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Differential effects of negative and positive emotional content over veridical and false recognition in aging and Alzheimer's disease

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ABSTRACT

Alzheimer's disease (AD) patients are known to present semantic memory impairments, and semantic processing plays a crucial role in the formation of false memories. We assessed 40 early stage AD patients and 35 matched healthy volunteers with an emotional version of the Deese-Roediger-McDermott paradigm, which allows the study of false memory formation. Participants were presented with three negative, three neutral and three positive lists of words, each semantically associated to a critical unpresented word. After the presentation of the lists the volunteers were asked to respond to a recognition questionnaire stating whether these critical lures, as well as other presented and unpresented words, had been previously shown or not. We replicate the pattern of decreased discriminability between list-related and -unrelated items for AD patients compared to healthy seniors observed in previous studies. Moreover, like control participants, AD patients displayed enhanced true recognition for emotional materials, both positive and negative. With regards to false recognition, our data show decreased discriminability between related and unrelated lures for positive material. These results point out differential involvement of semantic-based information during memory formation in AD patients compared to healthy seniors. Nevertheless, our data indicate that emotional content effects over semantic-based false memory formation persist in this population, at least at early stages of disease development.

1. Introduction

Even at early stages, patients with Alzheimer's disease (AD) are known to be affected by an episodic memory impairment that implies difficulties in learning new information (Fox, Warrington, Seiffer, Agnew, & Rossor, 1998). Furthermore, semantic memory deficits have also been observed in AD patients (Chertkow & Bub, 1990; Cuetos, Rodríguez-Ferreiro, Sage, & Ellis, 2012; Rodríguez-Ferreiro, Davies, González-Nosti, Barbón, & Cuetos, 2009) and some studies even point them out as a robust early cognitive marker of the disease (Cuetos, Rodríguez-Ferreiro, & Menéndez, 2009).

Episodic and semantic memory interact to support our decision-making and communication abilities. However, memory is error-prone and false memories are quite common in our everyday lives. The Deese-Roediger-McDermott paradigm (DRM; Deese, 1959;

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Roediger & McDermott, 1995) is usually applied to mirror spontaneous false memories in the laboratory (Díez, Gómez-Ariza, Díez-Álamo, Alonso, & Fernández, 2017; Watson, Bunting, Poole, & Conway, 2017). In a DRM task volunteers are presented with lists of words (e.g. "table", "sit", "legs", "seat", "couch" …) that are semantically related to a non-presented critical word (e.g. "chair"), and then asked to decide whether this critical lure, as well as other presented and unpresented words, had been shown or not. In this task, participants are usually very accurate in recognizing truly presented items. Furthermore, they also tend to falsely accept as studied the critical items most of the times (Roediger & McDermott, 1995). According to the activation-monitoring theory (Roediger, Watson, McDermott, & Gallo, 2001), the false memory effect in the DRM task can be attributed to the automatic spreading of associative activation from the representations of the list items to that of the critical lure. From this point of view, false memories are due to a failure during the source monitoring process at retrieval, leading the participant to accept as presented the associatively activated critical word. Alternatively, the fuzzy-trace theory (Reyna & Brainerd, 1995) assumes that the presentation of the lists during the study phase of a DRM task leads the participant to generate verbatim representations containing perceptual and contextual details of the presentation, as well as gist representations consisting of semantic information related to the general meaning evoked by the list. From this perspective, true memory of presented items relies on the presence of both verbatim and gist traces. In contrast, false recognition of the critical lure is attributed to the persistence of the gist, semantic-based, representation during the recognition phase, as well as inability to use verbatim traces of truly presented words to suppress the acceptance of critical distractors.

AD patients have been shown to present both decreased veridical and false recognition rates compared to healthy age-matched controls in the DRM paradigm (Balota et al., 1999; Budson, Daffner, Desikan, & Schacter, 2000; Budson, Sullivan, Daffner, & Schacter, 2003). From the perspective of the fuzzy-trace theory, these results could suggest that AD patients and healthy seniors rely on semantic activation to a different extent when faced with a DRM memory task. In the present work, we applied the DRM paradigm to the study of semantic processing of AD patients in relation to words with emotional content.

Susceptibility to false memories is known to be modulated by the affective content of the words, with negatively valenced words producing more memory distortion than neutral or positive words (Bookbinder & Brainerd, 2016). In the context of the fuzzy-trace theory, Brainerd, Stein, Silveira, Rohenkohl, and Reyna (2008) hypothesized that the presence of negative content in words enhances the processing of semantic relations among them. This produces stronger gist traces, hence, leading to higher levels of false memory. Regarding positively valenced material, the fuzzy-trace theory predicts that positive content strengthens verbatim traces, which allows for a more accurate suppression of unpresented lures (Brainerd et al., 2008).

The assessment of false memories of valenced words in AD patients is, thus, relevant for the study of semantic processing and could shed light on the effects of emotional content on the semantic deterioration observed in these patients. Nevertheless, to our knowledge, only two studies have been conducted with this aim so far (Brueckner & Moritz, 2009; Budson et al., 2006).

On the one hand, Budson et al. (2006) presented 19 AD patients (10 females; mean age = 76.6, range = 60–91) showing mild to moderate cognitive impairment and 19 healthy seniors with a false recognition DRM task including five emotional and five non-emotional lists. The authors found increased true recognition for emotional compared to non-emotional items in control participants but not in AD patients. Regarding false recognition, no effects of emotional content were observed when analyzing the performance of AD patients and age-matched controls. On the other hand, Brueckner and Moritz (2009) compared the performance of 36 AD patients (20 females; mean age = 70, SD = 6.1) presenting mild to moderate cognitive impairment with that of healthy controls in a DRM task with three emotional lists and one neutral list. Veridical recognition was higher for emotional compared to neutral lists in healthy participants but not in the AD group. The analyses of false recognition showed that all groups recognized emotional items more often than neutral ones. Thus, the two studies obtained similar results in relation to veridical recognition, but their results regarding false recognition were contradictory.

In sum, the effects of emotional content over false recognition in AD are still not clear. A possible source of the discrepancies observed in previous studies could be related to the nature of the emotional stimuli used. Whereas Budson et al. (2006) compared negative lists with a mixture of neutral and positive lists, Brueckner and Moritz (2009) used two negative lists and one positive list as emotional materials compared to one neutral list. In our study we aimed to clarify these results comparing the performance of AD patients with that of age-matched healthy volunteers in a DRM task with negative, neutral and positive material. The assessment of early-stage AD patients allows the study of semantic impairment while other cognitive abilities are still preserved. Given the reliance of false recognition on semantic activation, we expect AD patients to present reduced false memory rates compared to matched controls.

As for item valence, and following the fuzzy-trace theory (Bookbinder & Brainerd, 2016; Brainerd et al., 2008), we expect healthy controls to present higher false memory rates for negative words compared to neutral and positive words due to enhanced semantic connectivity between negative concepts leading to stronger gist representations. Regarding patients with AD, we expect them to present lower false memory rates than controls given the previously observed association between AD and semantic deficits (Chertkow & Bub, 1990; Fernando; Cuetos et al., 2012; Rodríguez-Ferreiro et al., 2009). Crucially, the presence of differential patterns of negative, neutral and positive false memories between patients and controls would point out a relevant role of emotional content during semantic deterioration.

2. Methods

2.1. Participants

A total of 75 seniors distributed in two subgroups took part in the study. They all were native Spanish-speakers. The first subgroup comprised 40 outpatients diagnosed with probable AD according to the NINCDS-ADRDA criteria (McKhann et al., 1984; Tierney

Table 1
Summary of the participants' demographic characteristics.

	n	females	Age mean(SD)	years of education mean(SD)	MMSE mean(SD)
AD	40	20	73.9(7.2)	9.3(3.3)	23.9(2.3)
Control	35	17	71.7(5.4)	9.8(3.8)	29.4(0.7)

et al., 1988). All the patients had been diagnosed prior to their inclusion in the study and underwent a full neurological evaluation, as well as blood tests, neuroimaging and neuropsychological assessment including, among others, the MiniMental State Evaluation (MMSE, Folstein, Folstein, & McHugh, 1975). They were situated at stages 3, very mild, or 4, mild, of the Global Deterioration Scale (Reisberg, Ferris, de Leon, & Crook, 1982). Besides, a control group of 35 matched healthy seniors was selected among relatives and caregivers of the patients. All the participants were native speakers of Spanish. We excluded from our sample participants with a history of psychiatric disorders, alcohol abuse or sources of cognitive impairment other than AD. We obtained informed consent for the participation in the study from all the participants or their caregivers. The study was conducted in accordance with the Declaration of Helsinki for experiments involving humans. A summary of the participants' socio-demographic characteristics is presented in Table 1. The groups were matched for age and years of education. In contrast, MMSE scores of the patient group were significantly different to those of the control group ($t(73) = -12.752$, $p < .001$), pointing out that the patients presented some degree of cognitive impairment.

3. Materials

We selected nine critical lures varying on valence values obtained from Spanish word emotion databases (Hinojosa et al., 2016; Redondo, Fraga, Comesaña, & Perea, 2005; Stadthagen-Gonzalez, Imbault, Pérez Sánchez, & Brysbaert, 2017). Vulgar and taboo words were avoided. The stimuli set comprised three groups of negative (e.g. treason), neutral (e.g. column) and positive (e.g. garden) valence respectively. The three groups of critical lures were significantly different in this variable ($ps < .001$). Nevertheless, they were matched ($ps > .1$) on arousal as well as subtitle-based lexical frequency and contextual diversity, phoneme, letter and syllable length, orthographic Levenshtein (OLD20) distance and subjective concreteness (Duchon, Perea, Sebastián-Gallés, Martí, & Carreiras, 2013). A summary of the items' characteristics is presented in Table 2. For each of the nine critical lures we constructed one DRM list of eight associated items selecting the most associated words from the Normas de Asociación Libre en Castellano database (Fernández, Díez, & Alonso, 2009). For example, the list corresponding to “betrayal” consisted of the words “infidelity”, “revenge”, “disappointment”, “suspicion”, “disloyal”, “neglect”, “lover” and “deserter”. The subsets of three negative, three neutral and three positive lists were matched on average backwards associative strength between the list items and their respective critical lures. The lists presented the words in decreasing order of association to the critical lure. Words from negative, neutral and positive lists were also matched in lexical frequency and contextual diversity ($ps > .3$). Negative list words presented significantly lower valence values than neutral and positive list words ($ps < .001$) and were also more arousing ($ps < .001$). Positive list words turned out to be more calming than neutral list words ($p = .04$). Finally we selected 18 new words semantically unassociated to any of the lists to be used as unrelated lures in the recognition questionnaire. Six of them were negative valenced words (e.g. rancid, unable), six were neutral words (e.g. temporal, profile) and the other six were positive words (e.g. smooth, invitation). The items used in the experiment are presented in the Appendix.

3.1. Procedure

The patients were tested during their routine cognitive assessment in the hospital. We created two different fixed pseudorandomized orders of presentation of the nine lists and randomly assigned the participants to one of them. The participants were instructed to try to remember the words they were going to read. The words were presented one by one in a computer screen using Calibri font, 88 pt. Each word appeared for 2600 ms and was followed by a 400 ms interval. After all the lists had been presented the volunteers were asked to respond to the recognition questionnaire. The questionnaire contained 27 target words (words presented in first, third and sixth positions in each list), nine critical lures (not presented words semantically related to the lists), and the 18 unrelated lures (not presented words) in a pseudorandomized order. The participants were asked to verbally state whether each word

Table 2
Summary of the characteristics of the critical lures.

	Valence mean(SD)	Arousal mean(SD)	lexical frequency mean(SD)	contextual diversity mean (SD)	Phonemes mean(SD)	Syllables mean(SD)	Concreteness mean(SD)	mean association to the list items mean (SD)
Negative	1.61(0.26)***	5.3(1.18)	20.22(5.03)	7.49(1.19)	7(1)	2.33(0.58)	4.58(1)	0.05(0.01)
Neutral	5.06(0.38)***	5.3(1.04)	33.97(13.8)	10.86(4.38)	6.67(1.53)	3(1)	5.46(0.51)	0.08(0.04)
Positive	7.84(0.32)***	5.67(1.09)	36.09(18.35)	12.03(4.16)	6.33(1.53)	2.33(0.58)	5.78(0.94)	0.07(0.004)

***$p < .001$ in the comparison with the other lists.

had been previously presented during the study phase or not. The study was conducted in accordance with the Declaration of Helsinki.

3.2. Analyses

For the analysis of our data, we first assessed the effects of valence and participant group over raw percentages of recognized words from the three categories: presented, not presented critical and not presented unrelated. However, this information could be misleading because recognition responses depend on how liberal or conservative the participants are. For instance, participants with a liberal response criterion tend to respond that a word has been presented more often than participants with a conservative response criterion irrespective of whether the word had been really presented or not (Stanislaw & Todorov, 1999). That is, they produce higher hit (responding "yes" to presented items) rates but also higher false alarm (FA: responding "yes" to unpresented items) rates.

Differences in response criteria are especially relevant in the case of studies with AD patients, who have been shown to present liberal response criteria (Balota et al., 1999; Brueckner & Moritz, 2009). In order to address this issue we applied the signal detection theory approach (Stanislaw & Todorov, 1999) and calculated sensitivity scores for each participant. Following Budson et al. (2006) we calculated three different discriminability scores. On the one hand, $d'_{veridical}$ compares hits to presented items with false alarms to unrelated not-presented items. This index reflects the participants' ability to recognize presented items based on episodic and semantic information. On the other hand, d'_{false} compares the false recognition of critical items to false alarms to unrelated not-presented items. This index is assumed to reflect the participants' semantic activation as the acceptance of critical lures relies on gist memory. Finally, we calculated $d'_{item\text{-}specific}$ comparing hits to presented items to false alarms to critical words. This index reflects the use of verbatim information regarding item-specific details of the presentation with no semantic support.

In the three cases, d' values close to zero indicate that the participant is unable to discriminate between the different item categories, whereas higher values indicate that the participant tends to accept target words (or critical words in the case of d'_{false}) and reject unpresented lures. Given that some of our participants presented zero hits or zero false alarms, which prevents the calculation of d' scores, we corrected our data following the procedure recommended by Snodgrass and Corwin (1988). The hit rate was calculated as (number of hits + 0.5)/(number presented items + 1). Accordingly, the false-alarm rate was calculated as (number of false alarms + 0.5)/(number of new items + 1).

4. Results

A summary of the percentages of recognition of the different word types is presented in Table 3. We first conducted separate repeated measures ANOVAs with the recognition percentages of the three different word types (see Table 3) with valence, negative, neutral, positive, as independent variable. Group (control vs. AD) was introduced as a between-participants factor. Regarding presented target words, we observed a significant effect of valence (F(2146 = 20.445, $p < .001$, $\eta_p^2 = .219$). Percentages of correctly recognized presented words were higher for both negative and positive words compared to neutral words (*p*s $< .005$). Neither the effect of group (F(1,73) = 2.814, $p = .098$, $\eta_p^2 = .037$) nor the interaction between these two variables reached significance (F (2,146) = 0.621, $p = .536$, $\eta_p^2 = .008$). The analysis of the recognition percentages corresponding to critical words showed a significant effect of valence (F(2,146) = 9.006, $p < .001$, $\eta_p^2 = .110$) but no effect of group (F(1,73) = 0.476, $p = .492$, $\eta_p^2 = .006$). The interaction between these two variables was significant (F(2,146) = 8.312, $p < .001$, $\eta_p^2 = .102$). Post hoc comparisons indicated that percentages of falsely recognized critical positive words were higher for AD compared to control participants ($p = .005$). The

Table 3
Percentages of recognition in response to critical (false recognition), target (veridical recognition) and unrelated (false alarms) words by the two groups of participants.

		Control mean%(SD)	AD mean%(SD)
critical	negative	72.38(33.08)	60(26.18)
	neutral	60.95(30)	63.33(30.77)
	positive	39.05(34.76)	60(27.4)
target	negative	81.27(24)	72.22(14.95)
	neutral	63.81(19.09)	59.44(18.74)
	positive	74.6(22.13)	70.28(15.14)
unrelated	negative	11.43(26.2)	28.33(16.05)
	neutral	12.38(28.29)	38.33(15.31)
	positive	4.76(29.85)	44.17(7.64)
$d'_{veridical}$	negative	2.53(0.59)	1.95(0.6)
	neutral	1.97(0.48)	1.41(0.6)
	positive	2.43(0.6)	1.65(0.44)
d'_{false}	negative	2.14(0.67)	1.55(0.6)
	neutral	1.85(0.67)	1.45(0.76)
	positive	1.55(0.63)	1.3(0.6)
$d'_{item\text{-}specific}$	negative	0.39(0.65)	0.4(0.62)
	neutral	0.12(0.65)	−0.04(0.62
	positive	0.88(0.6)	0.34(0.62)

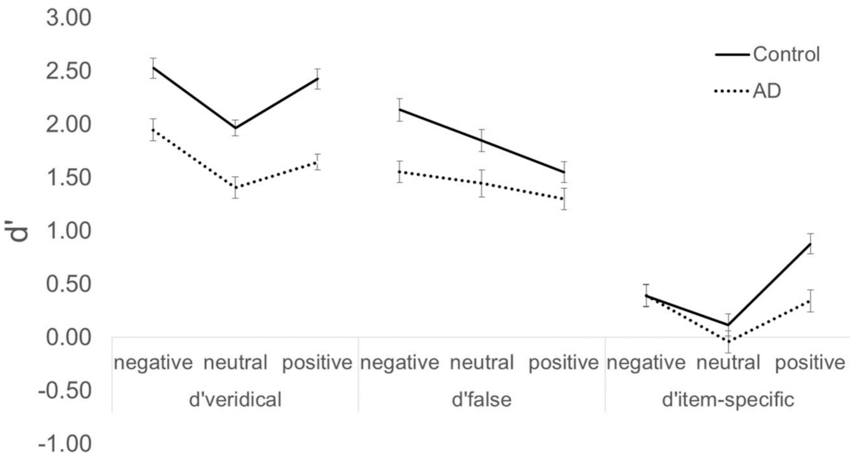

Fig. 1. Means and standard errors of sensitivity scores of the two groups in the three valence conditions for target (veridical recognition) and critical (false recognition) words compared to unrelated lures, as well as discriminability scores in the comparison between target and critical items (item-specific).

Control participants obtain higher d' scores than patients in both veridical and false recognition. In veridical recognition both groups present higher d' scores for emotional compared to neutral stimuli. Regarding false recognition, control and AD groups obtain lower d' scores for positive stimuli. Item-specific recognition indicates higher discriminability for emotional items. AD patients are less sensitive to discriminate between targets and critical lures than control participants but only for positive stimuli.

differences between percentages corresponding to negative (p = .079) and positive words were not significant (p = .736). Finally, regarding unrelated unpresented words, the ANOVA showed no effect of valence ($F(2,146) = 2.261$, $p = .108$, $\eta_p^2 = .030$). In contrast, we observed a significant effect of group, as control participants presented lower percentages of falsely recognized unrelated words than AD patients ($F(1,73) = 44.013$, $p < .001$, $\eta_p^2 = .376$). The interaction between valence and group was also significant ($F(2,146) = 8.392$, $p < .001$, $\eta_p^2 = .103$). The differences between recognized negative (p = .001), neutral ($p < .001$) and positive ($p < .001$) words for the control and AD groups were all significant. However, the differences were larger for positive and neutral words compared to negative words (see Table 3).

The significant interaction between group and valence in the analyses of raw critical lure percentages indicates that AD patients falsely recognized more positive critical lures than control participants. Nevertheless, this information could be misleading because, as we have already explained in the methods section, recognition responses are affected by the participants' response criteria.[1] Thus, we conducted separate analyses of discriminability data corresponding to the three d' scores (see Fig. 1). A repeated measures ANOVA with valence (negative vs. neutral vs. positive) as independent variable and group as between-participants factor on d' scores corresponding to veridical recognition showed significant effects of valence ($F(2,146) = 24.218$, $p < .001$, $\eta_p^2 = .249$). Paired comparisons showed that emotional targets were more easily discriminable than neutral ones ($ps < .001$), and that negative targets were more discriminable than positive ones (p = .02). A significant effect of group was also observed ($F(1,73) = 50.802$, $p < .001$, $\eta_p^2 = .410$), as control participants obtained higher d' values than patients. The interaction between valence and group was not significant ($F(2,146) = 1.181$, $p = .310$, $\eta_p^2 = .016$).

The same kind of analyses conducted with d' scores corresponding to false recognition showed significant effects of valence ($F(2,146) = 8.514$, $p < .001$, $\eta_p^2 = .104$). Pairwise comparisons showed that participants d' scores were lower for positive critical lures compared to negative ($p < .001$) and neutral ($p = .033$) lures, pointing out that semantic activation was lower for positive compared to negative and neutral lures. The differences between negative and neutral critical lures approached the significance threshold ($p = .074$). We also observed a significant effect of group ($F(1,73) = 18.513$, $p < .001$, $\eta_p^2 = .202$), as control participants displayed higher semantic activation than AD patients. The interaction between the two variables was not significant ($F(2,146) = 1.364$, $p = .259$, $\eta_p^2 = .018$).

Finally, the analysis of d' scores corresponding to item-specific recollection also pointed out significant effects of valence ($F(2,146) = 18.782$, $p < .001$, $\eta_p^2 = .205$). Pairwise comparisons showed that participants d' scores were higher for positive items compared to both negative ($p = .021$) and neutral ($p < .001$) items. Moreover, d' scores for negative items were also significantly higher than those corresponding to neutral items ($p < .001$). The effect of group was also significant ($F(1,73) = 5.631$, $p = .02$, $\eta_p^2 = .072$). Finally, the interaction between these two variables also reached significance ($F(2,146) = 4.295$, $p = .015$, $\eta_p^2 = .056$) showing that control participants obtained higher discriminability scores than AD patients although only in relation to positive items ($p < .001$).

[1] As expected, AD patients in our study presented more liberal response criteria (measured as C, with lower values indicating a more liberal bias) than control participants for both veridical (Control mean C = 0.34 vs. AD mean C = −0.05; $p < .001$) and false recognition (Control mean C = 0.56 vs. AD mean C = 0.03; $p < .001$). No differences appeared when comparing responses to target items and critical lures (Control mean C = −0.41 vs. AD mean C = −0.42; p = .95).

5. Discussion

In this study we aimed to explore the effects of AD over emotion-related semantic memory by means of a DRM task. Our results replicate previous findings (Balota et al., 1999; Brueckner & Moritz, 2009; Budson et al., 2000, 2003) and can be argued to indicate differential involvement of gist, or semantic-based information, during memory formation in AD patients compared to healthy seniors. These data, thus, confirm the presence of some degree of semantic deficit in AD patients at early stages.

The manipulation of item valence in our study also allowed us to investigate the effects of emotional content over false recognition in relation to AD. With regards to veridical recognition, both healthy controls and AD patients presented higher recognition rates for emotional compared to neutral items. This results are in conflict with those obtained by Budson et al. (2006) and Brueckner and Moritz (2009), who observed enhanced veridical recognition of emotional items in healthy seniors but not in AD patients. A possible source of the discrepancies between their results and ours could be related to the characteristics of the participants involved in the three studies. In the two previous studies, AD patients presented mild to moderate dementia, whereas we recruited AD participants with very mild to mild dementia for our experiment. The degree of dementia is obviously expected to have an impact over the results, and there is already evidence that patients in different disease stages present different performance profiles. In this sense, Brueckner and Moritz (2009), who included a group of mild cognitive impairment (a prodromal stage of AD, Albert et al., 2011) participants in their study, observed an effect of emotional content in their veridical recognition rates similar to that observed in control participants. Hence, differences between these studies can be accommodated if we take into account that our AD participants present, on average, a milder stage of dementia than those who took part in previous experiments.

With regards to false memories, previous studies had not observed any group differences between AD patients and age-matched controls in the effects of emotional content over false recognition patterns. Our results replicate this lack of effect, as shown by the null interaction effects observed in our analyses of $d'_{\text{false recognition}}$, although crucial differences appear between the specific emotion effects observed in the three studies. As we have already noted in the introduction, whereas Budson et al. (2006) did not observe a significant effect of emotional content on false recognition, Brueckner and Moritz (2009) obtained higher false memory rates for emotional, both negative and positive, material. Our data, however, show lower discriminability between critical and unrelated lures for positive items, which indicates decreased availability of semantic activation for this kind of stimuli. Along with differences between the samples of patients that took part in the two studies commented above, differences in the materials used in the two studies might play a crucial role in these incongruities. Brueckner and Moritz (2009) selected two negative, one neutral and one positive critical lures. In contrast, for our experiment we selected matched sets of three negative, three neutral and three positive critical lures. We believe that the use of only one positive list by Brueckner and Moritz (2009) makes their results more susceptible to idiosyncratic effects of the stimuli, i.e. specific psycholinguistic characteristics influencing word recognition.

From the perspective of the activation-monitoring account (Gallo & Roediger, 2002; Roediger et al., 2001) differential effects of word valence over false memory formation could be due to higher or lower activation levels for emotional words during encoding. More specifically, the presence of higher discriminability scores for negative critical lures in our study fits in with the predictions posed by the fuzzy-trace theory, according to which, negative valence increases semantic connections (Bookbinder & Brainerd, 2016; Brainerd et al., 2008). From this perspective, stronger gist traces due to enhanced semantic relations would lead to increased discriminability between critical and unrelated lures for negative lists. In contrast, positive valence strengthens verbatim traces (as shown by the increased discriminability between presented words and critical lures for positive stimuli evidenced in our analysis of $d'_{\text{item-specific}}$),[2] leading to reduced sensitivity to differentiate between critical and unrelated lures due to more efficient abilities to suppress not-presented items. Finally, the lack of differences between patients and control participants regarding valence effects over semantic availability indicates that emotional content does not play a crucial role in the deterioration of semantic capacities associated to AD, at least at early stages.

In sum, our data replicate differences in the involvement of semantic processing over false memories between healthy elderly and AD patients indicating a reduced contribution of semantic information during memory formation even at early stages of the disease development. Moreover, we found evidence for the persistence of emotion effects over semantic activation at these stages. Further studies including new materials and assessing patients at different disease stages should be conducted to clarify the role of emotional content over semantic-based false memory development in healthy elderly and AD patients.

Declarations of interest

None.

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[2] Note that the analysis of $d'_{\text{item-specific}}$ scores also showed that control participants were more sensitive to discriminate between positive targets and positive critical lures than AD patients. This could indicate an impaired capacity to use verbatim traces to suppress false recognition of unpresented but related items in AD participants.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jneuroling.2018.10.001.

Appendix. DRM lists used in the study

	Negative A	Negative B	Negative C
target 1	thermometer (termómetro)	frustrated (frustrado)	infidelity (infidelidad)
	flu (gripe)	defeat (derrota)	revenge (venganza)
target 2	delirium (delirio)	disappointment (desilusión)	disillusion (desengaño)
	chill (escalofrío)	deception (decepción)	distrust (desconfianza)
	fervor (fervor)	failing grade (suspenso)	disloyal (desleal)
target 3	malaria (malaria)	loser (perdedor)	abandonment (abandono)
	measles (sarampión)	victory (victoria)	lover (amante)
	temperature (temperatura)	error (error)	deserter (desertor)
critical	fever (fiebre)	failure (fracaso)	traitor (traidor)
	Neutral A	**Neutral B**	**Neutral C**
target 1	spokesman (portavoz)	detour (desvío)	row (fila)
	admired (admirado)	kilometer (kilómetro)	pillar (pilar)
target 2	idol (ídolo)	curve (curva)	back (espalda)
	champion (campeón)	truck driver (camionero)	spinal (espinal)
	initiative (iniciativa)	dangerous (peligrosa)	beam (viga)
target 3	follower (seguidor)	map (mapa)	greek (griega)
	protagonist (protagonista)	car (coche)	support (soporte)
	charisma (carisma)	route (ruta)	osseous (ósea)
critical	leader (líder)	road (carretera)	column (columna)
	Positive A	**Positive B**	**Positive C**
target 1	watchman (vigilante)	eden (edén)	rocker (balancín)
	holidays (vacaciones)	watering can (regadera)	memories (recuerdos)
target 2	sandal (sandalia)	grass (césped)	marble (canica)
	crab (cangrejo)	exterior (exterior)	school (colegio)
	walk (paseo)	rosebush (rosal)	sticker (cromo)
target 3	seagull (gaviota)	irrigation (riego)	school (escuela)
	rock (roca)	terrace (terraza)	trauma (trauma)
	float (flotador)	gate (verja)	doll (muñeca)
critical	beach (playa)	garden (jardín)	childhood (infancia)

Unrelated not-presented words for the recognition test Negative: conflict, coward, filth, rancid, tomb, unable (conflicto, cobarde, porquería, rancio, tumba, incapaz).
Neutral: foolishness, profile, snake, temporary, throat, wild (tontería, perfil, serpiente, temporal, garganta, salvaje).
Positive: delicious, glory, humble, invitation, salary, soft (delicioso, gloria, humilde, invitación, salario, suave).

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