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## Research report

# The impact of dementia, age and sex on category fluency: Greater deficits in women with Alzheimer's disease

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### ABSTRACT

A category specific effect in naming tasks has been reported in patients with Alzheimer's dementia. Nonetheless, naming tasks are frequently affected by methodological problems, e.g. ceiling effects for controls and "nuisance variables" that may confound results. Semantic fluency tasks could help to address some of these methodological difficulties, because they are not prone to producing ceiling effects and are less influenced by nuisance variables. One hundred and thirty-three participants (61 patients with probable AD; and 72 controls: 36 young and 36 elderly) were evaluated with semantic fluency tasks in 14 semantic categories. Category fluency was affected both by dementia and by age: while in nonliving-thing categories there were differences among the three groups, in living thing categories larger lexical categories produced bigger differences among groups. Sex differences in fluency emerged, but these were moderated both by age and by pathology. In particular, fluency was smaller in female than male Alzheimer patients for almost every subcategory.

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## 1. Introduction

On tests of picture naming, patients with Alzheimer's disease (AD) display a well-documented anomia that becomes more pronounced as pathological changes accrue in the brain. Furthermore, when AD patients do make naming responses, they tend to produce semantically related naming errors (e.g. 'tiger' for lion; 'celery' for asparagus) and demonstrate a strong item-to-item consistency across different tasks tapping semantic representations such as picture naming, word-to-picture matching or naming-to-definition (Chertkow and Bub, 1990). These findings have been widely assumed to reflect a breakdown in semantic memory (Bayles et al., 1990; Chertkow and

Bub, 1990; Done and Gale, 1997; Hodges et al., 1992). A deterioration in semantic memory function is thought to be one of the earliest markers of AD, being detectable even in Mild Cognitive Impairment cases, i.e. in pre-AD neuropathology (e.g. Adlam et al., 2006; Vogel et al., 2005). Indeed, the incidence of semantic memory deficits in mild AD has been estimated as high as 50% (Hodges et al., 1992).

Although the majority of research on category specific semantics occurs through single case studies of neurological patients, patients with AD offer an opportunity to test hypotheses about semantic organisation in moderately large patient samples. Silveri et al. (1991) carried one of the first works that reported category specific deficits in AD for naming

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pictures of living things. This study was later replicated by Tippett et al. (1996) who expanded on Silveri et al.'s findings by showing that living category impairments disappeared once the items were controlled for familiarity, lexical frequency and visual complexity (which all favoured nonliving things). In this way, Tippett and collaborators concluded that Silveri et al.'s findings were a product of uncontrolled nuisance variables. Most group-studies of picture naming in AD patients document a living thing impairment and in some cases, this may reflect the lack of control over nuisance variables. Nonetheless, the opposite pattern has been reported and so, would militate against this providing a complete explanation. A recent meta-analysis of 21 studies involving over 500 AD patients and 500 healthy controls (Laws et al., 2007) indicates, however, that the impression of a greater incidence of living thing deficits in AD patients may be misleading. Laws et al. (2007) found no significant difference in the effect size for naming pictures of living and nonliving things in AD patients. Hence, the evidence for category effects in AD patients on picture naming tasks is perhaps more ambivalent than imagined.

Furthermore, the semantic effects may have a strong relationship to the sex of participants: with men showing better performance in some nonliving subcategories, and women showing an advantage for some living subcategories (for reviews, see Gainotti, 2005; Laiacona et al., 2006). For example, in their study of 11 AD patients (seven males and four females) Laiacona et al. (1998) reported greater deficits for living things, specifically for animals, fruits and vegetables in males; on the other hand, women tended to have greater nonliving deficits specifically for furniture, tools and vehicles. Similar sex-by-domain interactions have been reported for healthy participants (e.g. Laws, 1999, 2004). This has led some authors to propose the existence of a sex specialization in the processing of some semantic subcategories (Barbarotto et al., 2002; Capitani et al., 1999; Laiacona et al., 2005; Laws, 1999, 2004; McKenna and Parry, 1994; Moreno-Martínez et al., 2007). Nevertheless, in a large fluency study, Marra et al. (2007) reported better furniture fluency in elderly females and female AD patients, and better bird fluency in elderly males, but not in male AD patients. Marra and co-workers use these findings to conjecture in favour of sex-based familiarity effects.

Picture naming is the most commonly used task to study category effects in AD patients (Laws et al., 2007); however, as noted, problems have arisen from the use of such tasks. The first one, already mentioned above, concerns the fact that various cognitive and psycholinguistic variables (also known as “intrinsic” or “nuisance variables”) tend to benefit the nonliving things (Funnell and Sheridan, 1992; Stewart et al., 1992; Tippett et al., 1996). A second disadvantage concerns the fact that the naming performance of control participants in most of the AD studies is invariably at ceiling or near a ceiling effect (Laws, 2005; Moreno-Martínez and Laws, 2007). These ceiling effects in control groups probably reflect the widespread reliance upon simple line drawings that controls have little difficulty in naming under normal conditions (Laws and Gale, 2002; Laws and Hunter, 2006). Studies comparing patient performance with that of ceiling level performance in controls may distort both the incidence and even the direction of category deficits reported (see Laws et al., 2005). Finally,

research into category specificity has focussed on a small range of living and nonliving subcategories (e.g. living is sometimes treated as equivalent to animals), thus making it difficult to form reliable conclusions about domain specific knowledge effects, especially in AD patients (Aronoff et al., 2006). While the overall living versus nonliving distinction is interesting, it is especially pertinent to examine more specific subordinate categories (e.g. body parts and plants) to gain detailed knowledge about salient differences that may contribute to and underpin category specific effects. Of course, it is possible that the reported category deficits in AD patients do not extend uniformly across all subcategories of living or nonliving things, respectively.

By comparison with picture naming tasks, category fluency tasks offer some methodological advantages, especially for the investigation of domain specific knowledge effects. Fluency tasks are especially sensitive in detecting semantic impairment and some authors have suggested that they are more adequate than picture naming tasks in studies of AD patients (Henry et al., 2004). For example, fluency tasks are not prone to producing ceiling effects in healthy subjects, although floor effects in (severe) dementia subjects can obviously occur. Additionally, since subjects are required to generate items for a specific category, their performance will not reflect a lack of control over nuisance variables such as familiarity (assuming that the category itself is broad enough and contains a sufficient large number of items: Laws, 2004).

The aim of the current study was to explore category specificity in three groups using a wide range of 14 semantic fluency tasks: AD patients, healthy elderly and healthy young participants. Since our research design included two different age control groups, we were able to not only test for dementia effects, but also for the reported inverse relationship between age and category fluency (Borod et al., 1980; Parkin et al., 1995; Peraita et al., 2000; Tomer and Levin, 1993; Whelihan and Leshner, 1985), including studies on large populations (Auriacombe et al., 2001; Crossley et al., 1997; Wiederholt et al., 1993).

We would expect dementia patients to have the lowest semantic fluency performance across all subcategories of knowledge. Similarly, we would predict an effect of aging, with the younger control group generally outperforming elderly controls in generating items for all subcategories. Predictions regarding the impact of age and dementia on specific subcategories would be more speculative (given that no previous study has examined this wide range of subcategories). Nonetheless, we would expect an interaction between sex and some subcategories and generally, such interactions would be expected to accord with the female advantage for living things and a male advantage for nonliving things. To reveal any category specific effects, it was particularly important to examine interaction effects involving the groups, sex, the two knowledge domains and their individual subcategories.

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## 2. Methods

### 2.1. Participants

There were 133 participants in this study divided into three groups: a group of 61 patients diagnosed with probable AD

and two age control groups, one of 36 healthy elderly participants and one of 36 healthy young participants (see Table 1). All the participants were native Spanish speakers. We administered the Mini Mental State Examination (MMSE: Folstein et al., 1975) to AD patients and the elderly group, but not to the young participants.

The 61 AD patients were consecutive admissions diagnosed by Spanish senior neurologists; these patients underwent neurological examination, laboratory tests and brain imaging to eliminate other possible causes of dementia. All of the patients fulfilled the NINCDS-ADRDA criteria (McKhann et al., 1984) and DSM-IV-TR for probable AD, and were in a mild-to-moderate stage of dementia (female MMSE range 4–30, median = 20; male MMSE range 8–27, median = 22). No patient showed depression or any other medical or neurological condition that could have affected cognitive performance.

The 36 healthy elderly and the 36 healthy young participants were volunteers with no history of alcoholism, drug abuse, psychiatric or neurological disorders. An additional exclusion criterion for the elderly participants was a MMSE score below 25 (after correcting for age and educational level in the Spanish population: Blesa et al., 2001).

The elderly control group did not differ significantly from the dementia group in terms of key demographic variables, including numbers of males and females,  $\chi^2(1) = .02, p = .90$ , mean age and education ( $p > .05$ ). All participants, or their families, gave their informed consent to participate in the study.

## 2.2. Procedure

The fluency task used in this study is a subset of the *Nombela* semantic battery (Moreno and Cañamón, 2005). This task includes 14 semantic subcategories, seven of the living domains: animals, body parts, insects, flowers, fruits, trees and vegetables; and seven of the nonliving domains: buildings, clothing, furniture, kitchen utensils, musical instruments, tools and vehicles. These subcategories were presented to each participant in a pseudorandom order with the following constraints: that two subcategories from the same domain never appear consecutively and that the subcategory of animals was always presented before the subcategory of insects, to avoid any possible priming effect.

Consistent with standard instructions, the participants were asked to generate in 60 sec as many words as possible of the above-mentioned subcategories. For each category, the total number of responses was recorded and transcribed.

Any repetition and intrusion (e.g. to include *pear* in the category of *trees*) were eliminated. Furthermore, items from a subcategory (e.g. *fish*) were accepted only if participant did not produce any exemplar of that subcategory (e.g. *sardine*).

## 3. Results

Multivariate Analysis of Variance (MANOVA) was conducted for each group to detect any sex differences in performance on the seven living and nonliving subcategories. For the dementia group, the MMSE scores were used as covariate to control for differences in dementia severity between males and females. Factorial mixed design Analysis of Variances (ANOVAs) with group and sex as between groups factors and domain and subcategory as within-subjects factors were used to compare the level of performance among the three groups (i.e. young, elderly and dementia subjects) and also across the two sets of seven subcategories for the living and nonliving domains. Inspection of the box plots revealed one extreme case among the males in the young control group and this was removed then from the analysis. No grave violations of the normality assumption (largest skewness value 1.6) emerged, but for some analyses the assumption of variance homogeneity was violated (largest F-max value: 12.6) as was the assumption of sphericity, in which case Huynh–Feldt  $\epsilon$ -adjusted degrees of freedom were used. Considering these violations and taking into account the moderate cells' sizes of the full factorial ANOVAs, as well as the number of statistical tests, it was decided to set statistical significance at a more stringent value of 1% in order to limit the experiment-wise error (Howell, 2002; Keppel and Wickens, 2004).

The ANOVAs were conducted by testing a full model first and, if possible, by then removing nonsignificant interaction effects from the model. Follow-up analyses for significant interactions involved testing of simple main effects followed by simple comparisons. For significant main effects, post-hoc comparisons were made for marginal means. For all follow-up analyses involving pairwise mean comparisons, Sidak–Bonferroni adjusted *p*-values were used to counter the effect of multiple testing with a family-wise alpha error set at 1%.

We fully explored the potential role of education as a confounder across all groups and all subcategories. Inspection of the correlations between education and the seven living subcategories revealed just one that was significant for vegetables in the young control group ( $r = -.48, p = .003$ ); one for animals in the elderly controls ( $r = -.35, p = .04$ ) and one borderline

**Table 1 – Demographic variables (mean and SD) for each group of participants**

	Young		Elderly		AD	
	Male (n = 18)	Female (n = 18)	Male (n = 17)	Female (n = 19)	Male (n = 28)	Female (n = 33)
Age	31.7 (6.9)	29.8 (7.7)	72.6 (6.2)	70.2 (7.9)	73.7 (6.0)	74.9 (9.3)
Education	10.1 (1.9)	9.9 (1.5)	10.7 (5.7)	9.2 (3.2)	9.2 (5.4)	7.1 (4.1)
MMSE <sup>a</sup>	n.a.	n.a.	29.3 (.8)	28.8 (1.7)	21.2 (4.2)	18.9 (4.9)

Note: n.a. = not applied.

<sup>a</sup> After correction for age and education for Spanish population (Blesa et al., 2001).

significant for vegetables in the dementia group ( $r = -.24$ ,  $p = .06$ ). All other correlations were weak and nonsignificant. Within the nonliving domain, we found one significant positive correlation in the elderly control group (musical instruments,  $r = .39$ ,  $p = .02$ ); one negative in the young control group (buildings,  $r = -.36$ ,  $p = .03$ ); and one positive in the dementia group (vehicles,  $r = .27$ ,  $p = .04$ ). All other correlations within this domain were nonsignificant and weak. This pattern of correlations did not imply that education was an important confounder in our study. Nonetheless, because of the previously reported importance of this variable (Ostrosky-Solis et al., 2007), we ran the mixed factorial ANOVAs reported below with education included as a covariate; however, as suspected, it had no adjusting power ( $p > .30$ ) and was therefore removed from the final model. The level of education reported here did not appear to differ from that in previous studies reporting an effect of education on category fluency in healthy controls (e.g. Capitani et al., 1999; Ostrosky-Solis et al., 2007).

### 3.1. Category specific sex differences in normal subjects

We first examined sex differences in category fluency in each of the two normal control groups separately for the living and nonliving subcategories (see Tables 2 and 3 for means and SDs). The MANOVA for the young group indicated no sex differences on either the seven living, *Hotelling's T* = .098,  $F < 1$ , or seven nonliving subcategories, *Hotelling's T* = .24,  $F < 1$ . By contrast, in the elderly group the MANOVA revealed significant sex differences for the living subcategories of considerable magnitude, *Hotelling's T* = 1.18,  $F(7, 28) = 4.73$ ,  $p = .001$ ,  $\eta_p^2 = .54$ , and also for the nonliving subcategories, *Hotelling's T* = 1.40,  $F(7, 28) = 5.61$ ,  $p < .001$ ,  $\eta_p^2 = .58$ . Univariate follow-up analysis with Bonferroni adjusted  $p$ -values revealed that elderly females had better fluency for flowers (Cohen's  $d = 1.14$ ), vegetables (Cohen's  $d = 1.35$ ) and kitchen utensils (Cohen's  $d = 1.10$ ), while elderly males showed better fluency for musical instruments (Cohen's  $d = .96$ ).

### 3.2. Category specific sex differences in dementia patients

We repeated the analysis for the AD patients, but with the MMSE scores included in the model as a covariate to adjust

the male and female groups for dementia severity. The MANCOVA in relation to the living subcategories revealed significant sex differences, *Hotelling's T* = .44,  $F(7, 52) = 3.27$ ,  $p = .006$ ,  $\eta_p^2 = .31$ , *Hotelling's T* = .38,  $F(7, 52) = 2.84$ ,  $p = .01$ ,  $\eta_p^2 = .28$ . Follow-up analyses showed that males performed significantly better on insects (Cohen's  $d = .82$ ,  $p = .002$ ) and trees (Cohen's  $d = .88$ ,  $p = .001$ ). There were also considerable sex differences on the nonliving subcategories, *Hotelling's T* = .44,  $F(7, 52) = 4.36$ ,  $p = .006$ ,  $\eta_p^2 = .37$ , when adjusted for severity of dementia, *Hotelling's T* = .59,  $F(7, 52) = 4.41$ ,  $p = .001$ ,  $\eta_p^2 = .37$ . Follow-up analyses revealed mean differences on vehicles (Cohen's  $d = .70$ ,  $p = .008$ ), tools (Cohen's  $d = .80$ ,  $p = .003$ ), and musical instruments (Cohen's  $d = .96$ ,  $p < .001$ ), with all again favouring male over female AD patients (Figs. 1 and 2).

### 3.3. Overall performance level on the living and nonliving domains

Overall performance for the living and nonliving domains was defined as the sum of the correct items named for each fluency task. A 3-factor mixed ANOVA with group and sex as between-subjects factors and domain (i.e. living vs. nonliving) as repeated measures factors yielded the following results: the main effect for group was significant,  $F(2, 126) = 187.1$ ,  $p < .001$ ,  $\eta_p^2 = .75$ , and domain approached significance,  $F(1, 126) = 5.53$ ,  $p = .02$ ,  $\eta_p^2 = .042$ , with a small advantage for living thing fluency. The group  $\times$  domain interaction was significant,  $F(2, 126) = 4.78$ ,  $p = .01$ ,  $\eta_p^2 = .069$ . No other significant effects emerged. Analysis of the simple effects for the group  $\times$  domain interaction revealed that the elderly control group performed significantly better with living than nonliving items,  $F(1, 126) = 13.48$ ,  $p < .001$ ,  $\eta_p^2 = .097$  ( $M = 81.1$  vs. 75.5). No difference between the living and nonliving domains was found for either the young controls ( $F < 1$ ) or the dementia patients ( $F < 1$ ).

Post-hoc comparisons of the marginal means of the three groups with Bonferroni adjusted  $p$ -values revealed a clear rank order in performance. The young control group performed significantly ( $p < .001$ ) better than the elderly control group on the living (Cohen's  $d = 1.19$ ) and nonliving domains (Cohen's  $d = 1.56$ ); similarly, the elderly control group performed significantly better ( $p < .001$ ) than the dementia patients on the living (Cohen's  $d = 2.70$ ) and nonliving domains (Cohen's  $d = 2.39$ ).

**Table 2 – Mean (SD) living fluency**

	Young		Elderly		AD <sup>a</sup>	
	Male	Female	Male	Female	Male	Female
Flowers	7.12 (2.76)	7.94 (2.75)	5.94 (2.56)	8.58 (2.09)*	2.70 (1.80)	2.89 (1.79)
Insects	10.53 (3.36)	10.00 (4.27)	7.53 (2.24)	7.79 (3.49)	4.00 (2.12)*	2.27 (2.11)
Trees	9.82 (3.45)	9.72 (3.63)	9.12 (2.45)	9.21 (3.52)	5.46 (2.89)*	2.89 (2.88)
Vegetables	10.59 (2.81)	11.94 (5.38)	8.35 (3.08)	12.21 (2.51)*	5.00 (2.52)	4.85 (2.51)
Fruits	13.00 (2.18)	14.00 (3.56)	11.06 (3.58)	12.68 (2.91)	6.53 (2.53)	5.67 (2.52)
Animals	21.65 (5.72)	22.83 (6.56)	16.53 (5.58)	16.05 (4.05)	8.32 (3.28)*	6.36 (3.27)
Body parts	26.41 (4.15)	25.44 (6.11)	19.00 (5.78)	18.11 (4.72)	9.23 (3.52)	8.04 (3.50)

\*Significant sex difference at  $p < .01$ .

<sup>a</sup> Means [SD] were adjusted for MMSE.

**Table 3 – Mean (SD) nonliving fluency**

	Young		Elderly		AD <sup>a</sup>	
	Male	Female	Male	Female	Male	Female
Buildings	11.41 (3.78)	11.17 (3.55)	6.82 (2.46)	7.05 (2.01)	4.08 (2.55)	3.11 (2.54)
Vehicles	13.94 (3.61)	13.61 (3.66)	9.00 (2.12)	9.89 (2.73)	5.71 (3.62)*	4.09 (2.64)
Tools	15.53 (4.09)	13.39 (4.43)	10.53 (3.69)	9.16 (3.61)	5.77 (2.64)*	3.74 (2.63)
Furniture	12.29 (1.83)	13.11 (4.79)	9.06 (2.46)	10.58 (1.98)	4.76 (2.16)	4.08 (2.15)
Musical Instruments	14.65 (4.08)	13.22 (3.96)	12.24 (3.25)*	9.37 (2.45)	5.52 (2.31)*	3.35 (2.30)
Kitchen Utensils	14.47 (3.61)	15.00 (5.05)	10.41 (2.43)	14.11 (4.12)*	6.16 (2.78)	6.16 (2.77)
Clothing	19.82 (4.20)	20.28 (4.79)	16.18 (3.15)	16.63 (3.56)	8.45 (3.36)	7.89 (3.34)

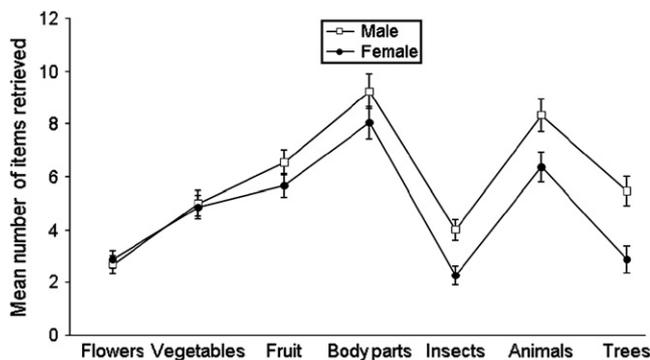
\*Significant sex difference at  $p < .01$ .  
<sup>a</sup> Means [SD] were adjusted for MMSE.

### 3.4. Performance comparisons at category level within the living domain

Differences in performance on the seven living subcategories were analysed using a univariate mixed ANOVA with group and sex as between-subjects factors and subcategory as a repeated measures factor. The 3-way subcategory  $\times$  group  $\times$  sex interaction was nonsignificant,  $F < 1$  and therefore removed from the model. Similarly, we also removed the group  $\times$  sex interaction, which reached only borderline significance,  $F(2, 126) = 3.96$ ,  $p = .021$  and represented a small cross-over interaction involving only the dementia patients and the elderly control groups.

In the reduced model, the group  $\times$  subcategory interaction yielded a highly significant result with a large effect size,  $F(9.21, 589.36) = 38.52$ ,  $p < .001$ ,  $\eta_p^2 = .38$ . The sex  $\times$  subcategory interaction was also significant, but with a small effect size,  $F(4.6, 589.36) = 5.75$ ,  $p < .001$ ,  $\eta_p^2 = .043$ . The simple effects analysis of the sex  $\times$  subcategory interaction suggested a moderate knowledge advantage for males regarding trees ( $p = .015$ , Cohen's  $d = .43$ ), and similarly for females a moderate, borderline significant knowledge advantage for vegetables ( $p = .028$ , Cohen's  $d = .40$ ).

Fig. 3 displays the group  $\times$  subcategory interaction, which is ordinal in nature suggesting both group performance differences and evidence for a task gradient ranging from flowers with the lowest average number to body parts with the highest average number. Compared to the elderly controls, the

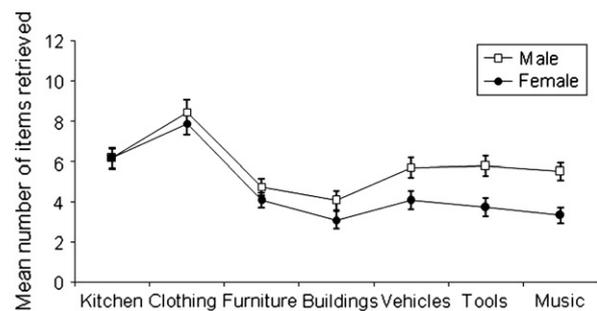


**Fig. 1 – Adjusted mean [SE] fluency in living subcategories for male and female AD patients. Note. Means are adjusted for MMSE scores.**

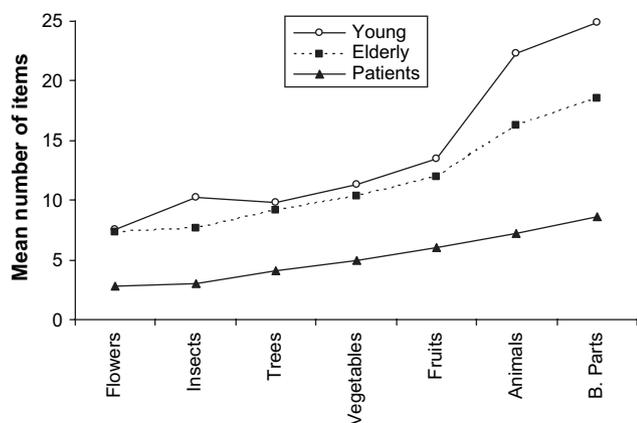
AD patients show impaired performance on all subcategories. By contrast, pronounced differences in performance between the elderly and the young controls are apparent for only animal and body parts, whereas on the other subcategories the profile of means is very similar between the two groups. The interaction was further analysed by breaking it down into simple effects for subcategory and group. All seven simple effects for factor subcategory were highly significant  $p < .001$  for each F-value (2, 128), suggesting that the groups differed significantly on each subcategory. Follow-up analyses involving pairwise mean comparisons revealed significant mean differences between the dementia patients and both control groups for all subcategories (all Sidak–Bonferroni corrected  $p < .001$ ). However, significant mean differences (Sidak–Bonferroni corrected  $p < .001$ ) between the young and elderly control group emerged only for insects (Cohen's  $d = .40$ ), animals (Cohen's  $d = 1.27$ ) and body parts (Cohen's  $d = 1.64$ ). The much better performance of younger participants with subcategories of animals and body parts is somewhat surprising considering the greater familiarity of these two living thing subcategories.

### 3.5. Performance comparisons at category level within the nonliving domain

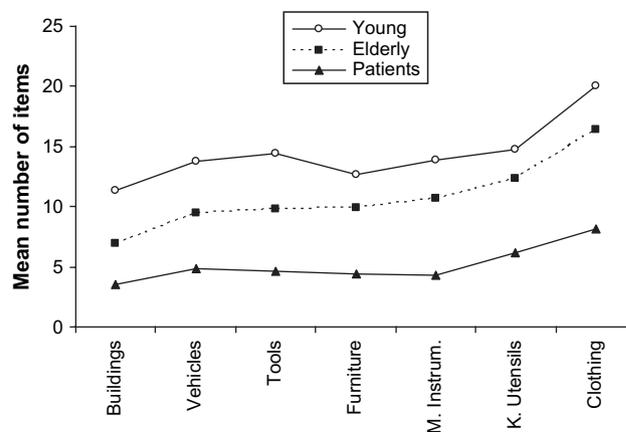
The above 3-factor mixed ANOVA for the subcategories of the living domain tasks was repeated for the seven nonliving subcategories. The 3-way subcategory  $\times$  group  $\times$  sex interaction and the group  $\times$  sex interaction were both nonsignificant ( $p > .05$ ) and therefore removed from the model. In the



**Fig. 2 – Adjusted mean [SE] fluency in nonliving subcategories for male and female AD patients. Note. Means are adjusted for MMSE scores.**



**Fig. 3 – Mean fluency for each group by living subcategories.**



**Fig. 4 – Mean fluency for each group by nonliving subcategories.**

reduced model, the main effect for group was highly significant with a very large effect size,  $F(2, 128) = 180.29, p < .001, \eta_p^2 = .74$ , as was the main effect for subcategory,  $F(6, 768) = 123.75, p < .001, \eta_p^2 = .49$ , but not the main effect for sex ( $p > .05$ ). Both 2-way interactions were significant; group  $\times$  subcategory interaction,  $F(12, 768) = 6.71, p < .001, \eta_p^2 = .09$ , sex  $\times$  subcategory interaction,  $F(6, 768) = 8.34, p < .001, \eta_p^2 = .06$ . The simple effects analysis for the sex  $\times$  subcategory interaction revealed a better performance for males only on tools ( $p < .001, \text{Cohen's } d = .45$ ) and musical instruments ( $p < .001, \text{Cohen's } d = .49$ ). Fig. 4 shows an interaction diagram for the group  $\times$  subcategory interaction. The profiles of the means do not cross-over between the groups and the differences in shape are overall rather modest. The profile of the means of the dementia patients is similar to that of the elderly controls except that it is at a much reduced fluency level. The rank order of the means for the young control group deviates somewhat from that of the elderly controls, but the most striking features of the interaction diagram are the strong main effects for group and category. A simple effects analysis for the factor subcategory revealed significant mean differences among the three groups for each of the seven nonliving subcategories (smallest  $F$ -value (2, 128) = 84.52). Further follow-up analyses involving pairwise comparisons showed that dementia patients performed significantly worse than the elderly controls on all subcategories and, likewise, the elderly controls performed significantly lower ( $p < .001$ ) than the young controls on all subcategories, except for kitchen utensils (and the latter accounts for the small, but significant interaction outlined above for group and subcategory).

#### 4. Discussion

This study expands upon previous work by showing that dementia and age affect category fluency (Auriacombe et al., 2001; Borod et al., 1980; Crossley et al., 1997; Parkin et al., 1995; Peraita et al., 2000; Tomer and Levin, 1993; Whelihan and Leshner, 1985; Wiederholt et al., 1993) and that these variables differentially affect the 14 fluency subcategories. In particular, the performance differences appeared to be constant

in AD patients, elderly and young healthy controls across all nonliving subcategories, regardless of the absolute level of performance in any one subcategory. By contrast, the seven living subcategories revealed a more varied profile, with no aging effect on the several plant-life subcategories, while animate subcategories were affected by both aging and dementia. Some evidence emerged for an overall domain specific effect, with an advantage for the living domain; however, this effect was strongly moderated by group, with just the elderly controls showing this difference.

Detailed analysis of the seven living subcategories revealed a significant group-by-subcategory interaction. While the AD patients performed worse than both the elderly and the young controls on all living subcategories, a pronounced age effect emerged for the three animate subcategories (i.e. animals, body parts, and insects), but not for the four plant-life subcategories (i.e. flowers, fruits, trees, and vegetables). The significant group-by-subcategory interaction for the seven nonliving subcategories revealed a quite different profile with the three groups differing from each other on every nonliving subcategory. Combined, these findings are consistent with important differences between the representations of plant-life and animate living things as well as nonliving things (e.g. Caramazza and Mahon, 2003, 2006). Furthermore, the more uneven fluency performance across living subcategories may partly explain some of the variability in fluency findings that has occurred with AD patients (for a meta-analysis, see Henry et al., 2004). These findings highlight the importance of examining a wide range of subcategories to reliably determine the impact of both age and dementia.

Animal and body parts fluency produced the greatest separation amongst all three groups and notably the largest fluency counts (see Fig. 3). In other words, for living things, the greatest separation for age and dementia occurs for the largest lexical subcategories. By contrast, this relationship does not hold for nonliving subcategories. We should note that poorer fluency for larger lexical subcategories (i.e. animals and body parts) might reflect their greater complexity and hence, increase the time to search for items in those subcategories. Such an account might partly explain the impact of age and

dementia on fluency in these subcategories. Diaz et al. (2004) reported a similar relationship between subcategory size and fluency for three subcategories (animals, fruits and vegetables) in AD patients. The current study confirms and extends this finding by showing that this phenomenon does not extend to nonliving subcategories. The finding for animals is particularly important because *animals* is probably the most frequently used subcategory in semantic fluency studies with AD patients as well as other groups including healthy subjects (Pekkala, 2004). Given that animal fluency seems to produce a particularly large difference relating both to pathology and to normal aging, we must consider the widespread use of animal fluency in research. The most obvious implication is that the choice of *animal* as the sole metric for category fluency is likely to reveal strong age and dementia effects that would be less pronounced or even absent on other subcategories (e.g. plant-life). It is also possible that this lexical effect extends to other tasks involving, for example, animal recognition on the picture naming tasks. Hence, more research is required to examine subcategory naming not just as here in fluency tasks, but also in picture naming tasks. No picture naming study has, of yet, compared such a range of subcategories in AD patients (for a review, see Laws et al., 2007).

Critically, our examination of a large range of living and nonliving subcategories reveals that the various subcategories are not interchangeable. It is apparent that the specific choice of nonliving subcategories is far less important than the specific choice of living thing subcategories. Hence, the specific choice of subcategories may provide quite different impressions of overall domain performance. For example, examining animals and body parts would point to a living domain advantage in all three groups; however, the choice of some plant-life subcategories, e.g. flowers and trees would be likely to produce an overall nonliving advantage. Moreover, there are grounds for arguing whether body parts should be included as a living subcategory at all. Domain effects are therefore, to some extent, subject to the vagaries of the specific subcategories examined. Although little doubt remains that body parts are atypical of the living (e.g. Barbarotto et al., 2001; Gale and Laws, 2006), the clustering of subcategories and their relationship to their assumed domains remains to be empirically determined.

Recent studies both with healthy participants and with patients have proposed an interaction between domain and sex of participants on picture naming tasks: men showing a better performance with some nonliving subcategories – generally, tools – and women with some living subcategories – commonly, fruits and vegetables (Barbarotto et al., 2002; Capitani et al., 1999; Laiacona et al., 1998; Laws, 1999, 2004; McKenna and Parry, 1994). Overall, our results revealed no significant sex differences in the ability to generate items; however, some intriguing sex differences emerged across age groups. While the young group showed no significant sex differences on any subcategory, elderly females had better fluency for flowers, vegetables and kitchen utensils and elderly males showed better fluency for musical instruments. These latter findings accord with the presence of gender role-based differences in healthy elderly subjects reflecting familiarity/socialisation effects (cf. Marra et al., 2007). By contrast, in the case of patients, female AD sufferers had worse fluency than males

in 13 of the 14 subcategories and were significantly more impaired in six out of fourteen. These six subcategories were from both domains (animals, insects, trees, musical instruments, tools and vehicles). Moreover, these sex differences were maintained after controlling for any differences in both dementia severity and education. This generalised relative impairment for women with AD overrides possible sex-related differences that emerge in the healthy elderly subjects.

Comparisons of men and women with equivalent AD severity have revealed that women with AD manifest greater semantic memory deficits on tasks such as picture naming and fluency (Buckwalter et al., 1993; Henderson and Buckwalter, 1994; McPherson et al., 1999; Ripich et al., 1995). Furthermore, as with our current findings, these sex differences remain after controlling for the effects of education and level of overall impairment (Buckwalter et al., 1993; Henderson and Buckwalter, 1994; Ripich et al., 1995). Consistent with this female disadvantage, a recent meta-analysis of picture naming in AD patients found that studies with higher proportions of females produced significantly worse picture naming in both domains (Laws et al., 2007). In the context, it is worth noting research on the apolipoprotein E (APOE: 19q13.2)  $\epsilon 4$  allele, which represents an established genetic risk factor for AD (Corder et al., 1993); in the healthy older population, those with the  $\epsilon 4$  allele also present with poorer cognitive performance, especially on memory tests (Soininen and Riekkinen, 1996); and importantly, it is linked directly with poorer animal fluency in healthy elderly  $\epsilon 4$  carriers (Rosen et al., 2005). Although still controversial, the APOE genotype is believed to affect the probability of developing AD to a greater extent in women than men (Bretsky et al., 1999; Gomez Isla et al., 1996; Payami et al., 1996), possibly by impacting on hippocampal atrophy in female AD sufferers (Fleisher et al., 2005); and that the effect exerted by APOE genotype on cognitive performance in the general population is also more pronounced in women than men (Bartres-Faz et al., 2002; Hyman et al., 1996). In accordance with these findings, our study points to a particular vulnerability in female AD sufferers to develop a profound lexical-semantic impairment.

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