

Processing of mass/count information in Alzheimer's disease and mild cognitive impairment[☆]

Vanessa Taler^{a,b,*} and Gonia Jarema^{a,b,c}

^a Centre de Recherche de l'Institut Universitaire de Gériatrie de Montréal, 4565 Chemin Queen Mary, Montreal, Que., Canada H3W 1W5

^b Département de Sciences Biomédicales, Université de Montréal, Montreal, Que., Canada

^c Département de Linguistique, Université de Montréal, Montreal, Que., Canada

Accepted 3 December 2003

Available online 4 February 2004

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 10 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 metonymous nouns. It is further claimed that, at least within the limits of the study, language impairments can be of the same severity and nature across AD and MCI subjects. © 2003 Elsevier Inc. All rights reserved.

1. 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 Caramelli, Mansur, & Mitrini, 1998; Smith, Chenery, & Murdoch, 1989a; Smith, Murdoch, & Chenery, 1989b). It has generally been claimed that syntax is more or less intact in AD (see, e.g., Irigaray,

1973; Bayles, 1982; Cummings, Benson, Hill, & Read, 1985; Murdoch, Chenery, Wilks, & 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 et al., 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 1. 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.

[☆]The research reported in this article was supported by an FCAR doctoral fellowship awarded to the first author, and a MCRI (Major Collaborative Research Initiative) grant from the Social Sciences and Humanities Research Council of Canada (412-95-0006) awarded to Gonia Jarema (Université de Montréal), director and coprincipal investigator, Eva Kehayia (McGill University), coprincipal investigator, and Gary Libben (University of Alberta), coprincipal investigator. Thanks go to Dr. Howard Chertkow and to Shelley Solomon and Chris Hossein for their assistance in recruiting the AD and MCI subjects, to all the subjects who participated in this study, and to an anonymous reviewer for helpful comments and suggestions.

*Corresponding author.

E-mail address: vanessa.taler@umontreal.ca (V. Taler).

Table 1
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 & 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 10 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 & Thomas Antérion, 2002) and decreased hippocampal volume (Jack et al., 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 experiments reported in this paper investigate the availability of information regarding the mass/count distinction in English-speaking AD and MCI subjects.

1.1. 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., *gravel*, *garlic*) cannot take the plural (**two garlics*), cannot take the indefinite article (**a gravel*), and cannot take quantifiers that necessarily denumerate (**many gravels*). 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, 1996, 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, & 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 participants, 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 metonymous 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 metonymous 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. Metonymous 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 is 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 (Kempen & Huijbers, 1983), 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.

2. Experiment 1

2.1. Method

Participants. Fourteen subjects meeting the criteria for probable Alzheimer's disease (pAD) (McKhann et al., 1984), 10 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. AD and MCI subjects were recruited from the Jewish General Hospital in Montreal. Details on individual AD subjects are provided in Table 2, and details on MCI subjects are provided in Table 3. 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 2
AD subjects

Subject	Age	Education	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	Moderate/severe	18	9	Aricept
JW	74	7	Moderate/severe	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 3
MCI subjects

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 A. 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 10 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 10 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 to 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.

2.2. 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 10 (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 Figs. 1 and 2.

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 4. These error patterns are discussed and interpreted below.

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. Furthermore, 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

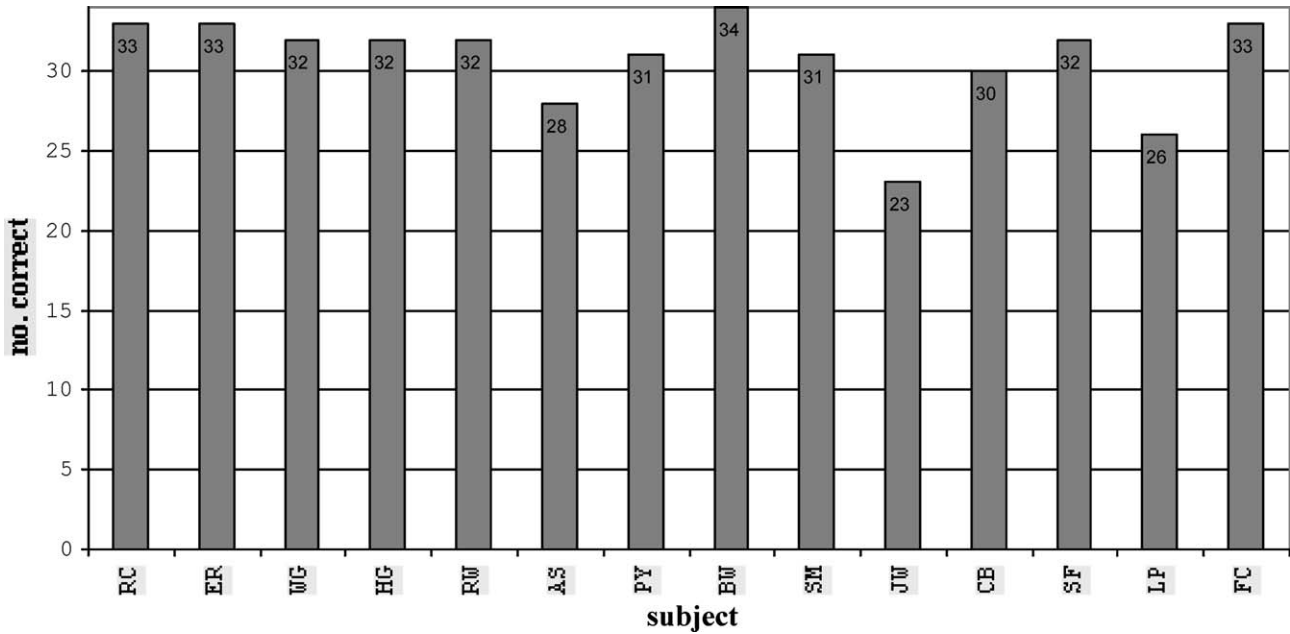


Fig. 1. AD subject results—overall.

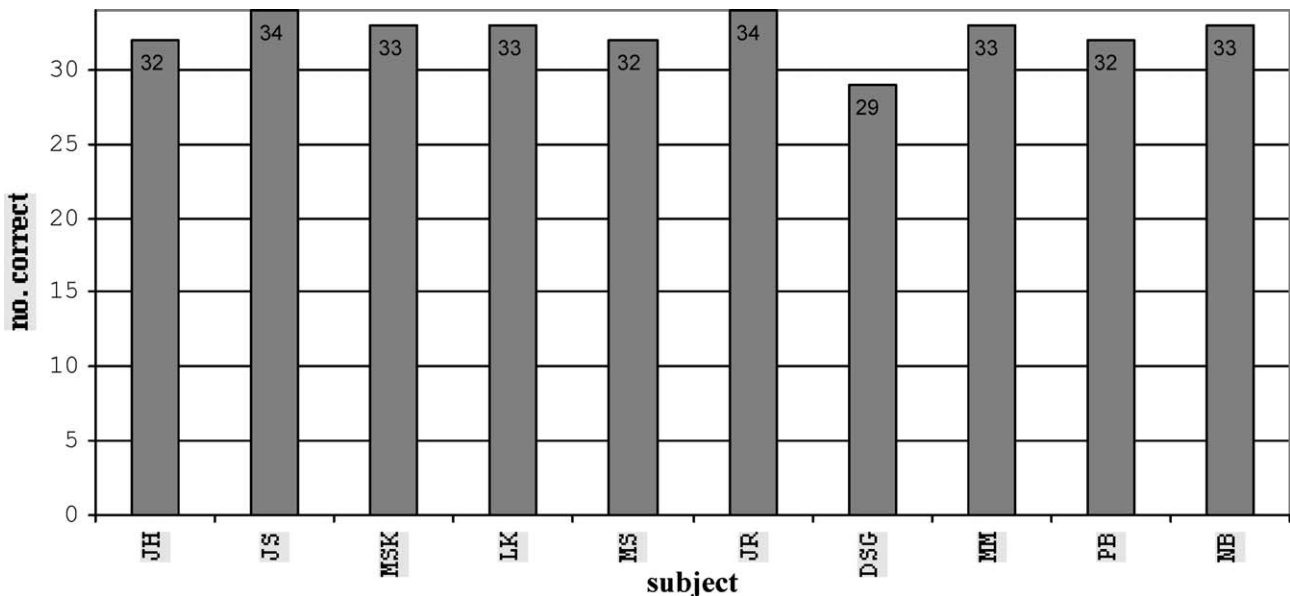


Fig. 2. MCI subject results—overall.

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

Table 4
Number of errors and items incorrectly judged in each category for impaired subjects

Subject	Count gram.	Count ungram.	Mass gram.	Mass ungram.
JW	2	4	2	2
items incorrectly judged	A swan A beetle	*Much button *Much beetle *A bit of medal *A bit of swan	Much paint Much snow	*A snow *A pork
AS	2	3	0	1
	A swan A beetle	*Much beetle *A bit of medal *A bit of swan		*A snow
LP	3	1	1	3
	A swan Each cat A beetle	*A bit of needle	Much paint	*Each gold *Every mustard *A pork
DSG	2	0	3	0
	Every doll A needle		A bit of mustard Much paint	

rejected all ungrammatical sentences indicates that she does not have difficulty detecting quantifier–noun violations.

In summary, 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 categorised as having moderate to severe AD, as opposed to the remaining subjects in the AD group, who were categorised 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. We have suggested above 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.

3. Experiment 2

3.1. Method

Participants. The subjects that took part in this experiment were the same as those that took part in Experiment 1; that is, 20 healthy older controls, 14 subjects meeting the criteria for a diagnosis of probable AD, and 10 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.

3.2. Results and discussion

Each subject received three scores out of 17. 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 Fig. 3, the MCI subjects' in Fig. 4. Asterisks next to a subject's code indicate that the subject manifested an impairment in Experiment 1.

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 ($p < .05$), 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 appear to comprehend 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 cor-

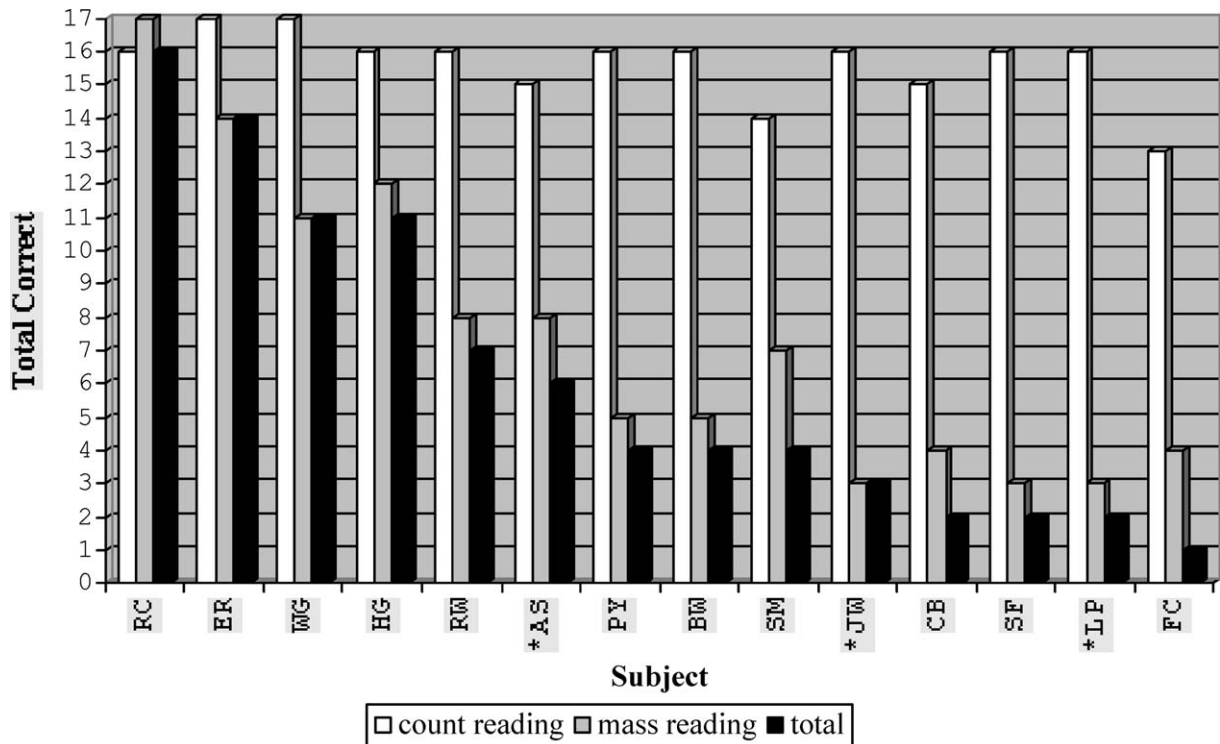


Fig. 3. AD subject results.

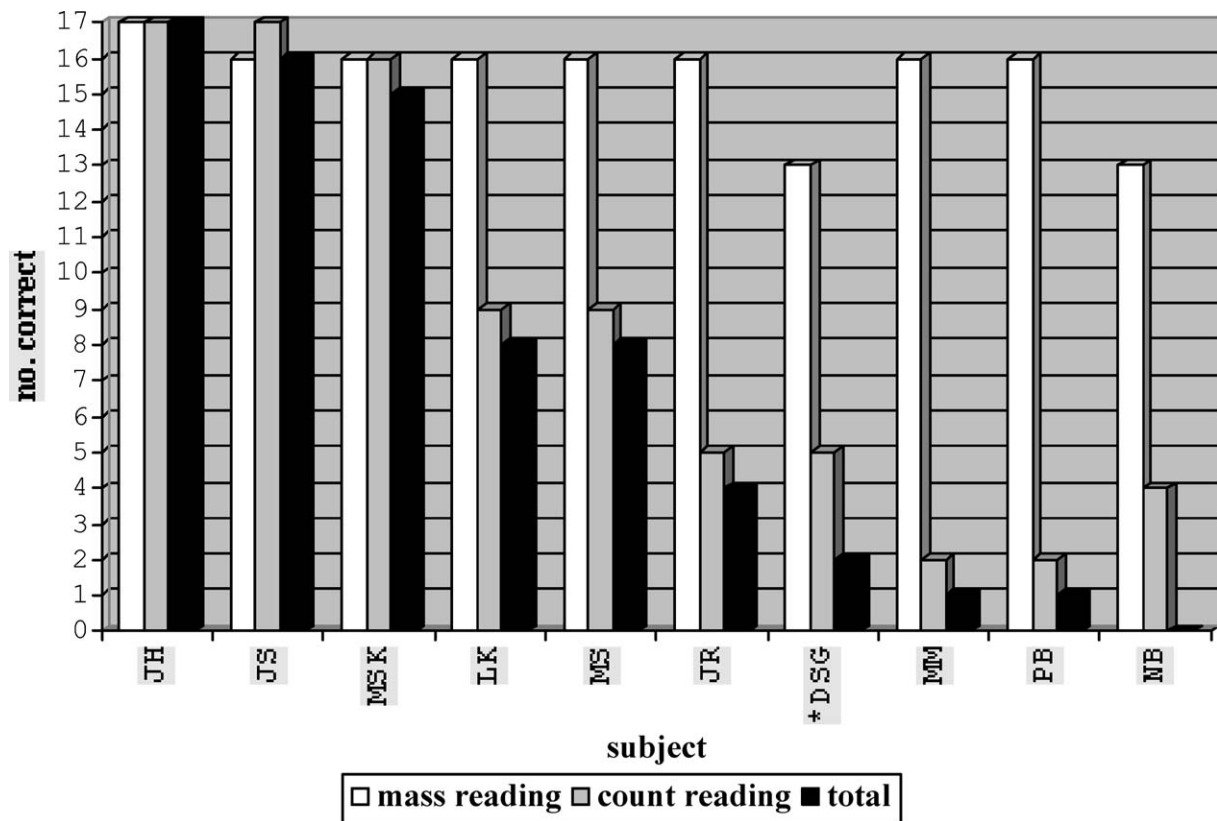


Fig. 4. MCI subject results.

rectly 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 claim 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 years 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 5. Twelve 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 5.

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 4) 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 Fig. 5. Many researchers (see, e.g., Chan, Salmon, & De La Pena, 2001; Fung et al., 2001; Montanes, Goldblum, & 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.

It can be seen in Fig. 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.

4. 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, 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

Table 5
Relative mass-count frequency by item and subgroup

Item	Type	Frequency
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

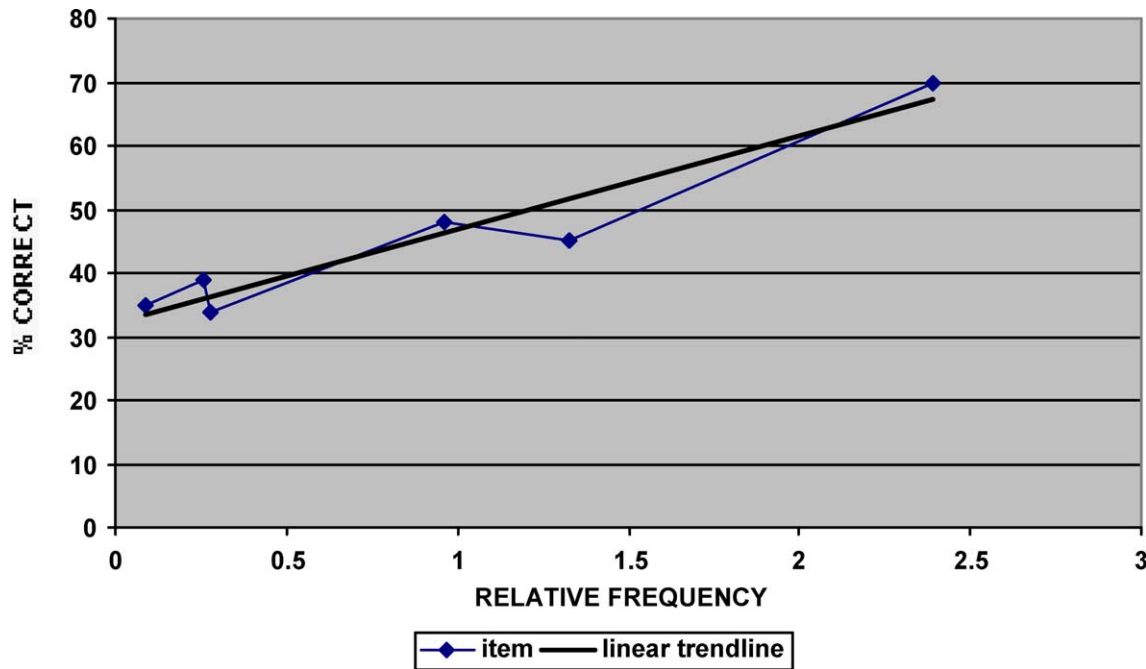


Fig. 5. Item/subgroup frequency by % correct.

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.

4.1. Attentional and/or learning factors

As was discussed above, four of the subjects in Group II demonstrated a response pattern which raised 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 realised that the absence of a determiner required a mass reading. In linguistic terms, we claim 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.

4.2. Semantic factors

Fifteen 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 proposed (Copestake & 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.

4.3. Grammatical factors

It was postulated 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 that allow both a mass and a count reading were included. Furthermore, in no case was the subject required to interpret the *absence* of a determiner, that is, a \emptyset 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.

4.4. Implications for a theory of lexical ambiguity processing in AD and MCI

The results of this study suggest that AD and MCI subjects have impaired access to or representation of the different senses of metonymous lexical items. This does not necessarily extend to other homonymous items. Chenery, Ingram, and Murdoch (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 (330 ms), as did control subjects. Clearly, the AD subjects had preserved access to both meanings of homophones. This points to 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 metonymous nouns (that is, nouns with meaning ambiguity and nouns with sense ambiguity). In the case of meaning ambiguity, it is hypothesised that each meaning has its own lexical entry, 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 deficit appears not to be a result of impaired 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.

4.5. *The effect of patient group*

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-demential 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.

4.6. *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 \emptyset 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 (2 of 14 AD subjects and 3 of 10 MCI subjects) exhibited no impairment on this task; their performance was statistically indistinguishable from that of control subjects. A second group, including 8 of 14 AD subjects and 5 of 10 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. We have 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.

Appendix A. 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:	<p>Count grammatical</p> <p>The baby likes every doll. The shirt is missing a button. The office sold every ticket. The embassy is flying a flag. The little boy fed a swan. The woman bought a lamp. The cat is stalking a beetle. The soldier cleaned each medal. The neighbour fed each cat. The woman bought a needle.</p> <p>Mass grammatical</p> <p>The child wants a bit of mustard. The meal included a bit of rice. The store doesn't have much paint. That ring doesn't contain much gold. Florida doesn't get much snow. The tide didn't move much sand. Norman ate a bit of pork.</p>	<p>Count ungrammatical</p> <p>*The girl doesn't love much doll. *The drycleaner loses much button. *They didn't have much ticket. *This shop doesn't have much flag. *The millionaire owns a bit of swan. *The house has a bit of lamp. *The lizard kills much beetle. *He has earned a bit of medal. *The baby doesn't like much cat. *The seamstress wants a bit of needle.</p> <p>Mass Ungrammatical</p> <p>*The boy spread every mustard. *The children ate each rice. *The dog spilled a paint. *The man polished each gold. *James is clearing a snow. *Harry couldn't weigh every sand. *The waitress served a pork.</p>

Appendix B. 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

Appendix B (continued)

	Count Reading	Mass Reading
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

- 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.
- Bayles, K. (1982). Language function in senile dementia. *Brain and Language*, 16, 265–280.
- Caramelli, P., Mansur, L. L., & Mitrini, R. (1998). Language and communication disorders in dementia of the Alzheimer's type. In B. Stemmer & H. Whitaker (Eds.), *Handbook of neurolinguistics*. 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.
- Copestake, A., & Briscoe, T. (1995). Semi-productive polysemy and sense extension. *Journal of Semantics*, 12, 15–67.
- Cruse, D. A. (1986). *Lexical semantics*. Cambridge, UK: 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*. Oxford: Oxford University Press.
- 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. (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., & 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.
- 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, UK: 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., & 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, UK: 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.
- 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.
- 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. (1989a). Semantic abilities in dementia of the Alzheimer type. 2. Grammatical semantics. *Brain and Language*, 36, 533–542.
- Smith, S., Murdoch, B., & Chenery, H. (1989b). Semantic abilities in dementia of the Alzheimer type. 1. Lexical semantics. *Brain and Language*, 36, 314–324.