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Impaired word recognition in Alzheimer's disease: The role of age of acquisition

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ABSTRACT

Studies of word production in patients with Alzheimer's disease have identified the age of acquisition of words as an important predictor of retention or loss, with early acquired words remaining accessible for longer than later acquired words. If, as proposed by current theories, effects of age of acquisition reflect the involvement of semantic representations in task performance, then some aspects of word recognition in patients with Alzheimer's disease should also be better for early than later acquired words. We employed a version of the lexical decision task which we term the lexical selection task. This required participants to indicate which of four items on a page was a real word (the three 'foils' being orthographically plausible nonwords). Twenty-two patients with probable Alzheimer's disease were compared with an equal number of matched controls. The controls made few errors on the test, demonstrating that the controls were cognitively intact, and that the words were familiar to participants of their age and level of education. The Alzheimer patients were impaired overall, and recognized fewer late than early acquired words correctly. Performance of the Alzheimer patients on the lexical selection task correlated significantly with their scores on the mini mental state examination. Word recognition becomes impaired as Alzheimer's disease progresses, at which point effects of age of acquisition can be observed on the accuracy of performance.

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1. Introduction

One of the earliest signs of Alzheimer's disease, along with impaired episodic memory, is difficulty in retrieving and understanding words. That problem is usually explained in terms of progressive degeneration affecting the conceptual-semantic representations of word meanings (Altmann & McClung, 2008; Chertkow & Bub, 1990; Hodges & Patterson, 1995; Hodges, Patterson, Graham, & Dawson, 1996; Rogers & Friedman, 2008). Not all words are equally affected, however: across patients, there is a degree of consistency regarding which words are retained better and for longer as the disease progresses (Ellis, in press; Juhasz, 2005). Most of the research investigating the retention and loss of words in Alzheimer's disease has employed word production tasks, notably object naming and category fluency (generating exemplars from a specified category such as 'animals' or 'items of clothing'). A factor that has emerged from several such studies as a significant predictor of the susceptibility of individual words to dementia is the age at which different words are learned (i.e., their age of

acquisition). All other things being equal, patients with Alzheimer's disease are better at retrieving and producing words learned earlier in life than words learned later. For example, Silveri, Cappa, Mariotti, and Puopolo (2002) found that the age of acquisition of object names significantly predicted the number of Alzheimer patients who would be able to name pictures of different objects. The contributions of object familiarity, word frequency and word length to predicting naming success in that study were not significant. Tippett, Meier, Blackwood, and Diaz-Asper (2007) found independent effects of both age of acquisition and word frequency in analyses of object naming by patients with mild and moderate Alzheimer's disease. Effects of age of acquisition in object naming by Alzheimer patients have also been reported by Cuetos, Gonzalez-Nosti, and Martínez, 2005, Cuetos, Rosci, Laiacona, and Capitani (2008), Holmes, Fitch, and Ellis (2006), Kremin et al. (2001), Rodríguez-Ferreiro, Davies, González-Nosti, Barbón, and Cuetos (2009), and Taylor (1998). Forbes-MacKay, Ellis, Shanks, and Venneri (2005) compared the performance of Alzheimer patients and healthy controls in a category naming task in which participants generated as many animal and fruit names as they could, given one minute per category. The words generated by Alzheimer patients were both earlier acquired and of higher average frequency than those generated by healthy controls. The mean age of acquisition of words produced proved to be a particularly effective predictor of whether a participant came from the patient group or the control group.

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Alzheimer patients experience problems in recognizing and understanding words as well as in retrieving and producing them (Hodges & Patterson, 1995; Hodges et al., 1996). Analysis of those problems has mostly focused on comparing the comprehension of words from different semantic domains (e.g., living versus nonliving things; Laws, Adlington, Gale, & Sartori, 2007; Tippett et al., 2007). One method for assessing whether or not patients still recognize once-familiar words is the lexical decision task in which participants decide whether written or spoken stimuli are real words or invented nonwords. Performance on the lexical decision task is relatively unaffected in the early stages of Alzheimer's disease (Cuetos et al., 2003; Madden, Welsh-Bonner, & Tupler, 1999), and the task has been discussed in the literature as a possible means of estimating premorbid cognitive performance in patients in the early stages of Alzheimer's disease (Baddeley, Emslie, & Nimmo-Smith, 1993; McFarlane, Welch, & Rogers, 2006). The fact that many Alzheimer patients perform reasonably well at lexical decision has also meant that researchers have been able to use the task to explore phenomena such as semantic priming, contributing to theoretical debate about the nature of the underlying semantic impairment in Alzheimer's disease (e.g., Giffard, Desgranges, & Eustache, 2005).

One reason why lexical decision is relatively immune to the early stages of Alzheimer's disease may be that it is possible to recognize a word as familiar without having a full and complete understanding of what the word means. This may be particularly true when it comes to performance on modified versions of lexical decision such as the 'Spot the Word' test of Baddeley et al. (1993) in which patients are presented with two stimuli on each trial (a word and an invented nonword) and are asked simply to indicate which one is the real word. Under those conditions, any sense of familiarity or residual meaning attaching to the real word may be enough to allow it to be discriminated from a nonword. Plaut (1997) proposed that lexical decision responses may be based on a sense of familiarity arising from broad activation of semantic representations (see also Millis & Button, 1989). For patients in the early stages of Alzheimer's disease, that activation might not be precise enough to allow a full and complete understanding of a word, or to discriminate between closely related words on the basis of their meaning, but could be sufficient to permit a word to be distinguished from a nonword in a forced-choice test.

If semantic representations suffer progressive degradation in Alzheimer's disease, and if recognizing a word as familiar depends to some extent on activating semantic representations, then a point should be reached where patients fail to recognize some words as familiar. Law and O'Carroll (1998) administered the full version of Baddeley et al.'s (1993) Spot the Word Test to 21 patients with an average score of 17.0 on the Mini Mental State Examination (MMSE: Folstein, Folstein, & McHugh, 1975); also to 50 matched controls. The controls made an average of 9.1 errors on the test while Alzheimer patients made an average of 13.8 errors. That difference was of marginal significance ($p = 0.098$) in a multivariate analysis of variance with participant age controlled as a covariate. Using a reduced version of the Spot the Word Test, Beardsall and Huppert (1997) obtained a mean score of 25.2 out of a maximum of 30 from normal controls. Patients classified as having minimal dementia obtained an average score of 23.6, which was not significantly different from that of controls. In contrast, patients classified as having mild/moderate dementia obtained an average score of 17.3, which was significantly worse that controls with average reading ability, and close to chance (15/30).

The present study is concerned with whether the age of acquisition of words predicts which words continue to be recognized as familiar by Alzheimer patients when they reach the point where they begin to make errors in lexical decision. If errors in lexical decision reflect semantic degeneration (rather, for example, than

random lapses of attention), then factors that affect word production should also affect recognition accuracy. The lexical property focused on in the present study – age of acquisition – has been found to exert a strong and consistent influence on lexical retrieval, not only in Alzheimer's disease but also in semantic dementia, stroke aphasia, and a range of other neuropsychological conditions (Ellis, 2006, in press; Juhasz, 2005). Studies of lexical decision speed in healthy adults also find a powerful influence of age of acquisition, with faster responses to early than late acquired words when other factors such as word frequency and imageability are controlled (e.g., Alija & Cuetos, 2006; Cortese & Khanna, 2007; Menenti & Burani, 2007; Morrison & Ellis, 2000).

Our own clinical experience indicated that if Alzheimer patients were asked to judge whether individually presented stimuli were words or nonwords, they sometimes had difficulty maintaining attention and remembering the task over a run of trials. On the other hand, a 'spot the word' version of the lexical decision test which required patients to discriminate a word from a single nonword could be too easy (given the 50% chance rate) and insensitive to semantic loss. The version of the task employed here involved presenting patients and matched controls with four stimuli on each trial, one word and three legal, pronounceable nonwords (i.e., sequences of letters which could be words but happen not to be). The real words were half early acquired and half late acquired. Age of acquisition was determined from norms obtained by Davies, Barbón, and Cuetos (submitted for publication). The early words are estimated to be learned before the age of 6 years (e.g., mariposa [butterfly], siesta [nap]) while the late word are typically learned between the ages of 8 and 12 years (e.g., cal [lime], torrente [torrent]). The sets of early and late acquired words were matched on two different measures of word frequency, also on imageability, letter length, syllable length, and number of orthographic neighbours. The participant's task was simply to point to the real word on each trial. We predicted that if the cause of recognition failure is the same loss of lexical-semantic representations as is responsible for the problems in word retrieval, then Alzheimer patients should fail to recognize more of the late acquired words than the early acquired words.

2. Materials and methods

2.1. Participants

Twenty-two patients with probable Alzheimer's disease (18 females and 4 males) with a mean age of 80.6 years (range 71–90) and a mean educational level of 5.2 years of study (S.D. = 2.9) participated in this study. The patients were selected on the basis of their medical history and a neuropsychological evaluation. The diagnosis of probable Alzheimer's disease (AD) was made according to the NINCDS-ARDA (Neurological and communicative disorders and stroke, and Alzheimer's disease and related disorders) criteria (McKahnn et al., 1984). The neuropsychological evaluation comprised the Mini Mental State Evaluation (Folstein et al., 1975), Tower of Hanoi test, the Stroop test, and several tasks from the Barcelona Test (verbal memory, visual memory, comprehension and phonological and semantic fluency; Peña, 1990). The patients had an average MMSE score of 20.6, with a range of 12–26.

Twenty-two healthy adults (18 females and 4 males) with a mean age of 80.7 years (range 72–94) acted as controls. The controls had a mean educational level of 5.1 years of study (S.D. = 2.9) and MMSE scores of 27 or above (mean 28.6, range 27–30). None had a psychiatric history, sensory deficiencies or medical conditions that could impair performance on the neuropsychological tests. All were volunteers.

All the participants came from a region of northern Spain whose economy has traditionally been based on industry and agriculture. All had been manual workers or housewives throughout their adult lives.

2.2. Stimuli

One hundred and twenty words and 180 nonwords were used in this study. Sixty of the words had early and 60 had late age of acquisition values (Davies, Barbón, & Cuetos, submitted for publication). In terms of estimated ages, the early words had a mean estimated age of acquisition of around 4 years (range 2–6 years) while the late words had a mean estimated AoA of around 9 years (range 8–12 years). The sets of early and late acquired words were matched on two different measures of word frequency. The first measure, Lexesp frequency, was taken from Sebastián, Martí,