The effects of ageing and Alzheimer’s disease on semantic and gender priming

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Summary
Normal ageing as well as age-associated pathological conditions, such as Alzheimer’s disease, are associated with modifications of language processing. In particular, an impaired performance in semantic tasks, associated with relatively spared syntactic processing, has been suggested to be the hallmark of the language disorder of Alzheimer’s disease. The present experiment tests semantic and syntactic aspects of language processing at the same time, using an on-line paradigm, in patients with Alzheimer’s disease, compared with elderly and young controls. Normal ageing was associated with a profile of performance, which was slowed but qualitatively comparable with that of young controls. Both gender agreement and congruent sentential semantics resulted in facilitation relative to baseline in young and elderly controls, with no significant interference effects of incongruent grammatical and semantic information. In contrast, Alzheimer’s disease patients presented both facilitation and interference effects. These findings suggest that interference effects are amplified by dementia, and may result from defective inhibitory processes due to Alzheimer’s disease pathology.

Keywords: priming; ageing; Alzheimer’s disease; gender; semantics

Introduction
There is ample evidence of age-associated changes in language processing on a variety of tasks (MacKay and Abram, 1996). Language impairment is also one of the features of cognitive impairment in the most common form of degenerative dementia, Alzheimer’s disease (Ramage and Holland, 2001).

According to one influential proposal, a common non-language-specific mechanism, i.e. a disorder in inhibitory processes, may account for the performance modifications in language tasks observed both in normal ageing and in the early stages of Alzheimer’s disease (Hasher and Zacks, 1988; Balota and Faust, 2001). At the neuropsychological level, this could be due to the presence of executive dysfunction, associated with prefrontal cortex involvement, in ageing and early Alzheimer’s disease. An alternative account is that the language changes in dementia reflect a direct involvement of language areas, resulting in loss or defective availability of linguistic knowledge. In particular, a lexical–semantic impairment, associated with preserved phonological and syntactic performance, has been considered to be specific for Alzheimer’s disease, and reflecting the relative sparing of prefrontal areas up to the advanced stages of disease (see, for example, Ullman, 2001).

The results of imaging studies provide partial support for the latter hypothesis, as they do not indicate a specific involvement of prefrontal areas in normal ageing and early Alzheimer’s disease. Investigations of brain morphology in ageing normal subjects have, in general, indicated the presence of a global linear decline in brain volume. Areas of accelerated decline appear to be the hippocampal regions (Scahill et al., 2003), as well as the insular and parietal cortex (Good et al., 2002), rather than the prefrontal cortex. In the case of early Alzheimer’s disease, both structural and
functional imaging indicate a relative sparing of prefrontal cortex in the early stages of disease (for a review see Perani and Cappa, 2001; for recent evidence see Thompson et al., 2003).

In order to assess independently the effects of ageing and disease on a specific test, several methodological factors should be taken into account. First, it is necessary to compare the performance of young controls with samples of healthy elderly subjects and of patients with a diagnosis of probable Alzheimer’s disease using the same experimental procedure. Secondly, the nature of the task should be taken into account. On-line processing tasks, such as priming paradigms, are ideally suited to assess the modifications of cognitive processing associated with normal ageing and early dementia. Priming is based largely on automatic processes, allowing the evaluation of actual linguistic competence. Semantic priming is of particular interest, given the general agreement that performance in tasks requiring access to semantic knowledge is affected from the early stages of Alzheimer’s disease. Whether the impairment represents a loss of semantic knowledge or defective access to that knowledge is a matter of debate (see, for example, Hodges et al., 1992; Ober and Shenaut, 1999). Semantic priming studies of normal ageing typically show that performance on lexical processing tasks is slowed, but semantic priming effects appear to be preserved (Myerson et al., 1997). On the other hand, semantic priming has been investigated extensively in Alzheimer’s disease, with contradictory results (for a review see Ober, 2002).

Priming effects can also be induced by syntactic information. For example, pronominal modifiers, such as the article, can also affect the processing of the nouns they modify. An article matching the noun in grammatical gender facilitates lexical access, while an incongruent article may interfere with the same process. The effects of grammatical gender and of semantic information (sentence context) on word reading have been investigated recently by Bentrovato et al. (2003). The results indicated the presence of a large, interacting facilitation effect of both context and gender in young individuals. This was taken to indicate that normal subjects could take advantage of both sources of information, with no significant interference when they are both discordant.

In the present experiment, we have used the same sentential priming paradigm in order to evaluate at the same time the effect of semantic and grammatical information on word reading in elderly normal subjects and in a sample of early Alzheimer’s disease patients. The aim of the study was to assess the impact of ageing and Alzheimer’s disease on the on-line effects of congruent and incongruent semantic and grammatical information.

**Methods**

**Subjects**

Three groups of subjects, all native Italian speakers, participated in the experiment: 25 university students (12 females and 13 males; mean age 22.8 years, range 19–27), 26 normal ageing subjects (nine males and 17 females, mean age 73.58 years, range 63–87) and 26 patients with the diagnosis of Alzheimer’s disease (nine males and 17 females, mean age 76.23 years, range 67–84). The diagnoses were made by a staff of neurologists of the San Raffaele Turro Hospital (Milan), following the National Institute of Neurological and Communicative Disorders (NINCDS) and Alzheimer’s Disease and Related Disorders Association (ADRA; McKhann et al., 1984) criteria. Patients with other neurological, metabolic and psychiatric pathologies were excluded. All the patients recruited received a complete neurological and neuropsychological evaluation. Informed consent was required from all participants, according to the guidelines of the local ethics committee. Statistical analyses showed that there was no difference between patients and normal ageing subjects based on age and education [age, \( t(50) = 1.751; P = 0.087 \); instruction \( t(50) = 0.459; P = 0.649 \)]; the same two samples, however, had significantly different Mini-Mental State Examination (MMSE) scores \( t(50) = -10.66; P < 0.0001 \). Table 1 summarizes the descriptive data.

**Materials and procedure**

The main test is the Italian Word Reading Test (Bentrovato et al., 2003). Every stimulus is a brief two-sentence narrative in Italian, presented orally, with a target word presented visually in one of the two sentences (the target position was varied within and between sentences).

**Word targets**

The 110 target words for reading are the transcription of the names produced by the majority of subjects for the corresponding picture-naming task used by Bentrovato et al. (1999): everyday objects (Snodgrass and Vanderwart, 1980; Dunn and Dunn, 1981; Kaplan et al., 1983; Abbate and LaChapelle, 1984) chosen from a list of 520 drawings from an International Picture-Norming Study (Bates et al., 2000). The 110 target words have the following properties: 56 masculine (44 end with the phonologically transparent vowel a, 12 with the phonologically ambiguous vowel e) and 54 feminine (46 end with the phonologically transparent vowel a, eight with the phonologically

<table>
<thead>
<tr>
<th>YC</th>
<th>EC</th>
<th>Alzheimer’s disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>Education (years)</td>
<td>Age (years)</td>
</tr>
<tr>
<td>Mean</td>
<td>22.56</td>
<td>16.88</td>
</tr>
<tr>
<td>SD</td>
<td>2.27</td>
<td>2.07</td>
</tr>
</tbody>
</table>

MMSE = Mini-Mental State Examination score.
have served as the semantically congruent target. The neutral contexts (equivalent in length and complexity to the experimental contexts: see also Wicha et al., 1997) served as a neutral baseline, used to assess whether any of the gender × semantics conditions resulted in facilitation or inhibition of the target reading. This condition was called N/N (see Table 2 for examples).

**List construction**

Five lists were prepared, in order to ensure that no single subject ever heard the same sentence or saw the same word twice. In the first list, the items were assigned in a quasi-random way to the five experimental conditions (G+S+, G+S−, G−S+, G−S− , N/N), until each of the five conditions reached 22 items without repetitions. At the end, the items were rotated across the five conditions: each word target might occur in G+S+ in list 1, G+S− in list 2, G−S+ in list 3, G−S− in list 4, and N/N in list 5.

**Procedure**

The subjects were seated in front of a 15 inch computer screen in a quiet testing room, wearing headphones with a microphone, that were connected to the sound amplifier port of the computer. Response times were collected in milliseconds through the Carnegie Mellon Button Box, a measuring device including a voice key with an external time crystal and 1 ms resolution, designed for use with a Macintosh Computer, connected to the modem port of the PowerBook.

The experimenter hand-recorded all naming errors on a score sheet during testing. The subjects were assigned randomly to one of the five lists based on their participant number.

At the beginning of the session, the participant saw the instructions on the screen; every experimental session was preceded by a practice session, in which 10 context–target pairs were presented, two for each experimental condition.

In the experimental session, the items were presented randomly, in a continuous way. First, the participant saw the fixation point (●) in the centre of the screen and heard the first part of the auditory context; at some point in the sequence, the sentence was halted and in the place of the fixation point the target appeared. The participant was instructed to read the word as soon as possible: when the voice was detected by the voice key, the word disappeared; after 500 ms, the second part of the context was heard. The time limit to read the word was 5 s: after this period the word disappeared even if the subject had

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**Table 2 Examples of test sentences**

<table>
<thead>
<tr>
<th>Prime</th>
<th>Target</th>
<th>Prime</th>
<th>Cond.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quando vado a letto prima di addormentarmi leggo sempre (When I go to bed before falling asleep I always read)</td>
<td></td>
<td>per questo mia mamma mi ha regalato una collezione di romanzi gialli (for this reason, my mother gave me a collection of murder mysteries)</td>
<td>G+S+</td>
</tr>
<tr>
<td></td>
<td>LIBRO (BOOK)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOPO (MOUSE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Sylvia took a test in English in which she had to repeat)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silvia ha fatto un test in inglese, in cui doveva ripetere</td>
<td>LIBRO (BOOK)</td>
<td>per cinque volte. L’insegnante ha detto che è l’unico modo per migliorare la pronuncia (five times. The teacher said that was the only way to improve her pronunciation)</td>
<td>NN</td>
</tr>
<tr>
<td></td>
<td>(L’unico modo per migliorare la pronuncia)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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The effects of ageing and Alzheimer’s disease on priming
yet not read it. The interval between two subsequent trials was 3 s for the young controls (YC) and 5 s for the elderly controls (EC) and for Alzheimer’s disease patients. This decision was taken in order to avoid fatigue effects. The entire experimental session lasted ~45 min.

Results

The reaction time (RT) analyses were based only on correct responses. A response was discarded if any irrelevant noise was recorded instead of the answer, if the microphone failed to record the response or if the participant gave a wrong response. Following these criteria, we excluded 2.27% of the trials for YC, 3.74% for EC (93% of them were due to recording failures) and 10.98% for Alzheimer’s disease patients (85% of them recording failures). The number of wrong responses was not significantly different in the three groups.

The RT data in the five experimental conditions are summarized in Table 3.

In order to assess the effects of matching gender and semantic congruence on the raw RT data, we performed a 2 × 2 within-subjects ANOVA over participants. The results in YC have already been reported by Bentrovato et al. (2003), and indicate significant effects of both gender \[ F(1,24) = 18.564; \ P = 0.0002 \] and semantic context \[ F(1,24) = 28.664; \ P < 0.0001 \], as well as a significant interaction \[ F(1,24) = 4.49; \ P = 0.0446 \], due to the larger effect of gender agreement in the semantically congruent condition (Fig. 1).

The results were the same in the case of EC subjects [gender, \( F(1,25) = 17.861; \ P = 0.0003 \); semantics, \( F(1,25) = 26.199; \ P < 0.0001 \); interaction, \( F(1,25) = 4.562; \ P = 0.0427 \)] (Fig. 2).

In contrast, in Alzheimer’s disease patients, while the two main effects were significant [gender, \( F(1,25) = 23.786; \ P < 0.0001 \); semantics, \( F(1,25) = 23.066; \ P < 0.0001 \)], there was no significant gender × semantics interaction \( F(1,25) = 0.226; \ P = 0.6385 \) (Fig. 3).

In order to compare the performance of the three groups directly, the presence of a significant slowing in RT associated with physiological ageing should be taken into consideration. We thus correlated the RTs of YC and EC in each condition with their ages. Since the equation calculated using the RTs in the NN condition was quite similar to the one obtained using all RTs (NN, coefficient = 6.766, \( t = 8.377, \ P < 0.001 \); all, coefficient = 6.716, \( t = 10.123, \ P < 0.001 \)), and the interaction between conditions and age was not significant \( F = 2.245, \ P > 0.05 \), we decided to use the equation calculated on the NN condition to correct all the performance data for physiological slowing. The corrected data are reported in Table 4. The 2 × 2 ANOVA on the corrected data replicated the results of the analysis on the raw RTs. Using the corrected RTs, we then ran three separate ANOVAs with one between-subjects factor (group). In all three comparisons (YC–EC, EC–Alzheimer’s disease, YC–Alzheimer’s disease), both factors showed a significant effect.

![Fig. 1](image1.png)  
Fig. 1 Reaction times in YC, according to the presence of an incongruent (−) or congruent (+) semantic (S) of grammatical (G) context. The NN line represents the neutral baseline condition. Both gender agreement and a congruent semantic context results in faster reading. The significant interaction indicated the presence of a larger effect of gender agreement in the semantically congruent condition.

![Fig. 2](image2.png)  
Fig. 2 In the group of EC, the results were comparable to YC. Significant effects of gender agreement and congruent semantic context.

Table 3 Reaction time data (ms)

<table>
<thead>
<tr>
<th>Condition</th>
<th>G+S+</th>
<th>G+S−</th>
<th>G−S+</th>
<th>G−S−</th>
<th>NN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alzheimer’s disease</td>
<td>Mean</td>
<td>915.74</td>
<td>1104.54</td>
<td>1018.53</td>
<td>1229.43</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>361.95</td>
<td>552.23</td>
<td>419.97</td>
<td>596.24</td>
</tr>
<tr>
<td>EC</td>
<td>Mean</td>
<td>767.46</td>
<td>848.17</td>
<td>825.64</td>
<td>876.93</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>218.49</td>
<td>273.92</td>
<td>269.61</td>
<td>268.22</td>
</tr>
<tr>
<td>YC</td>
<td>Mean</td>
<td>456.44</td>
<td>484.92</td>
<td>480.43</td>
<td>497.99</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>82.16</td>
<td>90.81</td>
<td>92.83</td>
<td>99.42</td>
</tr>
</tbody>
</table>
significant interaction with group [YC–EC; gender, $F(1,49) = 30.427, P < 0.001$; semantics, $F(1,49) = 40.480, P < 0.001$; group × gender, $F(1,49) = 4.282; P = 0.045$; group × semantics, $F(1,49) = 9.987, P = 0.004$; EC–AD: gender, $F(1,50) = 40.071, P < 0.001$; semantics, $F(1,50) = 36.483, P < 0.001$; group × gender, $F(1,50) = 8.055; P = 0.008$; group × semantics, $F(1,50) = 9.036, P < 0.005$; YC–AD: gender, $F(1,49) = 32.365, P < 0.001$; semantics, $F(1,49) = 26.423, P < 0.001$; group × gender, $F(1,49) = 16.083; P < 0.001$; group × semantics, $F(1,49) = 16.796, P < 0.001$].

In order to analyse these differences in further detail, and to determine the direction of priming, we compared the raw RTs of each condition with the neutral baseline, within each group (Fig. 4). In the case of YC, a significant facilitation was observed for the G+S+ condition [$F(1,24) = 6.509; P = 0.0139$], while the G–S– condition failed to induce a significant interference [$F(1,24) = 0.074; P > 0.05$] (data reported in Bentrovato et al., 2003). The two remaining conditions were also not significantly different from baseline [G+S–, $F(1,24) = 0.27; P > 0.05$; G–S+, $F(1,24) = 1.345; P > 0.05$]. In the case of EC, the raw RT data indicated a significant facilitation in G+S+ [$F(1,25) = 47.708; P = 0.0001$], no significant interference in G–S– [$F(1,25) = 0.727; P > 0.05$] and no significant differences for the two remaining conditions [G+S–, $F(1,25) = 1.495; P > 0.05$; G–S+, $F(1,25) = 4.231; P > 0.05$]. Only for Alzheimer’s disease patients, there were both significant facilitation effects with G+S+ [$F(1,25) = 21.625; P < 0.0001$] and interference effects with G–S– [$F(1,25) = 10.731; P = 0.0031$]. None of the other facilitation or interference effects reached significance [G+S–, $F(1,25) = 1.146; P > 0.05$; G–S+, $F(1,25) = 2.328; P > 0.05$].

**Discussion**

The present findings indicate that grammatical and semantic cues provide parallel information, which can be used quickly to predict the target word. Not surprisingly, the combination of matching gender and semantic congruence yields the largest facilitation effects in both control groups, as well as in Alzheimer’s disease patients. The significant interaction of gender with the semantic context clearly indicates a role for the integration of all sorts of available information.

Healthy ageing does not appear to affect this general pattern of results. While the RTs were slower for ECs, the profile of effects remained the same, including the presence of a significant gender × semantics interaction.

In contrast to these findings for both ECs and YCs, performance of the Alzheimer’s disease subjects was associated with two significant modifications. First, the interaction

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**Table 4** ‘Corrected’ reaction time data (ms)

<table>
<thead>
<tr>
<th></th>
<th>G+S+</th>
<th>G+S–</th>
<th>G–S+</th>
<th>G–S–</th>
<th>NN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alzheimer’s disease</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>717.64</td>
<td>885.47</td>
<td>816.95</td>
<td>1024.70</td>
<td>874.49</td>
</tr>
<tr>
<td>SD</td>
<td>196.97</td>
<td>354.72</td>
<td>218.48</td>
<td>385.61</td>
<td>294.55</td>
</tr>
<tr>
<td><strong>EC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>620.39</td>
<td>683.81</td>
<td>665.01</td>
<td>711.80</td>
<td>684.24</td>
</tr>
<tr>
<td>SD</td>
<td>142.94</td>
<td>170.52</td>
<td>164.09</td>
<td>181.68</td>
<td>202.57</td>
</tr>
<tr>
<td><strong>YC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>632.78</td>
<td>661.99</td>
<td>661.13</td>
<td>674.97</td>
<td>676.78</td>
</tr>
<tr>
<td>SD</td>
<td>53.45</td>
<td>62.33</td>
<td>65.84</td>
<td>70.44</td>
<td>65.19</td>
</tr>
</tbody>
</table>

---

**Fig. 3** In the AD group, only the two main effects were significant, with no interaction.

**Fig. 4** The bar graphs reports the difference of each condition to the neutral baseline, within each group, thus indicating the presence of facilitation or inhibition of word reading. In the case of YC and EC, there was only a significant facilitation effect induced by the condition of combined grammatical and semantic congruence (G+S+). Only AD patients, had both a significant facilitation effect for G+S+, and a significant interference effect in the case of the combined incongruence (G–S–).
between gender and context was not significant. A second, more striking difference from the findings in both young and elderly normal subjects was the appearance of an interference effect of the combined incongruence.

This pattern of results highlights the contribution of on-line tasks to the assessment of language processing in the case of both normal and neurologically impaired populations. In contrast to traditional metalinguistic methods, such as, for example, picture naming or sentence verification, these methods do not require explicit judgements about the structure or meaning of the test material. The latter feature is particularly attractive in the case of conditions associated with modifications of multiple cognitive abilities, such as dementia.

The preserved facilitation effect of sentence context is in line with previous findings. Semantic priming has been applied extensively to the investigation of lexical–semantic processing. The most widely used paradigms assess the effect of a preceding related or unrelated single word on tasks such as lexical decision or word reading. In general, studies of healthy ageing have reported an overall slowing of RTs, with preserved priming effects (Myerson et al., 1992). Semantic priming has been applied extensively to the investigation of the status of semantic memory in Alzheimer’s disease. The results may prima facie appear highly inconsistent, as priming effects have been reported to be reduced (Ober and Shnaut, 1988), normal (Nebes et al., 1984) or increased (Chertkow et al., 1989). While some of the discrepancies are related to differences in methodology, there is recent evidence that the heterogeneity of the effects may be due in part to the stage of disease, and to the severity of semantic impairment as measured by off-line tasks (Giffard et al., 2002). Recently, Giffard et al. (2002) have argued on the basis of longitudinal data that the presence of decreased or increased priming depends on relatedness conditions. An early increase is observed only in the case of coordinate priming (tiger–lion), while attribute priming (tiger–stripe) progressively declines from normal levels. The latter finding was considered to reflect the dynamics of semantic memory deterioration. When specific attributes begin to be lost, the loss of distinctions between close concepts results in increased coordinate priming. On the other hand, the same mechanism reduces attribute priming from the start. With the progression of semantic deterioration, priming progressively reduces in both conditions. Sentence context effects have been investigated less extensively in ageing and dementia. A facilitation of word processing has been observed when a word is a plausible completion of a sentence (Fischler and Bloom, 1985). Conversely, an incongruous word is processed more slowly, in particular in the case of young readers (West and Stanovich, 1978). In the case of lexical decision, the nature of the context modulates the facilitation effect. With high-constraint sentences, only expected congruous words are facilitated. With low-constraint contexts, both expected and unexpected congruous words enjoy facilitation effects (Schwanenflugel and LaCount, 1988). A small increase in the interference effect on picture naming has been reported in healthy elderly subjects (Roe et al., 2000). In the same study, facilitation was unaffected by age. With a similar task, a reduction of the neurophysiological N400 effect has been reported in normal elderly subjects (Cameli and Phillips, 2000). This has been attributed to defective inhibition of irrelevant semantic information in working memory, or ‘diffuse semantic activation’ (Miyamoto et al., 1998). In the case of Alzheimer’s disease, Nebes and Brady (1991), using a task in which the patient had to judge whether a word was a sensible completion of a sentence, reported a relative preservation of the facilitation effect of appropriate context on word processing. In a recent study with event-related potentials, Schwartz et al. (2003) found delayed but preserved lexical priming effects, which were greatly facilitated by the presence of a congruent sentential context, in a group of Alzheimer’s disease patients. The authors interpret this finding as evidence of preserved sensitivity to lexical and sentential factors, which actually show an increased additivity in comparison with normal elderly controls. An over-reliance on context has been suggested to be a feature of reduced comprehension skills. For example, there is evidence for increased benefit on reading times from predictable context in the case of less skilled readers (Perfetti and Roth, 1981).

The gender priming effect was also preserved. The evidence about priming effects induced by non-semantic information is more limited in both normal subjects and pathological conditions. At the sentence level, syntactic priming has been assessed in term of the probabilities of re-using particular syntactic structures in sentence production, when a prime sentence containing the specific structure has been presented (Bock, 1986).

Grammatical priming effects have also been induced in normal adults in inflected languages, such as Russian (Akhtutina et al., 1999) and Italian (Bates et al., 1996). In both languages, the gender of a noun modifier served both to facilitate (if congruent) and inhibit (if incongruent) recognition of the following noun. The same priming effects were shown to be present in ECs, but either missing altogether (in Italian; Bates et al., 2001) or severely attenuated (in Russian; Akhtutina et al., 2001) in both fluent and non-fluent aphasic patients in the same languages. The observation that gender priming is vulnerable in aphasic patients provides an interesting contrast to our present findings with Alzheimer’s disease patients.

It has been shown recently that the presentation of a mismatching article before a contextually expected noun elicits an event-related potential (ERP) negativity at the time of article presentation, similar to the N400 (Gunter et al., 2000; Wicha et al., 2003). As in the studies of young Italian subjects (Bentrovato et al., 1999, for picture naming; Bentrovato et al., 2003, for word reading), the findings of Wicha et al. (2003) suggest that both grammatical and semantic information is accessed early, and in parallel, during auditory language comprehension (see also Wicha et al., 1997). It is noteworthy that in off-line tasks, such as an off-line (untimed) variant of picture naming, there is evidence that when the response is a semantic paraphasia, in Alzheimer’s disease patients the gender
of the target word fails to exert the biasing effect which is observed in normal controls (Paganelli et al., 2003).

In the present study, the facilitation role of semantic and gender information on word naming appears to be additive, and to be preserved in both normal ageing and Alzheimer’s disease. While the lack of an interaction effect in the latter group may be taken to indicate the presence of subtle qualitative differences in the integration of different sources of information, the presence of the combined priming effects is compatible with a substantial preservation of semantic and grammatical knowledge.

The finding of a significant interference effect induced only by the combined grammatical and semantic violation in Alzheimer’s disease is in agreement with the notion of a combined effect of both types of information. Hasher and Zacks (1988) suggested that a basic feature of primary (normal) ageing is a loss of inhibition of irrelevant information. This process has been suggested to be defective in Alzheimer’s disease patients, as shown by their performance in a number of non-linguistic tasks (Balota and Duchek, 1991; Sullivan et al., 1995; Spieler et al., 1996; Faust et al., 1997; Amieva et al., 2002). In the case of language processing, this dysfunction may result in a situation in which the inappropriate information drives the response. For example, it may account for the frequency–regularity interaction observed in reading tasks in Alzheimer’s disease patients (Balota and Ferraro, 1993). In terms of the dual-route reading model (Morton and Patterson, 1980), there are two reading mechanisms, an addressed (lexical) and an assembled (sublexical) pathway. These mechanisms lead to different phonological outcomes, which enter into competition with each other. The lexical route always produces the correct output, and the output of the assembly route must be inhibited for the correct pronunciation of irregular words. In the case of on-line tasks, Faust and Gernsbacher (1996) have shown that inappropriate information from semantically ambiguous words had a larger interference effect on sentence comprehension in Alzheimer’s disease patients than in healthy elderly subjects. The subjects had to judge whether a word matched the overall meaning of a sentence. In some cases, the last word of a sentence was ambiguous, and the test word was related to one of its meanings, which, however, was not appropriate for the sentence (e.g. sentence, he dug with the spade; test word, ace). In these trials, the Alzheimer’s disease patients were significantly slowed (and made more errors) in comparison with matched elderly subjects, suggesting an inability to suppress the irrelevant meaning. The combined violation of expectancy induced by the G–S– condition in our study (but not the single gender mismatch or semantic incongruence) may represent a serious challenge to the reduced inhibitory abilities of Alzheimer’s disease patients. It has been suggested that the impairment of inhibitory mechanisms in Alzheimer’s disease is limited to tasks requiring at least some degree of controlled inhibition (Amieva et al., 2004), while completely automatic tasks, such as inhibition of return, appear to be unaffected. These authors propose that the automatic/controlled distinction, rather than the nature of the task, is the crucial determinant of the effect of Alzheimer’s disease. According to this view, the interference effect observed in the present study may be considered to reflect a failure of controlled suppression of the expectancy induced by the combined gender mismatch and semantic incongruence.

In conclusion, at least some of the modifications in language processing manifested in Alzheimer’s disease may be the result of dysfunction in non-linguistic domains, such as attention and executive control, rather than the consequence of loss of linguistic knowledge. This issue may be relevant for both behavioural and pharmacological interventions in early Alzheimer’s disease, and deserves further investigations, extending to other dementing conditions associated with prominent language dysfunction, such as frontotemporal dementia.

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