

Picture priming in normal aging and Alzheimer's disease

Soledad Ballesteros, José M. Reales and Julia Mayas
Universidad Nacional de Educación a Distancia

Picture priming in normal aging and Alzheimer's disease. The present study investigated age invariance for naming pictures and whether implicit memory is spared in Alzheimer's disease (AD). During the study phase, young adults, AD patients, and older controls were shown outlines of familiar pictures. After a distracter task, implicit memory was assessed incidentally. The results showed similar visual priming for the three groups, although young adults responded faster than the two older groups. Moreover, the number of errors was smaller for studied than for nonstudied pictures. This pattern of results was repeated across the three groups, although AD patients produced more errors than young adults and older controls, and there were no differences between these latter groups. These results confirmed previous visual and haptic findings showing unimpaired perceptual priming in normal aging and AD patients when implicit memory is assessed using identification tasks. These results are interpreted from a cognitive neuroscience perspective.

El trabajo estudió la existencia de *priming* perceptivo invariante con la edad y si la memoria implícita se mantiene en enfermos de Alzheimer (EA). Presentamos a adultos jóvenes, enfermos de Alzheimer (AD) y mayores controles durante la fase de estudio siluetas de dibujos familiares. Después de realizar una tarea distractora, evaluamos su memoria implícita de manera incidental. Los resultados mostraron un *priming* perceptivo similar en los tres grupos, aunque los jóvenes respondieron más de prisa que los dos grupos de mayores. Además, el número de errores fue menor en los tres grupos para los estímulos estudiados que para los no estudiados. Estos resultados confirman resultados visuales y hápticos previos y sugieren la existencia de *priming* perceptivo normal, invariante con la edad y la demencia, cuando la memoria implícita se evalúa con tareas de identificación perceptiva. Estos resultados se interpretan desde la perspectiva de la neurociencia cognitiva.

Aging is usually associated with a decline in many cognitive processes, specially memory, attention, and action fluency (Park, 1999; Perea, Ladera, & Rodríguez, 2005; Perry & Hodges, 1999) as well as an increase of the tip of the tongue phenomenon (Juncos-Rabadán, Facal, Álvarez, & Rodríguez, 2006). During the last decade, cognitive psychologists have made a great effort to identify the cognitive mechanisms responsible for the mental decline that people experience with age. As a result, several mechanisms have been proposed to account for the deterioration of cognitive performance. For example, Salthouse (1996) suggested the general slowing in information processing as the main cause of mental decline in the old age. Baltes and Lindenberger (1997) proposed sensory decline (specially vision and audition) as the main cause of cognitive impairment in the elderly. They argued that what caused poor performance in many cognitive tasks was not the decreased sensory function but that sensory function was just an indicator of good brain functioning and overall neurological integrity. Still other researchers believed that cognitive decline is due to the decrease of the amount of

working memory capacity (Craik & Byrd, 1982) or to the difficulty to ignore irrelevant information and to inhibit dominant responses (Hasher & Zacks, 1988).

Changes occurring in the brain structure and function are considered today the main cause of cognitive decline (Raz, 2000). As brain ages most cognitive functions became less efficient, specially memory. However, memory is not a unitary system and not all memories deteriorate with age (Prull, Gabrieli, & Bunge, 2000). It has been observed that voluntary remembering of facts and events becomes sometimes difficult for the elderly (Park, Lautenschlager, Hedden et al., 2002). This type of conscious recollection, known as explicit memory, is deteriorated in Alzheimer's disease patients (AD) (Fleischman & Gabrieli, 1998). Explicit memory has been traditionally assessed by recall, recognition and cued recall tasks. These tasks require participants to recall or recognize material presented previously during the encoding phase and task's instructions refer openly to previous experience with the stimuli. In contrast, implicit memory is unveiled when previous experience does not require intentional or conscious recollection of previously presented information (Schacter, 1997). This type of memory is assessed by indirect or incidental memory tasks that never refer to past experience with the stimuli. Implicit memory is demonstrated by showing better performance in accuracy or/and response time for «old» compared to «new» stimuli. This facilitation in performance is known as repetition priming. Over the years, implicit memory has been

Fecha recepción: ??? • Fecha aceptación: ???

Correspondencia: Soledad Ballesteros

Facultad de Psicología

Universidad Nacional de Educación a Distancia

28040 Madrid (Spain)

E-mail: mballesteros@psi.uned.es

assessed to a large extent using verbal materials and several incidental memory tasks such as *word identification*, *word-stem completion* and *word-fragment completion* (Roediger & Blaxton, 1987). More recently, however, researchers have focused on pictorial materials (Ballesteros, Reales, García, & Carrasco, 2006; Schacter, Cooper, & Delaney, 1990). Much less attention has been paid to the study of implicit memory for stimuli presented to other perceptual modalities such as touch (Ballesteros & Reales, 2004) or olfaction (Fusari & Ballesteros, 2006; Olsson & Fridén, 2001).

Implicit memory tasks attracted the interest of cognitive researchers because performance in these memory tasks dissociated from performance on explicit tasks (for a review, see Roediger & McDermott, 1993). These dissociations encountered in healthy individuals as well as in neurological patients lead cognitive neuroscientists to propose that different memory systems exist in the human brain (e.g., Tulving & Schacter, 1990).

When memory of healthy older individuals and AD patients is assessed using implicit memory tasks a pattern of results emerges that contrast clearly with the common findings in explicit memory tests. Initial studies found that repetition priming as a measure of implicit memory is age-invariant while it is greatly reduced at late stages of Alzheimer's disease. However, as Fleischman and Gabrieli (1998) noticed, these initial conclusions seem less supported with the passage of time. The proposal that priming as a measure of implicit memory is spared in normal aging was based on results from studies that report similar levels of facilitation for young and old participants in verbal tasks such as *word fragment completion*, *word stem completion* and *picture naming* (Light & Singh, 1987). In contrast, early AD studies showed that implicit memory and explicit memory were both impaired in these neurological patients (e.g., Shimamura, Salmon, Squire, & Butters, 1987).

The interest in the study of the effect of aging and dementia on implicit memory tasks has increased greatly during the last decade. Fleischman and Gabrieli (1998) reviewed over 180 experiments and concluded that priming was often unaffected by aging and affected by AD. However, many studies have found that priming is affected by aging and not by AD. These reviewers proposed at least three possible explanations for the inconsistencies encountered in the priming literature on aging and dementia. These explanations were inadequate power, heterogeneity of participants characteristics, and heterogeneity of task characteristics (p. 89). Previous studies with healthy elderly which used *speeded picture naming* to assess implicit memory reported age priming invariance with delays of 25 to 50 intervening items (Mitchell, 1989), and 1 to 3 weeks between study and test (Mitchell, Brown, & Murphy, 1990). A number of experiments conducted with AD have also showed preserved picture priming (see Park et al., 1998).

The present study was designed to find out whether implicit memory for pictures is age invariant and if perceptual priming is comparable in normal aging and AD patients when they are presented with a picture at a time during encoding under full attention conditions. In accordance to previous visual findings using unfamiliar visual displays with young (e.g., Cooper, Schacter, Ballesteros, & Moore, 1992; Schacter et al., 1990), older healthy adults (e.g., Schacter, Cooper, & Valdiserri, 1992) and AD patients (e.g., Gabrieli et al., 1994; Park et al., 1998) we hope to find that perceptual visual priming assessed by an implicit memory task that requires just stimulus identification is spared in normal aging and in AD patients.

Method

Participants

There were three groups of participants: 8 AD patients, 8 older healthy controls, and 12 young adults. The AD group was composed of 4 men and 4 women with a mean age of 72 years (range= 61- 83 years; SD= 6.06) and a mean educational level of 6 years (range = 4 -9 years; SD = 1.7). They were referred from the *Hospital-Fundación Alcorcón*. All the patients met the NINCDS-ADDRA criteria for the diagnosis of probable AD (McKhann et al., 1984). The evaluation included medical, neurological, neuropsychological and psychiatric examinations, laboratory testing and PET (Positron Emission Tomography). The Mini-Mental State (MMSE) Examination in its Spanish adaptation (Lobo, Escobar, Ezquerro, & Díaz, 1980) mean was 20.87 (range from 18 to 24; SD= 2.20) out of a possible 30 points. All the patients had a history of progressive cognitive decline, impairment of explicit memory, and a deficit in other cognitive areas. None had a history of psychiatric disorder, disturbance of consciousness, or were using anxiolytic, antidepressant, or sedative drugs. None of the subjects was institutionalized. The older control group was composed of 8 elderly volunteers (4 men and 4 women) recruited from a community center. The mean age of the group was 70 years (range= 64-79 years; SD= 5.99) and the mean educational level was 4 years (range 3-9 years; SD= 3). The mean MMSE score was 29.25 (range 28-30; SD= 0.83). None had a history of medical or psychiatric disorder or of taking psychoactive medication that affected the central nervous system at the time of the study.

The young adult group comprised 12 undergraduate students attending the Universidad Nacional de Educación a Distancia of Madrid with a mean age of 32 years (range= 19-47 year; SD= 8,5) and 14 years of education. The group was composed of 6 men and 6 women. All participants in the study were native Spanish speakers.

Apparatus and Stimuli

The stimuli were presented on a 14" color monitor of a Compatible PC, whose resolution was 640 × 480 pixels. The system was interfaced with a voice-key (Lafayette 60340) to record response time. A set of 120 outline pictures selected from the Snodgrass and Vanderwart's (1980) drawings were used as stimuli. Sixty were drawn as blue outlines and 60 as green outlines. The objects were selected from several basic-level categories (vegetables, tools, personal care objects, household objects, and animals). The pictures were approximately 10 × 10 cm subtending a visual angle of approximately 4° × 4°. Each picture was digitalized, saved in graphic BMP format, and presented at the centre of the computer screen as green or blue outlines over a white background. A voice key attached to the collar of the participant was used to recording latencies. This key stopped the internal clock of the computer to measure reaction time. Latency was measured from the time the picture outline appeared at the screen until vocal response.

Design

The experimental design consisted of a 3 Groups of participants (AD patients, healthy older adults, and young adults) × 2 Item types

(studied vs. nonstudied objects) \times 2 Colors (blue vs. green) mixed factorial design. The first variable was a between-subject variable whereas the last two were within-subject variables. In addition, the 120 target pictures were subdivided randomly into 4 subsets of 30 stimuli each (two subsets were drawn as green outlines and the other two as blue outlines), which appeared equally often as studied and nonstudied across subjects. Stimuli in the four subsets appeared equally often as studied and nonstudied stimuli in the implicit memory test. The computer program generated a different random presentation order for each participant.

Procedure

Study phase. Participants were seated comfortably at the table in front of a computer. They were tested individually in a quiet room. The experimenter informed that they were participating in a visual study and she explained the task. The session always started with a study phase in which participants were presented with a series of picture outlines, one by one. Each participant was presented with 60 study trials, 30 blue and 30 green in a different random order plus 5 more at the beginning and 5 at the end. On each trial, a sound from the computer informed the participant that

the picture was to appear at the center of the computer's screen. During the study phase, participants performed a speeded-naming task—they were asked to name as quickly as possible the picture. Following a 5-min distracter task, all the participants performed incidentally the implicit test.

Test phase. After completing the distracter task, they performed the *test-phase*. In this phase of the experiment, to the 60 studied pictures presented during the study phase another 60 nonstudied pictures were added. So, 120 stimuli were presented in this phase of the experiment: 60 old (30 green and 30 blue) and 60 new pictures (30 green and 30 blue) added for this phase of the experiment. The computer program generated a different random order for each participant. A tone from the computer announced that the stimulus was to appear on the screen. On each trial the outline of a familiar drawing appeared at the center of the screen. Participants performed a *speeded picture naming test*. A vocal key was used to stop the internal clock of the computer. Reaction times were measured from the time the stimuli appeared at the screen to the naming response. The test-phase started with 5 practice trials that were the same for all participants. The practice trials did not enter in the data analysis.

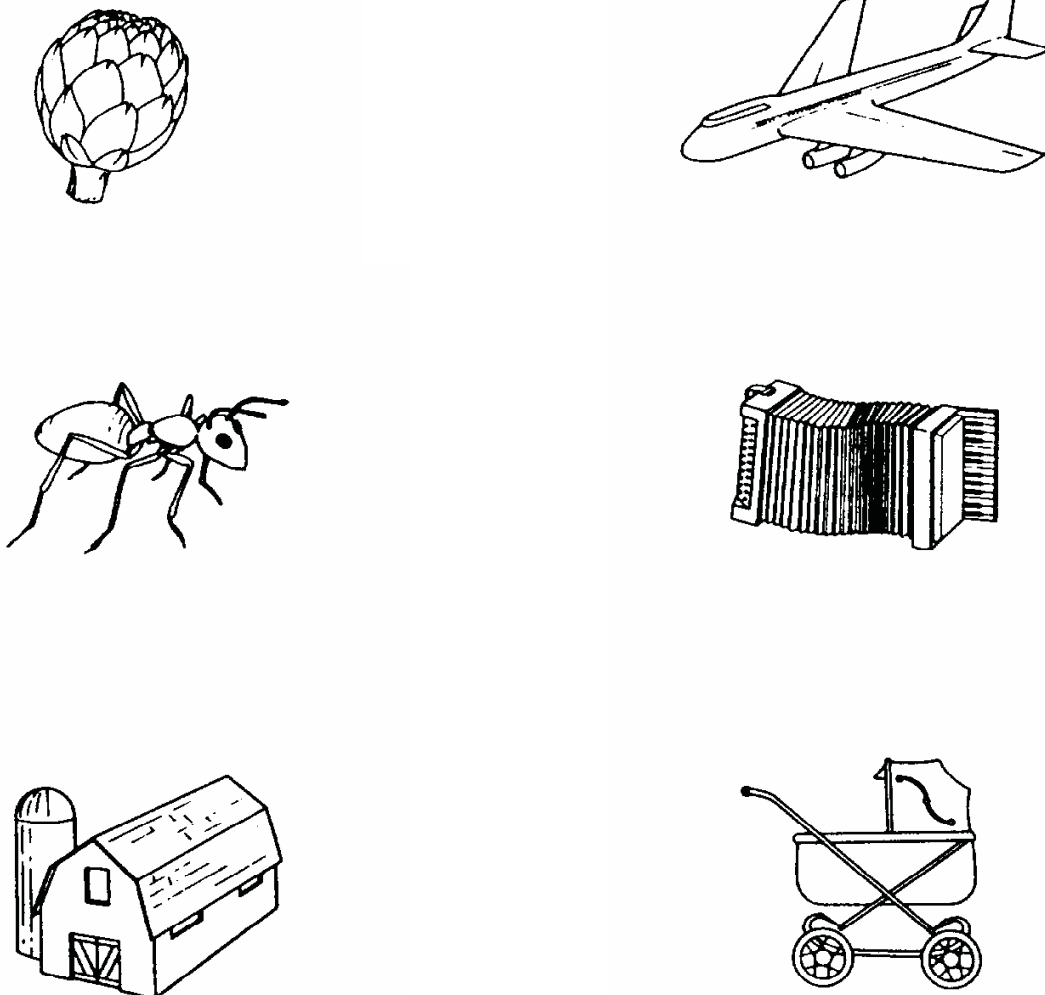


Figure 1. Examples of the set of 120 pictures selected from the Snodgrass and Vanderwart's (1980) drawings used in the study

Results

Latencies corresponding to correct responses were the main dependent variable, but accuracy was also recorded. The analysis of results corresponding to latencies is presented first followed by the analysis of accuracy.

Response time analysis

Figure 2 displays the latencies from the implicit memory task as a function of group (AD patients, older adults, and young adults) and item type (studied, nonstudied). The data showed a large facilitatory priming effect. Studied pictures (mean 1130.77 ms) were named faster than nonstudied pictures (mean 1203.83 ms). This pattern of results repeated for the three groups of participants as young adults, older adults, and AD participants named visually studied pictures faster than nonstudied pictures. On average, the facilitatory effect obtained for studied objects compared to nonstudied objects was 828.13 ms, 324.09 ms, and 227.85 ms for the AD group, the older adult group and the young adult group, respectively. Moreover, blue pictures (mean 1075.77 ms) were named faster than green pictures (mean 1118.59 ms) in the three groups.

Latencies corresponding to the correct responses were the main dependent variable in the statistical analysis. A three-factor mixed ANOVA was conducted on latency with Group as the between-subjects variable and Item type and Color as the within-subjects variables. The results confirmed the description of the data presented above. The main effect of Study condition was highly significant, $F(1,25) = 19.656$, $MSE = 72670.71$, $p < 0.001$. Studied pictures were named significantly faster than nonstudied pictures, showing a significant visual priming effect. The main effect of Group was also significant, $F(2,25) = 30.759$, $MSE = 202233.07$,

$p < 0.01$. Paired comparisons showed that young adults (825.64 ms) and older adults (988.36 ms) named the pictures significantly faster than AD patients (1613.26 ms) ($p < 0.001$). On the other hand, the two healthy groups did not differ significantly ($p > 0.05$). Finally, the main effect of Color was significant, $F(1,25) = 4.93$, $MSE = 8538.38$, $p < 0.005$. Blue pictures (1122.67 ms) were named significantly faster than the green pictures (1162.183 ms).

The interaction Color \times Item type was also significant, $F(1,28) = 8.621$, $MSE = 14393.76$, $p < 0.01$. The analysis of the interaction showed that blue nonstudied pictures were named faster (1148.86 ms) than green nonstudied pictures (1258.91 ms), $F(1,27) = 11.27$, $MSE = 15033$, $p < 0.01$. However, blue and green studied pictures did not differ significantly ($p > 0.05$). The Group \times Item type interaction was not significant, $F(2,31) = 0.541$, $p = 0.54$. The three groups of participants showed similar priming. In other words, priming was unaffected by both, aging and AD.

Error analysis

Errors were also analysed. Figure 3 displays means and 95% confidence intervals from the implicit memory task as a function of group (AD patients, older adults, and young adults) and item type (studied, nonstudied).

A second ANOVA was conducted with Group as between-subject factor and Item type (studied, nonstudied stimuli) and Color (blue, green) as within-subject factors having errors as the dependent variable. The number of errors was significantly smaller for studied objects (mean 3,34) than for nonstudied objects (mean 4,08), $F(1,25) = 5.65$, $MSE = 2.63$, $p < 0.005$. This pattern of results repeated across the three groups. These results suggest that there was not speed-accuracy-trade-off. The main effect of Group was also significant, $F(2,25) = 47.89$, $MSE = 12.97$, $p < 0.01$. Comparisons showed that young adults (mean 1,229) and older adults (mean 1,281) produced less errors than AD patients (mean

Visual Priming for familiar pictures

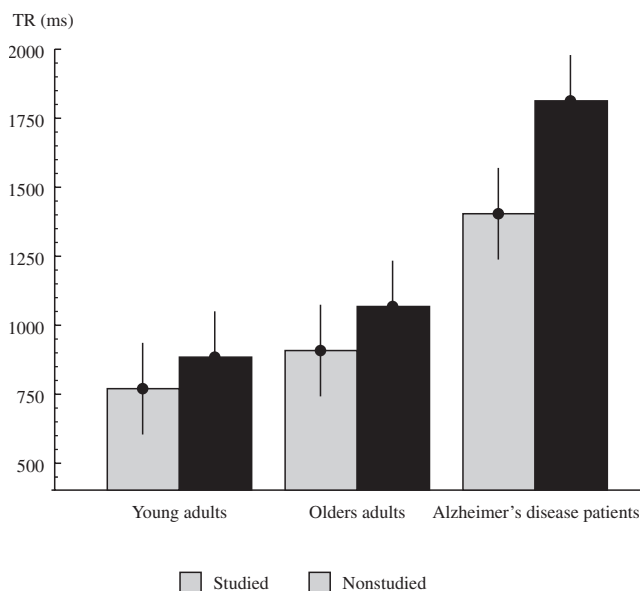


Figure 2. Mean reaction times for studied and nonstudied pictures as a function of group (young adults, older adults, and AD patients). The error bars show the 95% confidence interval

Errors for familiar pictures

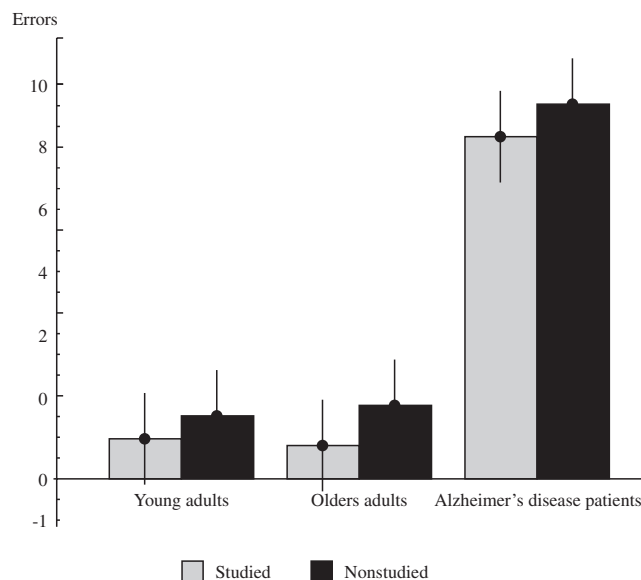


Figure 3. Mean of errors for attended, unattended and nonstudied pictures as a function of group. The error bars show the 95% confidence interval

8,62). Moreover, both healthy groups did not differ between them, $p_s > 0.05$. Color was significant, $F(1,25) = 4.80$, $MSE = 2.87$, $p < 0.001$. Blue drawings produced more errors than green ones, $F(1,25) = 4.80$, $MSE = 2.87$, $p < 0.001$.

The interaction between Group and Color was significant, $F(2, 25) = 8.12$, $MSE = 1.89$, $p < 0.05$. Healthy old adults produced more errors with green pictures while young adults and AD patients produced more error with blue pictures. The interaction between Color and Item type was also significant, $F(1,25) = 19.85$, $MSE = 1.96$, $p < 0.01$. Studied blue pictures produced more errors than nonstudied blue pictures while there was not difference for the green pictures. Finally, the 3-way interaction among Group, Study condition and Color was significant, $F(2, 25) = 9.07$, $MSE = 1.96$, $p < 0.05$. To study this interaction we performed a simple effect analysis as a function of color. The only significant effect was found in AD who produced more errors for studied than for nonstudied green pictures while the opposite occurred for the blue pictures, $F(1,7) = 6.46$, $MSE = 8.13$, $p < 0.05$.

Discussion

The main goal of this study was to test the idea that AD patients showed visual priming when outlines of familiar pictures are presented at encoding one by one under full attention in the computer screen and implicit memory is assessed incidentally at test. A second goal was to find out whether the priming effect in AD patients was comparable to the facilitation obtained in young and older healthy adults that acted as controls. The results of the present study showed that AD patients showed intact visual priming in a *speeded-picture naming task*. Furthermore, the priming effect did not differ from the perceptual facilitation obtained either by older controls or young adults despite the difference in education. The unimpaired perceptual priming obtained in normal aging and AD patients are consistent with the identification-production hypothesis proposed by Gabrieli and his colleagues (Gabrieli et al., 1994; 1999). According to this proposal, AD patients would showed perceptual priming in implicit memory tasks that require identification of the stimuli in contrast to those implicit tasks that require response generation. The *speeded picture naming task* requires just identification.

The preserved priming in healthy aging and AD patients that did not differ from the priming effect obtained in young adults has also been observed when objects are presented to touch and young and older participants performed a haptic speeded object naming task (Ballesteros & Reales, 2004). Spared priming in older adults has also been found in an olfactory identification task with edible and non-edible familiar odor stimuli (Fusari & Ballesteros, 2006). Moreover, the preservation of implicit memory with aging has been obtained in cross-modal studies in which stimulus presentation are shifted from study to test—from visual to auditory ecological events and auditory to visual ecological events; visual to haptic and haptic to visual objects—(Ballesteros, Reales, Mayas, González, & García, 2005). The preserved priming effects in normal aging and AD are also congruent with other results showing intact perceptual priming in visual task (Keane, Gabrieli, Mapstone, Johnson, & Corkin, 1995).

In a previous study with young adults, we (Reales & Ballesteros, 1999) reported complete cross-modal priming

between vision and touch, and the cross-modal priming effects were equivalent to within modal visual and haptic priming. To explain these results, we proposed that visual and haptic object representations might be shared between vision and touch because these two perceptual modalities are well adapted to represent the structure of objects. Touch as well as vision are two modalities well adapted to extract the shape and the structure of objects (vision in the large space and touch in the close space).

Alzheimer's disease, the most common senile dementia, is characterized by a progressive global impairment of cognitive functioning. Explicit memory deficits appear early in the course of the disease. Lesions in the medial-temporal lobe and diencephalic brain regions produce a selective decline in declarative (episodic and semantic) memory tasks, including conceptual representation of natural and artifactual categories (Peraita & Moreno, 2006). Explicit memory depends on the medial-temporal lobe system (Tulving & Schacter, 1990). The spared implicit memory observed in visual studies may be explained by the sparing of modality specific cortical areas. In vision, these areas are the extrastriate visual areas. However, recent behavioural and imaging findings in touch support the idea that the extrastriate areas of the occipital cortex, that are relatively preserved at early phases of AD, play an important role in haptic priming. A large body of research using unfamiliar objects, 2-D shapes and even Braille letters have reported common activation of the lateral occipital complex (LOC) during visual and haptic exploration. These findings suggest that areas of the ventral visual pathway previously associated with visual processing are recruited during haptic perception as well (for reviews see Amedi, Kriegstein, Atteveldt, Beauchamp, & Naumer, 2005; T.V. James et al., 2002; Pascual-Leone, Theoret, Merabet, Kauffman, & Schlaug, 2006; Prather, Votaw, & Shatian, 2004).

In short, using a *speeded object naming task* to assess implicit memory, AD participants showed intact visual priming. Moreover, similar perceptual facilitation was shown by AD, young adults and older controls although the two healthy groups responded faster than AD. *Post-mortem* studies of AD have found little damage of the primary sensory neocortical areas, the basal ganglia and de cerebellum (Carlesimo & Oscar-Berman, 1992). Today a large body of research supports the idea that LOC is mainly involved in object shape analysis and identification. The area is relatively spared during the first stages of AD. This may explain why AD patients exhibit normal priming for both, visually and haptically experienced objects. Finally, one implication of the present results may be that the existence of the perceptual priming effect in AD patients allows rehabilitation professionals to use the spared implicit memory resources to enhance learning performance in these patients.

Acknowledgments

We acknowledge the support by the *Dirección General de Investigación Científica y Técnica* (SEJ 2004-00752). Julia Mayas was supported by a Predoctoral grant from the Spanish Ministry of Education and Science (Ref.: AP2003-0639). The authors are grateful to Dr. José Luis Dobato, neurologist from *Hospital-Fundación Alcorcón* that assessed the Alzheimer's patients. We also thank two anonymous reviewers for helpful comments in an early version of this article.

References

- Amedi, A., Kriegstein, K., van Atteveldt, N.M., Beauchamp, M.S., & Naumer, M.J. (2005). Functional imaging of human crossmodal identification and object recognition. *Experimental Brain Research*, *166*, 559-571.
- Ballesteros, S., & Reales, J.M. (2004). Intact haptic priming in normal aging and Alzheimer's disease: Evidence for dissociable memory systems. *Neuropsychologia*, *42*, 1063-1070.
- Ballesteros, S., Reales, J.M., Mayas, J., González, M., & García, B. (July 2005). *Crossmodal priming in normal aging*. Paper presented at the 9th European Congress of Psychology, Granada, Spain.
- Ballesteros, S., Reales, J.M., García, E., & Carrasco, M. (2006). Selective attention affects implicit and explicit memory for familiar pictures at different delay conditions. *Psicothema*, *18*, 88-99.
- Baltes, P.B., & Lindenberger, U. (1997). Emergence of a powerful connection between sensory and cognitive functions across the adult life span: A new window at the study of cognitive aging? *Psychology and Aging*, *12*, 12-21.
- Carlesimo, G.A., & Oscar-Berman, M. (1992). Memory deficits in Alzheimer's patients: A comprehensive review. *Neuropsychological Review*, *3*, 119-69.
- Cooper, L.A., Schacter, D.L., Ballesteros, S., & Moore, C. (1992). Priming and recognition of three-dimensional objects: Effects of size and reflection. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *18*, 43-57.
- Craik, F.M.I., & Byrd, (1982): Aging and cognitive deficits: The role of attentional resources. En F.I.M. Craik and S. Trehub (eds.): *Aging and cognitive processes* (pp. 191-211). Nueva York: Plenum.
- Fleischman, D.A., & Gabrieli, J.D.E. (1998). Repetition priming in normal aging and in Alzheimer's disease. A review of findings and theories. *Psychology and Aging*, *13*, 88-119.
- Fusari, A., & Ballesteros, S. (September 2006). Identification of odors as affected by aging: Normative data and priming effects. Paper presented at the 17th Congress of the European Chemoreception Research Organization, Granada, Spain.
- Gabrieli, J.D.E., Keane, M.M., Stanger, B.Z., Kjelgaard, M.M., Banks, K.S., & Corkin, S. et al. (1994). Dissociations among structural-perceptual, lexical-semantic and event-fact memory systems in Alzheimer's, amnesic and normal subjects. *Cortex*, *30*, 75-103.
- Gabrieli, J.D., Vaidya, C.J., Stone, M., Francis, W.S., Thompson-Schill, S.L., Fleischman, D.A., Tinklenberg, J.R., Yesavage, J.A., & Wilson, R.S. (1999). Convergent behavioral and neuropsychological evidence for a distinction between identification and production forms of repetition priming. *Journal of Experimental Psychology: General*, *128*(4), 479-498.
- Hasher, L., & Zacks, R.T. (1988). Working memory, comprehension and aging: A review and a new view. In G.H. Bower (ed.): *The psychology of learning and motivation* (vol. 22, pp. 193-225). San Diego, CA: Academic Press.
- James, T.W., Humphrey, G.K., Gati, J.S., Servos, P., Menon, R.S., & Goodale, M.A. (2002). Haptic study of three-dimensional objects activates extrastriate visual areas. *Neuropsychologia*, *40*, 1706-1714.
- Juncos-Rabadán, O., Facal, D., Álvarez, M., & Rodríguez, S. (2006). El fenómeno de la punta de la lengua en el proceso de envejecimiento. *Psicothema*, *18*, 501-506.
- Keane, M.M., Gabrieli, J.D.E., Mapstone, H.C., Johnson, K.A., & Corkin, S. (1995). Double dissociation of memory capacities after bilateral occipital lobe or medial temporal lobe lesion. *Brain*, *118*, 1129-1148.
- Light, L.L., & Singh, A. (1987). Implicit and explicit memory in young and older adults. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *13*, 531-541.
- Lobo, A., Escobar, V., Ezquerro, A., & Díaz, S. (1980). El minixamen cognoscitivo. *Revista de Psiquiatría y Psicología Médica*, *5*, 39-57.
- MacKhanan, G., Drachman, D., Folstein, M., Katzan, R., Price, D., & Stadlan, E.M. (1984). Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRA work group under the auspices of Department of Health and Human Services task force on Alzheimer's disease. *Neurology*, *34*, 938-944.
- Mitchell, D.B. (1989). How many memory systems? Evidence from aging. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *15*, 31-49.
- Mitchell, D.B., Brown, A.S., & Murphy, D.R. (1990). Dissociations between procedural and episodic memory: Effects of time and aging. *Psychology and Aging*, *5*, 264-276.
- Olsson, M.J., & Fridén, M. (2001). Evidence of odor priming: Edibility judgments are primed differently between the hemispheres. *Chemical Senses*, *26*, 117-123.
- Park, D.C. (1999): The basic mechanisms accounting for age-related decline in cognitive function. In D.C. Park and N. Schwarz (eds.): *Cognitive aging. A primer*. Philadelphia, PA: Psychology Press.
- Park, D.C., Lautenschlager, G., Hedden, T., Davidson, N., Smith, A.D., & Smith, P. (2002). Models of visuospatial and verbal memory across the adult life span. *Psychology and Aging*, *17*, 299-320.
- Park, S.M., Gabrieli, J.D.E., Reminger, S.L., Monti, L.A., Fleischman, D.A., Wilson, R.S., Tinklenberg, J.R., & Yesavage, J.A. (1998). Preserved priming across study-test picture transformations in patients with Alzheimer's disease. *Neuropsychology*, *12*, 340-352.
- Pascual-Leone, A., Theoret, H., Merabet, L., Kauffman, T., & Schlaug, G. (2006). The role of visual cortex in tactile processing: A metamodal brain. In M.A. Heller and S. Ballesteros (eds.): *Touch and blindness. Psychology and neuroscience* (pp. 171-1196). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Peraita, H., & Moreno, F.J. (2006). Análisis de la estructura conceptual de categorías semánticas naturales y artificiales en una muestra de pacientes de Alzheimer. *Psicothema*, *18*, 492-500.
- Perea, V., Ladera, V., & Rodríguez, A. (2005). Fluencia de acciones en personas mayores. *Psicothema*, *17*, 263-266.
- Perry, R.J., & Hodges, J.R. (1999). Attention and executive deficits in Alzheimer's disease. A critical review. *Brain*, *122*, 383-404.
- Prather, S.C., Votaw, J.R., & Shatian, K. (2004). Task-specificity recruitment of dorsal and ventral visual areas during tactile perception. *Neuropsychologia*, *42*, 1079-1087.
- Prull, M.W., Gabrieli, J.D.E., & Bunge, S.A. (2000). Age-related changes in memory: A cognitive neuroscience perspective. In F.I.M. Craik and T.A. Salthouse (eds.): *The handbook of aging and cognition* (2nd ed., pp. 91-153). Mahwah, NJ: Erlbaum.
- Raz, N. (2000). Aging of the brain and its impact on cognitive performance: Integration of structural and functional findings. En F.I.M. Craik and T.A. Salthouse (eds.): *The handbook of aging and cognition* (pp. 1-90). Mahwah, NJ: Lawrence Erlbaum Associates.
- Reales, J.M., & Ballesteros, S. (1999). Implicit and explicit representations of visual and haptic objects: A cross-modal study. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *20*, 1-25.
- Roediger, H.L., & Blaxton, T. (1987). Effects of varying modality, surface features and retention interval on priming in word fragment completion. *Memory & Cognition*, *15*, 379-388.
- Roediger, H.L., & McDermott, K.B. (1993). Implicit memory in normal human subjects. *Handbook of Neuropsychology*, *8* (pp. 63-131). Amsterdam: Elsevier.
- Salthouse, T.A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review*, *103*, 403-428.
- Schacter, D.L. (1997). *Journal of Experimental Psychology: Learning, Memory and Cognition*, *13*, 501-518.
- Schacter, D.L., Cooper, L.A., & Delaney, S.M. (1990). Implicit memory for unfamiliar objects depends on access to structural descriptions. *Journal of Experimental Psychology: General*, *119*, 5-24.
- Schacter, D.L., Cooper, L.A., & Valdiserri, M. (1992). Implicit and explicit memory for novel visual objects in older and younger adults. *Psychology and Aging*, *2*, 299-308.
- Shimamura, A.P., Salmon, D.P., Squire, L.R., & Butters, N. (1987). Memory dysfunction and word priming in dementia and amnesia. *Behavioural Neuroscience*, *101*, 347-351.
- Snodgrass, J.L., & Vanderwart, M. (1980). A standardized set of 260 pictures: norms for name agreement, image agreement, familiarity and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, *6*, 807-815.
- Tulving, E., & Schacter, D.L. (1990). Priming and human memory systems. *Science*, *247*, 301-306.