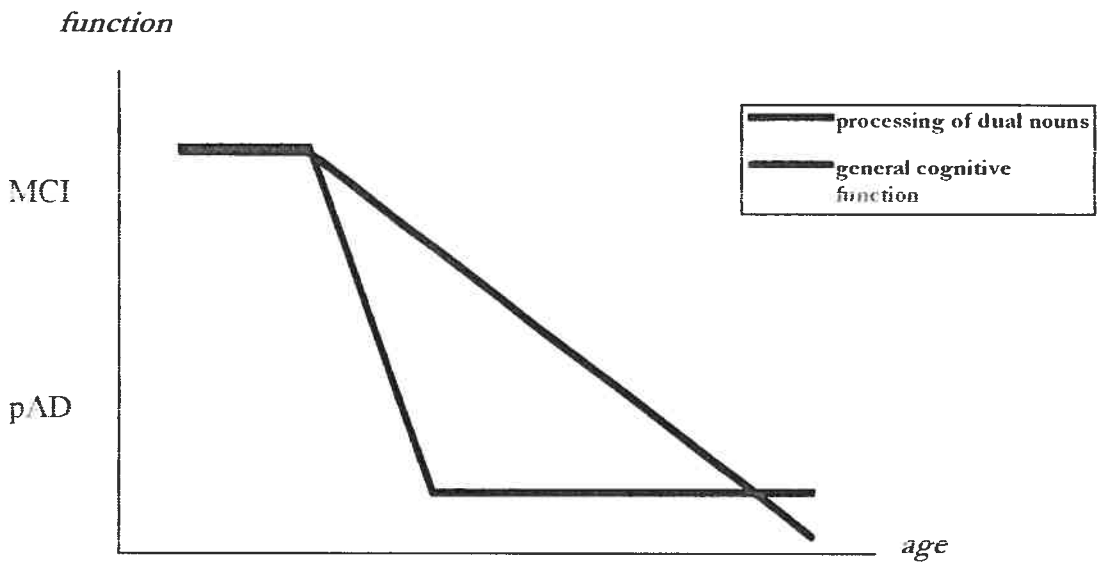
The present research is of particular interest on a clinical level in the case of AD and MCI. A diagnosis of MCI is an important risk factor for eventual development of AD; these individuals have a 6-25% risk of developing AD per annum, compared with 0.2-3.9% in the general population (Petersen, Stevens, Ganguli, Tangalos et al., 2001). MCI has thus been identified as an important target group for identifying prognostic markers for AD.

It should however be noted that there exists a significant subgroup of individuals diagnosed with MCI who do not go on to develop AD, even after 10 years (Chertkow, 2002). Thus, a diagnosis of MCI does not in itself constitute sufficient evidence that the individual will develop AD to warrant the use of pharmacological treatment. As such, one of the major goals in research into MCI is to identify which individuals are simply at the bottom of the Gaussian curve in terms of neuropsychological performance and which are in fact manifesting the earliest clinical signs of AD.

Identification of subtle cognitive and/or behavioural alterations seen both in MCI and in AD, as in the research presented here, provides a possible avenue for exploration of deficits that may be predictive of AD. The fact that identical patterns of performance were seen in these two patient groups, both in off-line and in on-line tasks (Studies 1 and 3, respectively) suggests that alterations in processing and/or representation of dual nouns in AD may occur very early in the disease course.

We suggest that the processing and/or representation of subtle semantic information, such as the mass/count flexibility of a dual noun, may be one of the earliest signs of lexicosemantic impairment in AD. That is, impairment in performance on tasks tapping into this semantic information may show early, precipitous decline, as opposed to the more gradual generalized cognitive decline that is seen as an individual progresses from MCI to AD. This dissociation is represented in Figure 6.17 below.

Figure 6.17: Processing of dual nouns relative to general cognitive function in MCI and AD




While the small numbers of participants in the studies reported here clearly preclude the drawing of any definitive conclusions, the findings suggest the possibility of such a distribution. Larger longitudinal studies examining on-line language processing, based on the findings reported here, are clearly required. These may point the way toward the development of sensitive diagnostic tools, which in combination with other neuropsychological, genetic and neuroimaging markers may eventually allow the identification of individuals who are at high risk of developing AD.

REFERENCES

Allen, J. & Seidenberg, M. (in press). The emergence of grammaticality in connectionist networks. In MacWhinney, B. (Ed.) Emergentist Approaches to Language: Proceedings of the 28th Carnegie Symposium on Cognition. Erlbaum.

Allen, P., Madden, D. & Crozier, L. (1991) Adult age differences in letter-level and word-level processing. Psychology and Aging, 6, 261-271.

Allen, P., Madden, D., Weber, T. & Groth, K. (1993) Influence of age and processing stage on visual word recognition. Psychology and Aging, 8, 274-282.

Almor, A., MacDonald, M.C., Kempler, D., Andersen, E.S., & Tyler, L.K. (2001) Comprehension of long distance number agreement in probable Alzheimer's disease. Language and Cognitive Processes, 16, 35-63.

Andrews, S. (1997) The effect of orthographic similarity on lexical retrieval: Resolving neighborhood confliucts. Psychonomic Bulletin and Review, 4, 439-461.

Appell, J., Kertesz, A., & Fisman, M. (1982) A study of language functioning in Alzheimer patients. Brain and Language, 17, 73-91.

Apresjan, J. (1974) Regular polysemy. Linguistics, 142, 484-504.

Azuma, T. and Van Orden, G. (1997) Why SAFE is better than FAST: The relatedness of a word's meanings affects lexical decision times. Journal of Memory and Language 36: 484-504.

Baddeley, A.D. (2000) The episodic buffer: A new component of working memory? Trends in Cognitive Sciences, 4, 11, 417-423.

Baddeley, A.D. (2001) The concept of episodic memory. Philosophical Transactions of the Royal Society, London, B, 356, 1345-1350.

Baddeley, A.D. (2003). Working memory: looking back and looking forward. Nature Reviews Neuroscience, 4, 829-839.

Baddeley, A.D. & Hitch, G.J. (1974) Working memory, In G.H. Bower (Ed.) The psychology of learning and motivation (pp. 47-90). New York: Academic Press.

Baddeley, A.D., & Wilson, B.A. (1986). Amnesia, autobiographical memory and confabulation. In D.C. Ruben (Ed.) Autobiographical memory. Cambridge: Cambridge University Press, 225-252.

Balota, D.A., & Chumbley, J.I. (1990). Where are the effects of frequency in visual word recognition tasks? Right where we said they were! Comment on Monsell, Doyle and Haggard (1989). Journal of Experimental Psychology: General, 119, 231-237.

Bastiaanse, R. & Jonkers, R. (1998) Verb retrieval in action naming and spontaneous speech in agrammatic and anomic aphasia. Aphasiology, 12:951-969.

Bates, E., Friederici, A. & Wulfeck, B. (1987) Grammatical morphology in aphasia: evidence from three languages. Cortex, 23: 545-574.

Bayles, K. (1982) Language function in senile dementia. Brain and Language 16:265-280.

Bayles, K.A. & Kaszniak, A.W. (1987) Communication and cognition in normal aging and dementia. Boston: Little Brown and Co.

Bayles KA, Tomoeda CK, Trosset MW. (1990) Naming and categorical knowledge in Alzheimer's disease: the process of semantic memory deterioration. Brain and Language, 39: 498-510.

Beretta, A. & Munn, A. (1998) Double-agents and trace-deletion in agrammatism. Brain and Language, 65(3):404-21

Bickel, C., Pantel, J., Eysenbach, K., & Schröder, J. (2000) Syntactic comprehension deficits in Alzheimer's disease. Brain and Language, 71, 432-448.

Bloom, P. (1999). The role of semantics in solving the bootstrapping problem. In Jackendoff, R., Bloom, P. & Wynn, K. (Eds) Language, Logic and Concepts: Essays in Memory of John MacNamara. Cambridge, MA: MIT Press.

Bloomfield, L. (1933) Language. New York: Henry Holt.

Bouras, C. (2002) Evolution of AD pathology in the aging brain. Geneva, Switzerland: American Academy of Neurology.

Bowles, N.I. & Poon, I.W. (1981) The effect of age on speed of lexical access. Experimental Aging Research, 7:417-425.

Bowles, N.I. & Poon, I.W. (1985) Aging and retrieval of words in semantic memory. Journal of Gerontology, 40:71-77.

Bowles, N., Williams, D. & Poon, L. (1983) On the use of word association norms in aging research. Experimental Aging Research, 9, 175-77.

Braitenberg, V. and Schüz, A. (1998) Cortex: Statistics and Geometry of Neuronal Connectivity. New York: Springer-Verlag.

Broca, P. (1861) Remarques sur la siège de la faculté de la parole articulée, suivies d'une observation d'aphémie (perte de parole). Bulletin de la Societé d'Anatomie, 36, 330-357.

Brosseau, J., & Cohen, H. (1996) The representation of semantic categories in aging. Experimental Aging Research, 22, 381-391.

Bunt, H.C. (1985) Mass Terms and Model-Theoretic Semantics. Cambridge: Cambridge University Press.

Burgess, C. & Simpson, G.B. (1988) Cerebral hemispheric mechanisms in the retrieval of ambiguous word meanings. Brain and Language, 33, 86-103.

Burke, D.M., MacKay, D. & James, L. (2000) Theoretical approaches to language and aging. In T. Perfect & E. Maylor (eds.) Models of Cognitive Aging (pp. 204-237). Oxford: Oxford University Press.

Burke, D.M., MacKay, D., Worthley, J., & Wade, E. (1991) On the tip of the tongue: What causes word finding failures in younger and older adults? Journal of Memory and Language, 30, 542-579.

Burke, D. & Peters, L. (1986) Word association in old age: Evidence for consistency in semantic encoding during adulthood. Psychology and Aging, 1, 283-291.

Butters, N., Granholm, E., Salmon, D.P., Grant, I. & Wolfe, J. (1987) Episodic and semantic memory: A comparison of amnesic and demented patients. Journal of Clinical and Experimental Neuropsychology, 9, 479-497.

Butterworth, B. L. (1983). Lexical representation. In Butterworth, B. L. (Ed.). Language production, Vol 2: Development, writing and other language processes. London: Academic Press.

CSHA (1994) Canadian Study of Health and Aging Working Group: study methods and prevalence of dementia. Canadian Medical Association Journal, 150: 899-913.

Caramazza, A. & Zurif, E. (1976) Dissociation of algorithmic and heuristic processes in language comprehension: evidence from aphasia. Brain and Language, 3:572–82

Cheng, C. (1973) Comments on Moravcsik's paper. In Hintikka, K.J.J., Moravcsik, J.M.E. & Suppes, P. (Eds.), Approaches to Natural Language (pp. 286-288), Dorcrecht: Reidel.

Chertkow, H. (2002) Mild Cognitive Impairment. Current Opinion in Neurology 15: 401-407.

Chertkow H. & Bub, D. (1990) Semantic memory loss in dementia of Alzheimer's type. What do various measures measure? Brain, 113: 397-417.

Chertkow, H., Bub, D. & Seidenberg, M. (1989) Priming and semantic memory loss in Alzheimer's disease. Brain and Language, 36, 420-446.

Chialant, D. & Caramazza, A. (1995) Where is morphology and how is it processed? The case of written word recognition. In L. Feldman (Ed.) Morphological Aspects of Language Processing. Hillsdale, NJ: Erlbaum Press. 55-76.

Clahsen, H. (1999) Lexical entries and rules of language: A multi-disciplinary study of Germal inflection. Behavioral and Brain Sciences, 22, 991-1013.

Clahsen, H. (in press) Dual-mechanism morphology. To appear in K. Brown (Ed.) Encyclopedia of Language and Linguistics. Elsevier: Oxford.

Cohen, G. & Faulkner, D. (1986) Memory for proper names: Age differences in retrieval. British Journal of Developmental Psychology, 4, 187-197.

Conway, M.A. (2001) Sensory-perceptual episodic memory and its context: autobiographical memory. Philosophical Transactions of the Royal Society, London, B, 356: 1375-1384.

Copestake, A. and Briscoe, T. (1995) Semi-productive polysemy and sense extension. Journal of Semantics 12:15-67.

Craik, F. (2000) Age-related changes in human memory. In Park, D. & Schwartz, N. (Eds.) Cognitive Aging: A Primer. Philadelphia: Psychology Press.

Craik, F. & Byrd, M. (1982) Aging and cognitive deficits: The role of attentional resources. In Craik, F. & Trehub, S. (Eds.) Aging and Cognitive Processes (pp. 191-211). New York: Plenum Press.

Craik, F. & Jennings, JM (1992) Human memory. In In F. Craik & T. Salthouse (Eds.) The Handbook of Aging and Cognition (2nd ed., pp. 51-110). Mahwah, NJ: Erlbaum.

Craik, F.I.M., Morris, R.G., & Gick, M.L. (1990) Adult age differences in working memory. In G. Vallar & T.Shallice (Eds.) Neuropsychological Impairments of Short-Term Memory. Cambridge, England: Cambridge University Press.

Cummings, J. (2000) Cognitive and behavioral heterogeneity in Alzheimer's disease: seeking the neurobioloigcal basis. Neurobiology of Aging, 21, 845-861.

Cummings, J. (2004) Alzheimer's disease. New England Journal of Medicine, 351, 56-67.

Damasio,A.R. (1989a) Time-locked multiregional retroactivation: A systems level proposal for the neural substrates of recall and recognition. Cognition, 33, 25-62.

Damasio, A.R. (1989b) The brain binds entities and events by multiregional activation from convergence zones. Neural Computation, 1, 123-132.

Damasio, A.R., Damasio, H., Tranel, D. & Brandt, J.P. (1990). Neural regionalization of knowledge access: preliminary evidence. Symposia on Quantitative Biology, 55, 1039-1047.

Damasio, A.R., & Damasio, H. (1994) Cortical systems for retrieval of concrete knowledge: the convergence zone framework. in C. Koch (Ed.) Large-scale neuronal theories of the brain. Cambridge, MA: MIT Press, 61-74.

Damasio, H., Tranel, D., Grabowski, T., Adolphs, R., & Damasio, A.R. (2004). Neural systems behind word and concept retrieval. Cognition, 92, 179-229.

Diagnostic and statistical manual of mental disorders: DSM-IV. 4th ed (1994). Washington, DC: American Psychiatric Association.

Dobbs, A.R. & Rule, B.G. (1989) Adult age differences in working memory. Psychology and Aging, 4, 500-503.

Dommes, A., & Le Rouzo, M.-L. (2004) Vieillisement cognitif et compréhension d'ambigüités lexicales: effect d'amorcage sémantique et familiarité du sens de paires homophoniques. Proceedings of the Cognitio 2004 conference, 60-72.

Duffy, S.A., Morris, R.K., & Rayner, K. (1988) Lexical ambiguity and fixation times in reading. Journal of Memory and Language, 27, 419-446.

Eichenbaum, H., & Cohen, N.J. (2001) From conditioning to conscious recollection: memory systems of the brain. New York: Oxford University Press.

Embick, D. & Poeppel, D. (in press) Mapping Syntax Using Imaging: Prospects and Problems for the Study of Neurolinguistic Computation. To appear in K. Brown (Ed.) Encyclopedia of Language and Linguistics. Elsevier: Oxford.

Emery, V.O.B., & Breslau, L.D. (1989) Language deficits in depression: comparisons with SDAT and normal aging. Journal of Gerontology, 44, M85-92.

Emery, V.O.B. (1985) Language and aging. Experimental Aging Research, 11, 3-60.

Eulitz, C., & Lahiri, A. (2004) Neurobiological evidence for abstract phonological representations in the mental lexicon during speech recognition. Journal of Cognitive Neuroscience, 16, 577-583.

Federmeier, K., Van Petten, C., Schwartz, T. & Kutas, M. (2003) Sounds, words, sentences: Age-related changes across levels of language processing. Psychology and Aging, 18, 858-872.

Forster, K.I., & Chambers, S.M. (1973) Lexical access and naming time. Journal of Verbal Learning and Verbal Behavior, 12, 627-635.

Frazier, L. and Rayner, K. (1990) Taking on semantic commitments: Processing multiple meanings vs. multiple senses. Journal of Memory and Language, 28: 181-200.

Frisson, S. & Frazier, L. (in press) Carving up word meanings: Portioning and grinding. Journal of Memory and Language.

Fuster , J.M. (1997). Network memory. Trends in Neurosciences, 20, 451–459.

Galmiche, M. (1989) Massif/comptable: de l'un à l'autre et inversement. In David, J. & Kleiber, G. (Eds.) Termes Massifs et Termes Comptables (Recherches linguistiques 13, pp. 63-77), Paris: Klincksieck.

Gabrieli, J.D.E., Cohen, N.J., & Corkin, S. (1988). The impaired learning of semantic knowledge following bilateral medial temporal lobe resection. Brain and Cognition, 7, 157-177.

Gardiner, J.M. (2001). Episodic memory and autonoetic consciousness: a first-person approach. Philosophical Transactions of the Royal Society, London, B, 356, 1352-1361.

Garrard, P. & Hodges, J. (1999). Semantic dementia: Implications for the neural basis of language and meaning. Aphasiology, 13(8), 609-623.

Garrard, P. & Hodges, J. (2000) Semantic dementia: clinical, radiological and pathological perspectives. Journal of Neurology, 247(6):409-22.

Geschwind, N. (1965) Disconnexion syndromes in animal and man. Brain, 88, 237-294.

Gillon, B. (1996) The lexical semantics of English mass and count nouns. In E Viegas (ed.) Breadth and Depth of Semantic Lexicons. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Gillon, B., Kehayia, E. and Taler, V. (1999) The mass/count distinction: Evidence from on-line psycholinguistic performance. Brain and Language 68(1-2): 205-211.

Goodglass, H. & Kaplan, E. (1972) Assessment of Aphasia and Related Disorders. San Diego, CA: Academic Press.

Gordon, P. (1985) Evaluating the semantic categories hypothesis: The case of the mass/count distinction. Cognition, 20, 209-242.

Grodzinsky, Y. (1984) The syntactic characterization of agrammatism. Cognition, 16:99-120.

Grodzinsky, Y. (2000) The neurology of syntax: Language use without Broca's area. Behavioral and Brain Sciences, 23, 1-21.

Grodzinsky, Y., & Finkel, L. (1998) The neurology of empty categories: Aphasics' failure to detect ungrammaticality. Journal of Cognitive Neuroscience, 10, 281-292.

Grossman, M., Carvell, S. and Peltzer, L. (1993) The sum and substance of it: The appreciation of mass and count quantifiers in Parkinson's Disease. Brain and Language 44: 351-384.

Grossman, M., Mickanin, J., Onishi, K. and Hughes, E. (1995) An aspect of sentence processing in Alzheimer's disease: Quantifier-noun agreement. Neurology 45: 85-91.

Hamm, V.P. & Hasher, L. (1992) Age and the availability of inferences. Psychology and Aging, 7, 56-64.

Harasty, J.A., Halliday, G.M., Code, C. & Brooks, W.S. (1996) Quantification of cortical atrophy in a case of progressive fluent aphasia. Brain, 119: 181-190.

Hartsuiker, R.J. & Kolk, H.H. (1998) Syntactic facilitation in agrammatic sentence production. Brain and Language, 62:221-254.

Hasher, L., Stoltzfus, E.R., Zacks, R.T. & Rypma, B. (1991) Age and inhibition. Journal of Experimental Psychology: Learning, Memory and Cognition, 17: 163-169.

Hasher, L. & Zacks, R.T. (1988) Working memory, comprehension and aging: A review and a new view. In G.H. Bower (Ed.) The psychology of learning and motivation: Advances in research and theory (Vol. 22). San Diego, CA: Academic Press.

Haughey, N. J., Nath, A., Chan, S. L., Borchard, A. C., Rao, M. S. & Mattson, M. P. (2002) Disruption of neurogenesis by amyloid beta-peptide, and perturbed neural progenitor cell homeostasis, in models of Alzheimer's disease. Journal of Neurochemistry, 83, 1509-1524

Hebb, D.O. (1949) The Organization of Behavior. A Neuropsychological Theory. New York: Wiley.

Hodges, J.R., Salmon, D.P. & Butters, N. (1992) Semantic memory impairment in Alzheimer's disease: Failure of access or degraded knowledge? Neuropsychologia, 30, 301-314.

Hodges, J.R., Salmon, D.P. & Butters, N. (1991) The nature of the naming deficit in Alzheimer's and Huntington's disease. Brain, 114: 1547-1558.

Howard, D. (1980) Category norms: A comparison of the Battig and Montague (1969) norms with the responses of adults between the ages of 20 and 80. Journal of Gerontology, 35, 225-231.

Howard, D. (1983) The effects of aging and degree of association on the semantic priming of lexical decisions. Experimental Aging Research, 9:145-151.

Huff, F.J., Corkin, S. & Growdon, J.H. (1986) Semantic impairment and anomia in Alzheimer's disease. Brain and Language, 28, 235-249.

Irigaray, L. (1973) Le langage des dements. The Hague: Mouton.

Jack, C., Petersen, R., Xu, Y., O'Brien, P., Smith, G., Ivnik, R., Boeve, B., Waring, S., Tangalos, E., and Kokmen, E. (1999) Prediction of AD with MRI-based hippocampal volume in mild cognitive impairment. Neurology 52: 1397-1403.

Jackendoff, R. (1992). Parts and boundaries. In B. Levin & S. Pinker (Eds.), Lexical and conceptual semantics (Cognition Special Issues). Cambridge, MA: Blackwell.

Joanisse, M.F., & Seidenberg, M.S. (1999) Impairments in verb morphology after brain injury: a connectionist model. Proceedings of the National Academy of Sciences USA, 96, 7592-7597.

Joosten, F. (2003). Accounts of the count-mass distinction: A critical survey. Nordlyd, 31(1), 216-229.

Kempen, G., & Huijbers, P. (1983). The lexicalization process in sentence production and naming: Indirect election of words. Cognition, 14, 185-209.

Kempler, D., Curtiss, S., and Jackson, C. (1987) Syntactic preservation in Alzheimer's disease. Journal of Speech and Hearing Research, 30, 343-350.

Kemtes, K.A. & Kemper, S. (1997) Younger and older adults' on-line processing of syntactic ambiguities. Psychology and Aging, 12, 362-371.

Kertesz, A. (1994) Language deterioration in dementia. In V.O.B. Emery & T.E. Oxman (Eds.) Dementia: Presentations, differential diagnosis and nosology. Baltimore: Johns Hopkins University Press.

Kleene, S.C. (1956) Representation of events in nerve nets and finite automata. In C.E. Shannon & J. McCarthy (Eds.) Automata Studies. Princeton University Press, Princeton NJ, 3-41.

Klepousniotou, E. (2002) The processing of lexical ambiguity: Homonymy and polysemy in the mental lexicon. Brain and Language 81: 205-223.

Klepousniotou, E. & Baum, S. (2003). Processing homonymous and polysemous words: The effects of focal left- and right-hemisphere damage. Presented at the Academy of Aphasia annual meeting, Vienna, Austria.

Klepousniotou, E., & Baum, S. (2005) Unilateral brain damage effects on processing homonymous and polysemous words. Brain and Language, 93, 308-326.

Klepousniotou, E. & Baum, S. (in press). Processing homonymy and polysemy: Effects of sentential context and time-course following unilateral brain damage. Brain and Language.

Knowles, R. B., Wyart, C., Buldyrev, S.V., Cruz, L., Urbanc, B., Hasselmo, M.E., Stanley, H.E., & Hyman, B.T. (1999) Plaque-induced neurite abnormalities: implication for disruption of neural networks in Alzheimer's disease. Proceedings of the National Academy of Sciences, USA: Neurobiology, 96, 5274-5279.

Kontiola P, Laaksonen R, Sulkava R, Erkinjuntti T. (1990) Pattern of language impairment is different in Alzheimer's disease and multi-infarct dementia. Brain and Language, 38, 364–83.

Laurent, B. and Thomas Antérion, C. (2002) Incertitudes et limites du MCI: apport de la neuropsychologie. Revue Neurologique 158(10): 5S11-5S20.

Lautenschlager, N.T., Riemenschneider, M., Drzezga, A. & Kurz, A.F. (2001) Primary degenerative mild cognitive impairment: Study population, clinical brain imaging and biochemical findings. Dementia and Geriatric Cognitive Disorders, 12, 379-386.

Laver, G.D. & Burke, D.M. (1993) Why do semantic priming effects increase in old age? A meta-analysis. Psychology and Aging, 8, 34-43.

Levelt, W.J.M., Roelofs, A., & Meyer, A.S. (1999) A theory of lexical access in speech production. Behavioral and Brain Sciences, 22, 1-45.

Lichtheim, L. (1885) On aphasia. Brain, 7, 433-484.

Light, L.L. (1996) Memory and aging. In Bjork, E.L. & Bjork, R.A., (Eds.) Memory (pp. 443-490). San Diego, CA: Academic Press.

Light, L.L. & Albertson, S.A. (1993) Comprehension of pragmatic implications in young and older adults. In L.L. Light & D.M. Burke (Eds.) Language, Memory and Aging. New York: Cambridge University Press.

Light, L. & Burke, D.M. (1993) Patterns of language and memory in old age. In L.L. Light & D.M. Burke (Eds.) Language, Memory and Aging. New York: Cambridge University Press.

Lindenberger, U. & Baltes, P.B. (1994) Sensory function and intelligence in old age: A strong connection. Psychology and Aging, 9, 339-355.

Lindenberger, U. & Baltes, P.B. (1997) Intellectual functioning in old and very old age: Cross-sectional results from the Berlin Aging Study. Psychology and Aging, 12, 410-432.

Longoni F., Grande M., Hendrich V., Kastrau F., & Huber W. (2005). An fMRI study on conceptual, grammatical and morpho-phonological processing. Brain and Cognition, 57, 131-134.

Lopez, O., Jagust, W., DeKosky, S. & Becker, J. Risk factors for mild cognitive impairment in a population study. Neurology, 58, A238.

Lovelace, E. & Cooley, S. (1982) Free associations of older adults to single words and conceptually related word triads. Journal of Gerontology, 37, 432-437.

Lukatela K, Shankweiler D, Crain S. (1995) Syntactic processing in agrammatic aphasia by speakers of a Slavic language. Brain and Language, 49(1):50-76

Madden, D., Turkington, T., Coleman, R., Provenzale, J., DeGrado, T. & Hoffman, J. (1996) Adult age differences in regional cerebral blood flow during visual word identification: Evidence from $H_2{}^{15}O$ PET. Neuroimage, 3, 127-142.

Madden, D., Langley, L., Denny, L., Turkington, T., Provenzale, J., Hawk, T. & Coleman, R. (2002) Adult age differences in visual word identification: Functional neuroanatomy by positron emission tomography. Brain and Cognition, 49, 297-321.

Markman, E.M. (1985) Why superordinate category terms can be mass nouns. Cognition, 19, 31-53.

Marslen-Wilson, W. (1973) Linguistic structure and speech shadowing at very short latencies. Nature, 244, 522-523.

Marslen-Wilson, W. D. (1987). "Functional parallelism in spoken word-recognition." Cognition, 25, 71-102.Forster, 1979

Marslen-Wilson, W.D., & Tyler, L. (1980) The temporal structure of spoken language processing. Cognition, 8, 1-71.

Marslen-Wilson, W., Tyler, L., Waksler, R., & Older L. (1994) Morphology and meaning in the English mental lexicon. Psychological Review, 101, 653-675.

Marslen-Wilson, W. D., & Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. Cognitive Psychology, 10, 29-63.

Martin, A. & Fedio, P. (1983) Word production and comprehension in Alzheimer's disease: The breakdown of semantic knowledge. Brain and Language, 19, 124-141.

Massaro, D. W., Venezky, R. L. & Taylor, G. A. (1979). Orthographic Regularity, Positional Frequency, and Visual Processing of Letter Strings: Revisited. Journal of Experimental Psychology: General, 108(1), 107-124 & 131-132.

Massoud, F., Chertkow, H., Whitehead, V., Overbury, O., & Bergman, H. (2002) Word-reading thresholds in Alzheimer disease and mild memory loss: A pilot study. Alzheimer Disease & Associated Disorders, 16, 31-39.

Mattson, M.P. (2000). Apoptosis in neurodegenerative disorders. Nature Reviews Molecular Cell Biology, 1, 120-129.

Mauner,G., Fromkin, V.A., & Cornell, T.L. (1993) Comprehension and acceptability judgements in agrammatism: Disruptions in the syntax of referential dependency. Brain and Language, 45, 340-370.

Maylor, E. (1990) Age and prospective memory. Quarterly Journal of Experimental Psychology, 42A, 471-493.

McCulloch, W.S., & Pitts, W.H. (1943) A logical calculus of ideas immanent in nervous activity. Bulletin of Mathematical Biophysics, 5, 115-133.

McKhann, G., Drachman, D., Folstein, M., Katzman, R., Price D., and Stadlan, E.M. (1984) Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRDA work group under the auspices of Health and Human Services Task Force on Alzheimer's Disease. *Neurology* 34, 939-944.

Mesulam, M. (1982). Slowly progressive aphasia without generalized dementia. Annals of Neurology, 11, 592-598.

Mesulam, M. (2003). Primary progressive aphasia – a languae-based dementia. New England Journal of Medicine, 349, 1535-1542.

Meyer, A.S., & Schvanevelt, R.W. (1971) Facilitation in recognizing words: Evidence of a dependence upon retrieval operations. Journal of Experimental Psychology, 90, 227-234.

Mishkin, M., Malamut, B., & Bachevalier, J. (1984) Memories and habits: two neural systems. In G. Lynch, J.L. McGaugh, & N.W. Weinburger (Eds.) Neurobiology of learning and memory. New York: Guilford Press, 65-77.

Miyamoto, T., Katayama, J., & Koyama, T. (1998). ERPs, semantic processing and age. International Journal of Psychophysiology, 29, 43-51.

Monsch, A.U., Bondi, M.W., Butters, N., Salmon, D.P., Katzman, R. & Thal, L.J. (1992) Comparisons of verbal fluency tasks in the detection of dementia of the Alzheimer type. Archives of Neurology, 49: 1253-1258.

Morton, J. (1969). The interaction of information in word recognition. Psychological Review, 76, 165-178.

Morton, J. (1970). A functional model for memory. In D.A. Norman (Ed.), Models of human memory. New York: Academic Press.

Murdoch, B.E., Chenery, H.J., Wilks, V. & Boyle, R.S. (1987) Language disorders in dementia of the Alzheimer type. Brain and Language, 31:122-137.

Nebes, R.D. & Brady, C.B. (1991) The effect of contextual constraint on semantic judgments by Alzheimer patients. Cortex, 27, 237-246.

Nadeau, S., Rothi, L., & Crosson, B. (2000) Aphasia and Language. New York: Guilford Press.

Nebes, R.D. & Brady, C.B. (1992) Generalized cognitive slowing and severity of dementia in Alzheimer's disease: implications for the interpretation of response-time data. Clinical and Experimental Neuropsychology, 14(2):317-26.

Ober, B.A., Dronkers, N.F., Koss, E., Delis, D.C. & Friedland, R.P. (1986) Retrieval from semantic memory in Alzheimer-type dementia. Journal of Clinical and Experimental Neuropsychology, 8, 75-92.

Ober, B.A. & Shenaut, G.K. (1988) Lexical decision and priming in Alzheimer's disease. Neuropsychologia, 26, 273-286.

Obler, L. & Gjerlow, K. (1999) Language and the Brain. Cambridge: Cambridge University Press.

Park, D. (2000) The basic mechanisms accounting for age-related decline in cognitive function. In Park, D. & Schwartz, N. (Eds.) Cognitive Aging: A Primer. Philadelphia: Psychology Press.

Pasquier, F., Lebert, F., Grymonprez, L. & Petit, H. (1995) Verbal fluency in dementia of frontal lobe type and dementia of Alzheimer type. Journal of Neurology, Neurosurgery and Psychiatry, 58:81-4.

Patel, P.G. & Satz, P. (1994) The language production system and senile dementia of the Alzheimer's type: Neuropathological implications. Aphasiology, 8, 1-18.

Pelletier, F.J. (1979). Non-singular reference: Some preliminaries. In F.J. Pelletier (Ed.), Mass terms: Some philosophical problems. Dordrecht: Reidel.

Perea, M., Rosa, E., & Gomez, C. (2002) Is the go/no-go lexical decision task an alternative to the yes/no lexical decision task? Memory and Cognition, 30, 34-45.

Petersen, R., Smith, G., Waring, S., Ivnik, R., Tangalos, E. and Kokmen, E. (1999) Mild cognitive impairment: Conceptual basis and current nosological status. Lancet 355: 225-228.

Petersen, R.C., Stevens, J.C., Ganguli, M., Tangalos, E.G., Cummings, J.L., & DeKosky, S.T. (2001). Practice parameter: Early detection of dementia: Mild cognitive impairment (an evidence-based review): Report of the Quality Standards Subcommittee of the American Academy of Neurology. Neurology, 56, 1133-1142.

Phillips, C., Pellathy, T., Yeung, H. & Marantz, A. (in preparation) Phonological feature representation in the auditory cortex.

Piñango, M.M. (2000). On the Proper Generalization for Broca's Aphasia Comprehension Pattern: Why Argument Movement may not be at the Source of the Brocas Deficit. Behavioral and Brain Sciences 23(1): 48-49.

Pinker, S. (1994) The language instinct: How the mind creates language. New York: Harper Collins.

Pinker , S. (1999) Words and rules: the ingredients of language. New York, NY: Basic Books.

Poeppel, D. & Embick, D. (in press) Defining the relation between linguistics and neuroscience. (To appear in A. Cutler ed. Twenty-first century psycholinguistics: Four cornerstones, Lawrence Erlbaum).

Poldrack, R. & Packard, M.G. (2003). Competition among multiple memory systems: converging evidence from animal and human brain studies. Neuropsychologia, 41, 245-251.

Pulvermüller, F. (1999) Words in the brain's language. Behavioral and Brain Sciences, 22, 253-279.

Pulvermüller, F. (2001). Brain reflections of words and their meaning. Trends in Cognitive Sciences, 5, 517-524.

Pulvermüller, F. (2002) A brain perspective of language mechanisms: From discrete neuronal ensembles to serial order. Progress in Neurobiology, 67, 85-111.

Pulvermüller, F., Assadollahi, R., & Elbert, T. (2001) Neuromagnetic evidence for early semantic access in word recognition. The European Journal of Neuroscience, 13, 201-205.

Pustejovsky, J. (1995) The generative lexicon. Cambridge, MA: MIT Press.

Quine, W.V.O. (1960) Word and object. Cambridge, MA: MIT Press.

Rayner, K., Binder, K.S., & Duffy, S.A. (1999) Contextual strength and the subordinate bias effect: Comment on Martin, Vu, Kellas and Metcalf. The Quarterly Journal of Experimental Psychology, 52, 841-852.

Rayner, K., & Frazier, L. (1989) Selection mechanisms in reading lexically ambiguous words. Journal of Experimental Psychology: Learning, Memory and Cognition, 15, 779-790.

Rayner, K., Pacht, J.M., & Duffy, S.A. (1994) Effects of prior encounter and global discourse bias on the processing of lexically ambiguous words: Evidence from eye fixations. Journal of Memory and Language, 33, 527-544.

Rochon, E., Waters, G.S., & Caplan, D. (1994) Sentence comprehension in patients with Alzheimer's disease. Brain and Language, 46, 329-349.

Rodd, J.M., Gaskell, G. & Marslen-Wilson, W. (2002) Making sense of semantic ambiguity: Semantic competition in lexical access. Journal of Memory and Language, 46, 245-266.

Rugg, M.D. (1983) Further study of the electrophysiological correlates of lexical decision. Brain and Language, 19, 142-152.

Rumelhart, D.E., & McClelland, J.L. (Eds.) (1986) Parallel distributed processing: Explorations in the microstructure of cognition. Cambridge, MA: MIT Press.

Salthouse, T. A. (1991) Theoretical Perspectives on Cognitive Aging. Hillsdale, NJ: Erlbaum.

Salthouse, T. (1993) Effects of aging on verbal abilities: Examination of the psychometric literature. In L. Light & D.M. Burke (Eds.) Language, Memory and Aging. New York: Cambridge University Press.

Salthouse, T.A. (1996) The processing-speed theory of adult-age differences in cognition. Psychological Review, 103, 403-428.

Savin, H.B. (1963) Word frequency effects and errors in the perception of speech. Journal of the Acoustical Society of America, 35, 200-206.

Schachter, D.L., & Tulving, E. (1994) Memory systems 1994. Cambridge, MA: MIT Press.

Schilling, H.E.H., Rayner, K., & Chumbley, J.I. (1998) Comparing naming, lexical decision and eye fixation times: Word frequency effects and individual differences. Memory and Cognition, 26, 1270-1281.

Schreuder, R. & Baayen, H. (1995) Modeling morphological processing. In L. Feldman (Ed.) Morphological Aspects of Language Processing. Hillsdale, NJ: Erlbaum Press. 131-154.

Schwartz, M., Marin, O. & Saffran, E. (1979) Dissociations of language funstion in dementia: A case study. Brain and Language, 7, 277-306.

Seidenberg, M.S., Tanenhaus, M.K., Leiman, J.M., & Bienkowski, M. (1982) Automatic access of the meanings of ambiguous words in context: Some limitations of knowledge-based processing. Cognitive Psychology, 14, 489-537.

Shillcock, R. (1990) Lexical hypotheses in continuous speech. In G.T.M. Altmann (Ed.) Cognitive models of speech processin: Psycholinguistic and computational perspectives. Cambridge, MA: MIT Press, 24-49.

Simpson, G.B., & Burgess, C. (1985) Activation and selection processes in the recognition of ambiguous words. Journal of Experimental Psychology: Human Perception and Performance, 11, 28-39.

Simpson, G.B., & Krueger, M.A. (1991) Selective access of homograph meanings in sentence context. Journal of Memory and Language, 30, 627-643.

Small, D. H., & McLean, C. A. (1999) Alzheimer's disease and the amyloid β-protein: what is the role of amyloid? Journal of Neurochemistry, 73, 443-449.

Spieler, D. & Balota, D. (2000) Factors influencing word naming in younger and older adults. Psychology and Aging, 15, 225-231.

Semenza, C., Mondini, S. and Cappelletti, M. (1997) The grammatical properties of mass nouns: An aphasia case study. Neuropsychologia 35(5): 669-675.

Shapiro, L., Zurif, E., Carey, S. and Grossman, M. (1989) Comprehension of lexical subcategory distinctions by aphasic patients: Proper/common and mass/count nouns. Journal of Speech and Hearing Research 32: 481-488.

Snowden, J.S., Goulding, P.J. & Neary, D. (1989). Semantic dementia: A form of circumscribed cerebral atrophy. Behavioural Neurology, 2, 167-182.

Soja, N.N., Carey, S., & Spelke, E. (1991) Perception, ontology and word meaning. Cognition, 45, 101-107.

Squire, L.R., & Knowlton, B.J. (2000) The medial temporal lobe, the hippocampus and the memory systems of the brain. In M.S. Gazzaniga (Ed.) The new cognitive neurosciences. Cambridge, MA: MIT Press, 765-780.

Steriade D.(1995) Markedness and underspecification in the study of segments. In J. Goldsmith (Ed.) A Handbook of Phonological Theory. Cambridge, MA and Oxford, UK: Blackwell.

Strain, E., Patterson, K., & Seidenberg, M.S. (1995). Semantic effects in single-word naming. Journal of Experimental Psychology: Learning, Memory and Cognition, 21, 1140-1154.

Swinney, D.A. (1979) Lexical access during sentence comprehension: (re)consideration of context effects. Journal of Verbal Learning and Verbal Behavior, 18, 645-659.

Swinney, D.A. (1991) The resolution of indeterminacy during language comprehension: Perspectives on modularity in lexical, structural and pragmatic process. In G.B. Simpson (Ed.) Understanding word and sentence. Amsterdam: Elsevier Science Publishers, 367-385.

Swinney, D., Zurif, E., and Nicol, J. (1989). The effects of focal brain damage on sentence processing: an examination of the neurological organization of a mental module. Journal of Cognitive Neuroscience, 1,:25-37.

Tabossi, P. (1988) Accessing lexical ambiguity in different types of sentential contexts. Journal of Memory and Language, 27, 324-340.

Taft, M., & Forster, K. (1975). Lexical storage and retrieval of prefixed words. Journal of Verbal Learning and Verbal Behaviour, 14, 638–647.

Tainturier, M.-J., Tremblay, M. & Lecours, A. (1989) Aging and the word frequency effect: A lexical decision investigation. Neuropsychologia, 27, 1197-1203.

Tanenhaus, M.K., Leiman, J.M., & Seidenberg, M.S. (1979) Evidence for multiple stages in the processing of ambiguous words in syntactic contexts. Journal of Verbal Learning and Verbal Behavior, 18, 427-440.

Ter Meulen, A. (1981) A Instensional Logic for Mass Terms. Philosophical Studies, 40:105-125.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), Organization of memory. New York: Academic Press.Whitaker, H. (1976) A case of isolation of language function. In H. Whitaker & H.A. Whitaker (Eds.) Studies in Neurolinguistics. New York: Academic Press.

Tulving, E. (1995) Organization of memory: quo vadis? In M.S. Gazzaniga (Ed.) The cognitive neurosciences. Cambridge, MA: MIT Press, 839-847.

Tulving, E. (2001) Episodic memory and common sense: How far apart? Philosophical Transactions of the Royal Society, London, B, 356, 1505-1515.

Ullman, M.T. (2001) A neurocognitive perspective on language: the declarative/procedural model. Nature Reviews Neuroscience, 2, 717-726.

Ullman, M.T. (2004) Contributions of memory circuits to language: the declarative/procedural model. Cognition, 92, 231-270.

Ullman, M.T., Corkin, S., Coppola, M. Hickock, G., Growdon, J.H., Koroshetz, W.J., & Pinker, S. (1997) A neural dissociation within language: evidence that the mental dictionary is part of declarative memory, and that grammatical rules are processed by the procedural system. Journal of Cognitive Neuroscience, 9, 266-276.

Wernicke, K. (1874) Der Aphasische Symptomencomplex. Breslau: Cohn und Weigert.

Whiting, W., Madden, D., Langley, L., Denny, L., Turkington, T., Provenzale, J., Hawk, T. & Coleman, R.E. (2003) Lexical and sublexical components of age-related changes in neural activation during visual word identification. Journal of Cognitive Neuroscience, 15, 475-487.

Wierzbicka, A. (1991). Semantic rules know no exceptions. Studies in Language, 15, 371-398.

Wilson, B.A., & Baddeley, A.D. (1998). Semantic, episodic and autobiographical memory in a post-meningitic amnesic patient. Brain and Cognition, 8, 31-46.

Wingfield, A., Stine, E.A., Lahar, C.J. & Aberdeen, J.S. (1988) Does the capacity of working memory change with age? Experimental Aging Research, 14, 103-107.

Wingfield, A. & Stine-Morrow, E. (2000) Language and speech. In F. Craik & T. Salthouse (Eds.) The Handbook of Aging and Cognition (2nd ed., pp. 359-416). Mahwah, NJ: Erlbaum.