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An overall decline both in recollection and familiarity in healthy aging

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Abstract

Background: In the area of recognition memory, the experimental data have been inconsistent about whether or not familiarity declines in healthy aging. A recent meta-analysis concluded that familiarity is impaired when estimated with the remember-know procedure, but not with the process-dissociation procedure. **Method:** We present an associative recognition experiment with remember-know judgments that allow us to estimate both recollection and familiarity using both procedures in the same task and with the same participants (a sample of healthy older people and another sample of young people). Moreover, we performed a within-subjects manipulation of the type of materials (pairs of words or pairs of pictures), and the repetition or not of the pairs during the study phase. **Results:** The results show that familiarity, estimated using both estimation procedures, declines significantly with age, although the effect size obtained with the process-dissociation procedure is significantly smaller than the one obtained with the remember-know procedure. **Conclusions:** Our results show that aging is associated with significant decreases both in recollection and, to a lesser extent, familiarity.

Keywords: memory, aging, recognition, associative recognition, recollection, familiarity.

Resumen

Un declive global tanto en recuperación como en familiaridad en el envejecimiento. **Antecedentes:** en el ámbito de la memoria de reconocimiento existen datos experimentales discrepantes en relación a si la familiaridad decae o no en el envejecimiento saludable. En un reciente meta-análisis se concluyó que la familiaridad decae cuando la estimamos con el procedimiento recordar-saber, pero no cuando la estimamos con el procedimiento de disociación de procesos. **Método:** presentamos un experimento de reconocimiento asociativo con juicios recordar-saber que nos permite estimar tanto la recuperación como la familiaridad mediante ambos procedimientos en una sola tarea y en los mismos participantes (una muestra de mayores sanos y otra muestra de jóvenes). Manipulamos así mismo intrasujeto el tipo de materiales (pares de palabras o pares de fotografías) y la repetición o no de los pares durante la fase de estudio. **Resultados:** los resultados muestran que la familiaridad, estimada mediante ambos procedimientos de estimación, decae con la edad de forma significativa, si bien el tamaño del efecto de la edad obtenido del procedimiento de disociación de procesos es significativamente menor que el obtenido con el procedimiento recordar-saber. **Conclusiones:** nuestros resultados muestran que el envejecimiento se asocia con decrementos significativos tanto en recuperación como, en menor medida, en familiaridad.

Palabras clave: memoria, envejecimiento, reconocimiento, reconocimiento asociativo, recuperación, familiaridad.

A major theory in the memory literature consists of the dual-process models of recognition memory (Wolk, Signoff & DeKosky, 2008). *Dual-process* models (e.g. Yonelinas, 2002) suggest that in retrieval information from the episodic memory, two processes intervene: a conscious process of recollection of episodic or contextual details associated with the item to be recognized (*recollection*) and an automatic process that involves estimating the strength of the memory trace in the absence of episodic details (*familiarity*). In contrast to the dual process models, the *single-process* theories (e.g. Dunn, 2004) propose that recognition is based only on a quantitative estimation of the strength of the memory trace: what dual models call familiarity would be considered weak memories, while recollection would refer to strong memories. Dual-process theory has received considerable experimental support, even in experiments with rodents and primates (e.g. Yonelinas, Ally, Wang & Koen, 2010). Moreover, recollection and familiarity seem to rest on different neuro-anatomic bases (hippocampus and perirhinal cortex, respectively; e.g. Koen & Yonelinas, 2014; Schoemaker, Gauthier & Pruessner, 2014; Yonelinas et al., 2010).

It is generally agreed that aging affects recall more than recognition (Danckert & Craik, 2013; Ruiz Gallego-Largo, Suengas, Simón & Pastor, 2015) and the reason could be that familiarity may mask recollection deficits in older people (Danckert & Craik, 2013). Therefore accurate experimental procedures to estimate both familiarity and recollection are needed, among which the remember-know procedure (RK), the process-dissociation

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procedure (PD), and the receiver operating characteristics procedure (ROC) stand out (Koen & Yonelinas, 2014, in press). Briefly (see e.g. Yonelinas, 2002, for a review), the RK procedure presents participants with a recognition test on which, after each "old" response, they emit a second introspective judgment about whether this positive recognition was based on the recollection of episodic details associated with the item (remember or R judgment) or on a mere sensation of familiarity with the item, in the absence of episodic details (know or K judgment). Recollection and familiarity estimates are derived from the proportion of hits on R and the proportion of hits on K/(1-R), respectively. Meanwhile, the PD procedure asks participants to study two lists of words, and then it presents them with two recognition tests. On the inclusion test, participants must recognize the words studied on the two lists, while on the exclusion test, they only have to recognize the words from one of the lists studied. Recollection estimation is derived from the proportion of hits on the inclusion test minus the proportion of false alarms on items to be excluded on the exclusion test (FAexc), whereas the familiarity estimation is derived from FAexc/(1-recollection estimation). Finally, the ROC procedure involves a recognition test on which participants make their old/new judgments using a confidence scale from "sure old" to "sure new", and these confidence judgments are used to construct ROC curves (hits vs. false alarms) across the multiple levels of confidence in a cumulative fashion.

Two recent literature reviews have shown that even though there seems to be unanimity in accepting that recollection tends to decline with age (Koen & Yonelinas, 2014) and cognitive impairment (Schoemaker et al., 2014), the experimental results related to familiarity are not as conclusive and differ depending on the experimental paradigm used. Thus, in healthy aging, familiarity was not impaired in studies using ROC or PD methods, but it was impaired in studies that used the RK procedure (Koen & Yonelinas, 2014; although Prull, Dawes, Martin, Rosenberg & Light, 2006, comparing these three paradigms, only found an age invariance on familiarity using the PD procedure). With regard to familiarity in participants with cognitive impairment, results are even less consistent (see Schoemaker et al., 2014 for a review).

Given the discrepancy in the results depending on the methodology used, it would be useful to have convergent estimations of the recollection and familiarity processes, and this is the main purpose of the present study. Recently, Wolk et al. (2008; Wolk, Mancuso, Kliot, Arnold, & Dickerson, 2013) used the associative recognition paradigm as estimation method of both recollection and familiarity, following the logic of the PD procedure, given that intact and rearranged pairs represent the inclusion and exclusion conditions, respectively. In the same way, and given that the associative recognition paradigm also allows the inclusion of introspective RK judgments (e.g. Kilb & Naveh-Benjamin, 2011), we propose an associative recognition procedure with RK judgments to achieve recollection and familiarity estimations based on both the RK paradigm and the PD paradigm (e.g. Prull et al., 2006). To the degree that the recollection and familiarity estimations obtained with the two procedures coincide, the results will provide convergent information about whether familiarity really declines with age or not. This is a crucial aspect of the theoretical justification for the dual models, which assume that familiarity, unlike recollection, is stable in healthy aging, and that its decline in old age can be interpreted as a prodromal marker of cognitive impairment (Koen & Yonelinas, 2014; Wolk et al, 2013).

On this associative recognition task, we also manipulate two other independent variables within subjects. On the one hand, we contrast the recollection and familiarity estimations found on both pairs of words and pairs of pictures, as it has been suggested that familiarity is not affected by age or cognitive impairment when the materials consist of images rather than verbal stimuli, although the results vary in this regard (Koen & Yonelinas, 2014; Schoemaker, et al., 2014). As Koen and Yonelinas (2014) point out, no study has compared age-related differences in recollection and familiarity with verbal stimuli compared to nonverbal stimuli within subjects (but see Ruiz Gallego-Largo, et al., 2015), and for this reason, we decided to include this variable in our design. Moreover, we also manipulate the repetition of the pairs during the study phase because this variable has been shown to strengthen both associative and item information (e.g. Buchler, Faunce, Light, Gottfredson & Reder, 2011; Kilb & Naveh-Benjamin, 2011; Wolk et al., 2008) and will allow us to analyze our procedure's sensitivity to capture its effect on recollection and familiarity judgments.

In summary, two samples of healthy people (young vs. older) are compared in an associative recognition experiment with RK judgments in which two independent variables are manipulated (within subjects): materials (word pairs vs. picture pairs) and repetition (repeated vs. non repeated pairs during study). Our main aim is to analyze whether or not familiarity declines with aging by comparing two estimation procedures (RK and PD), given the conflicting results about this question. The originality of our research is that these estimates will be made from data coming from the same experimental task (and not from, as usual, two different tasks) and from the same participants (and not from, as usual, two different samples).

Method

Participants

Participants, all volunteers, were 30 young adults (undergraduates at the University of Valencia; 8 men, 22 women, mean age = 21.77 years, *SD* = 4.21, range 18-37 years) and 30 older adults (recruited from an adult continuing education program at the University of Valencia and various senior citizen centers in the city of Valencia; 8 men, 22 women, mean age = 68.27 years, *SD* = 6.74, range 58-81 years). All participants reported that they were in good physical and mental health and that they were not taking medication for mental or emotional problems. In this regard, the mean on the Mini-Mental State Examination (Folstein, Folstein & McHugh, 1975) for the older adults was 28.43 (*SD* = 1.06), showing no memory impairment. The two groups were matched on gender, WAIS vocabulary (t_{58}=1.13; means of 9.21 and 10.03, *SD* = 2.89 and 2.56, ranges = 5-13 and 5-16, for the young and older groups, respectively), and years of education (t_{58}<1; means of 15.70 and 15.17 years, *SD* = 2.89 and 3.10, ranges = 13-22 and 10-24, for the young and older groups, respectively).

Instruments

The same materials were used as in Pitarque, Sales, Meléndez & Algarabel (2015). Picture pairs (see, e.g., Kilb & Naveh-Benjamin, 2011) consisted of 64 ID-card sized color photographs (145 × 160 pixels) of anonymous faces (16 of older men, 16 of older women, 16 of young men, and 16 of young women,) and 64 color photographs of unfamiliar everyday scenery (800 × 600 pixels), of which one-third were open natural scenes (beaches, mountains, etc.), another third were open urban scenes (streets, building, etc.), and the remaining third were interiors of building (living rooms, kitchens, etc.). With these photographs, we then created 4 different lists of 64 pairs of photographs each, putting a randomly chosen face in the center of a randomly chosen scene. Word pairs consisted of 128 Spanish words selected from the Alameda and Cuetos (1995) database. With these words, we then created 4 different lists of 64 pairs of words each, randomly paired, and matched on frequency and number of letters. These 4 lists (both words and pictures) were counter-balanced between subjects, and later analyses of the hits and false alarms confirmed that there were no significant differences among them.

Procedure

The participants performed one associative recognition test of pairs of words and another of pairs of images (each of which lasted about 20 minutes), counter-balanced between subjects, and separated by 30 minutes, during which they took the WAIS vocabulary test and, only in the case of the older people, the Mini-Mental State Examination.

Each of the associative recognition tasks consisted of a study phase with 64 pairs of stimuli and a recognition task with 60 pairs. In the study phase, 60 pairs of stimuli ± 2 distractors were presented randomly at the center of a computer screen for 2.5 seconds each (with a 1-second interval between them). On the study task, 20 pairs were presented once (later making up the *non repeated intact* and *non repeated rearranged* recognition conditions), and 20 pairs were presented twice (later making up the *repeated intact* and the *repeated rearranged* recognition conditions). Participants were instructed to pay attention to the two stimuli of each pair (words or pictures) for a subsequent task memory. In the recognition phase, 60 pairs of stimuli were presented randomly at the center of a computer screen: 10 corresponded to the *non repeated intact* condition, 10 corresponded to the *repeated intact* condition, 10 corresponded to the *non repeated rearranged* condition (randomly re-matching the stimuli in a different order from the one studied), 10 corresponded to the *repeated rearranged* condition (randomly re-matching the stimuli in a different order), and 20 corresponded to the *new* condition. The participants had to respond (self-paced) by indicating whether these words or images had appeared together or not on the study task by choosing one of these four response options: (a) yes, because I *remember* some details; (b) yes, because I *know* they went together, but not the details; (c) no, both stimuli appeared before, but they are *rearranged*; (d) no, neither stimulus appeared before, so they are *new*. Prior to performing the first recognition task, and following strict RK instructions (see, e.g., Koen & Yonelinas, 2014, in press), the differences between "remembering" and "knowing" were explained to participants (see Kilb & Naveh-Benjamin, 2011), emphasizing that a *remember* response should only be given if they could communicate a retrieved detail to the experimenter if asked, whereas a *know* response should be given if they believe the pair was previously studied but they were unable to retrieve any specific detail. A practice recognition task was performed to make sure all the subjects understood the instructions.

Data analysis

We used an experimental design with 3 independent variables: 2 groups (young and older people; between subjects) × 2 materials (word pairs vs. picture pairs; within subjects) × 2 repetition conditions (non repeated and repeated pairs; within subjects). The dependent variables were individual rates of hits (H) and false alarms (FA) on R and K judgments, total "yes" (R+K) H and FA judgments, FA on new pairs (Table 1), and estimations of recollection and familiarity using the PD and RK procedures (Table 2). To calculate the estimations of recollection and familiarity, we followed the work of Prull et al. (2006) in which familiarity was corrected taking into account the FA rates of each

Table 1
Means (and SE) of hits on remember judgments (HR), hits on know judgments (HK), false alarms on remember judgments (FAR), false alarms on know judgments (FAK), and total hits and false alarms on the associative recognition task as a function of materials, groups and repetition conditions

			Words		Pictures	
			Young	Older	Young	Older
Hits	**Non rep**	HR	0.59 (0.05)	0.32 (0.05)	0.59 (0.04)	0.39 (0.05)
		HK	0.14 (0.03)	0.15 (0.03)	0.16 (0.03)	0.23 (0.04)
		Total H	0.72 (0.04)	0.48 (0.04)	0.76 (0.03)	0.62 (0.04)
	Rep	HR	0.80 (0.04)	0.49 (0.05)	0.83 (0.03)	0.60 (0.05)
		HK	0.11 (0.03)	0.16 (0.04)	0.09 (0.02)	0.19 (0.04)
		Total H	0.90 (0.03)	0.66 (0.04)	0.91 (0.02)	0.80 (0.03)
False alarms	**Non rep**	FAR	0.03 (0.01)	0.15 (0.03)	0.03 (0.01)	0.17 (0.03)
		FAK	0.06 (0.02)	0.10 (0.02)	0.08 (0.01)	0.13 (0.02)
		Total FA	0.10 (0.02)	0.25 (0.04)	0.12 (0.02)	0.31 (0.04)
	Rep	FAR	0.03 (0.01)	0.29 (0.05)	0.03 (0.01)	0.28 (0.05)
		FAK	0.08 (0.02)	0.12 (0.02)	0.05 (0.02)	0.15 (0.03)
		Total FA	0.12 (0.03)	0.40 (0.05)	0.08 (0.02)	0.42 (0.05)
	New	FAR	0.00 (0.00)	0.05 (0.02)	0.00 (0.00)	0.04 (0.01)
		FAK	0.01 (0.00)	0.03 (0.01)	0.00 (0.00)	0.05 (0.01)
		Total FA	0.01 (0.00)	0.08 (0.02)	0.00 (0.00)	0.08 (0.02)

sample. The data were analyzed by means of analysis of variance. The significance level for all statistical tests was $p<.05$.

Results

Overall recognition performance

With regard to total hits (H on R judgments + H on K judgments, see Table 1), a mixed ANOVA of 2 groups (young vs. older people; between subjects) × 2 materials (word pairs vs. picture pairs; within subjects) × 2 repetition conditions (non repeated and repeated pairs; within subjects) showed significant main effects of the three independent variables: groups ($F_{1,58}$ = 30.19, $p<.0001$, η^2_p = .34), materials ($F_{1,58}$ = 8.36, p = .005, η^2_p = .13) and repetition conditions ($F_{1,58}$ = 99.88, $p<.0001$, η^2_p = .63), indicating that young people had more hits than older people (means of 0.82 and 0.64, respectively), pictures led to more hits than words (means of 0.77 and 0.69, respectively), and repeated stimuli led to more hits than non repeated stimuli (means of 0.81 and 0.65, respectively). None of the interactions among the three independent variables was significant.

Regarding hits on R judgments (HR, see Table 1), a similar ANOVA showed significant main effects of the variables groups ($F_{1,58}$ = 24.97, $p<.0001$, η^2_p = .30) and repetition conditions ($F_{1,58}$ = 100.42, $p<.0001$, η^2_p = .63), indicating that young people had more hits on R judgments than older people (means of 0.70 and 0.45, respectively), and repeated stimuli led to more hits on R judgments than non repeated stimuli (means of 0.68 and 0.47, respectively). Neither the main effect of the variable materials nor any of the interactions was significant.

With regard to hits on K judgments (HK, see Table 1), neither the main effects of the three independent variables nor any of their interactions was significant.

False alarms were analyzed using two different statistical analyses: one analyzing FA on rearranged pairs and the other analyzing FA on new pairs. With regard to total FA on rearranged pairs (FA on R judgments + FA on K judgments, see Table 1), a mixed ANOVA of 2 groups × 2 materials × 2 repetition conditions showed significant main effects of the variables groups ($F_{1,58}$=53.73, $p<.0001$, η^2_p = .48) and repetition conditions ($F_{1,58}$ = 10.52, p = .002, η^2_p = .15), indicating that older people committed more FA than young people (means of 0.35 and 0.10, respectively), and repeated stimuli led to more FA than non repeated stimuli (means of 0.26 and 0.19, respectively). However, these results could be explained by the significant Group × Repetition Condition interaction ($F_{1,58}$ = 14.15, $p<.0001$, η^2_p = .20). Regarding the analysis of this significant interaction, post-hoc Bonferroni t-tests showed that the difference in FA between non repeated and repeated stimuli was significant in the older group (t_{29} = 3.83, p = .001; means of 0.28 and 0.41, respectively), but not in the young group (means of 0.11 and 0.10, respectively), indicating that stimuli repetition increases FA rates in older people, but not in young people.

With regard to total FA on new pairs (table 1), a mixed ANOVA of 2 groups × 2 materials only showed a significant main effect of the variable groups ($F_{1,58}$ = 19.94, $p<.0001$, η^2_p = .26), indicating that older people committed more FA on new pairs than young people (means of 0.08 and 0.01, respectively).

Regarding FA on R judgments (FAR, Table 1), the ANOVA agrees with the results found for total FA, as there were significant main effects of the variables groups ($F_{1,58}$ = 43.65, $p<.0001$, η^2_p = .43) and repetition conditions ($F_{1,58}$ = 12.64, p = .001, η^2_p = .18), as well as their interaction ($F_{1,58}$ = 16.69, $p<.0001$, η^2_p = .22). For the analysis of this significant interaction, post-hoc Bonferroni t-tests showed that the difference in FAR between non repeated and repeated stimuli was again significant in the older group (t_{29} = 2.74, p = .01; means of 0.16 and 0.28, respectively), but not in the young group (means of 0.03 and 0.02, respectively), indicating that stimuli repetition increases FAR rates in older people, but not in young people (e.g., Pitarque et al., 2015).

With regard to FA on K judgments (FAK), the analysis showed that only the main effect of the variable groups was significant ($F_{1,58}$ = 9.36, p = .003, η^2_p = .14), indicating that older people made more FAK than young people (means of 0.12 and 0.07, respectively).

Finally, with regard to FAR on new pairs (Table 1), a mixed ANOVA of 2 groups × 2 materials showed that only the main effect of the variable groups was significant ($F_{1,58}$ = 11.74, $p<.0001$, η^2_p = .17), indicating that older people committed more FAR on new pairs than young people (means of 0.04 and 0.00, respectively). The same pattern of results was found when analyzing FAK on new pairs (Table 1), as only the main effect of the variable groups was significant ($F_{1,58}$ = 17.68, $p<.0001$, η^2_p = .23), indicating again that older people made more FAK on new pairs than young people (means of 0.04 and 0.01, respectively). Overall, these data clearly show that older people tend to consistently make more false alarms than young people, which can be a bias that we have to correct in our estimations of recollection and familiarity (e.g,. Prull et al., 2006), as is usually done in the false memories literature.

Table 2

Means (and SE) of the estimations made by the process-dissociation (PD) and remember-know (RK) procedures for recollection and corrected familiarity as a function of materials, groups and repetition conditions

			Words		Pictures	
			Young	**Older**	**Young**	**Older**
PD procedure	**Non rep**	Recollection	0.60 (0.05)	0.22 (0.04)	0.63 (0.03)	0.31 (0.05)
		Corrected F	0.36 (0.05)	0.25 (0.04)	0.42 (0.05)	0.34 (0.04)
	Rep	Recollection	0.76 (0.05)	0.25 (0.05)	0.80 (0.03)	0.37 (0.06)
		Corrected F	0.70 (0.05)	0.47 (0.05)	0.57 (0.06)	0.58 (0.04)
RK procedure	**Non rep**	Recollection	0.51 (0.05)	0.17 (0.03)	0.54 (0.03)	0.21 (0.05)
		Corrected F	0.35 (0.06)	0.11 (0.05)	0.33 (0.06)	0.22 (0.04)
	Rep	Recollection	0.73 (0.05)	0.20 (0.06)	0.77 (0.03)	0.32 (0.06)
		Corrected F	0.63 (0.07)	0.18 (0.06)	0.56 (0.06)	0.28 (0.07)

Estimations of recollection and familiarity

With regard to the analysis of the estimations of recollection using the PD procedure (see Table 2), a mixed ANOVA of 2 groups × 2 materials × 2 repetition conditions showed significant main effects of the three independent variables: groups ($F_{1,58}$ = 84.51, p<.0001, η^2_p = .59), materials ($F_{1,58}$ = 4.57, p<.05, η^2_p = .07) and repetition conditions ($F_{1,58}$ = 14.90, p<.0001, η^2_p = .63), indicating that young people use recollection more efficiently than older people (means of 0.70 and 0.29, respectively), pictures lead to better recollection than words (means of 0.53 and 0.46, respectively), and repeated stimuli lead to better recollection than non repeated stimuli (means of 0.54 and 0.44, respectively). The Group × Repetition Condition interaction was also significant ($F_{1,58}$ = 4.86, p<.05, η^2_p = .08), as young people improved their recollection capacity with repetition (t_{29} = 4.25, p<.001; means of 0.61 and 0.78 for non repeated and repeated stimuli, respectively), whereas older people did not (means of 0.26 and 0.30, respectively). None of the remaining interactions among the three independent variables was significant.

The analysis of the recollection estimations using the RK procedure (Table 2) showed significant main effects of the variables groups ($F_{1,58}$ = 69.96, p<.0001, η^2_p = .55) and repetition conditions ($F_{1,58}$ = 35.92, p<.0001, η^2_p = .38), indicating again that young people use recollection more efficiently than older people (means of 0.64 and 0.23, respectively), and repeated stimuli lead to better recollection than non repeated stimuli (means of 0.51 and 0.36, respectively). The Group x Repetition Condition interaction was also significant ($F_{1,58}$ = 9.39, p = .003, η^2_p = .14), as young people improved their recollection capacity with repetition (t_{29} = 5.76, p<.0001; means of 0.53 and 0.75, for non repeated and repeated stimuli, respectively), whereas older people did not (means of 0.19 and 0.26, respectively). None of the remaining interactions among the three independent variables was significant.

Overall, the recollection analyses show that the two estimation methods compared yield completely congruent results. Thus, recollection capacity declines with age (agreeing with the published literature; e.g., Koen & Yonelinas, 2014; Schoemaker at el., 2014; Yonelinas, 2002); images lead to better recollection than words, probably because they are codified with greater perceptual richness, which facilitates their later recall or recognition (or "picture superiority effect"; e.g., Defeyter, Russo & McPartlin, 2009); and repetition improves correct recollection much more in young people than in older people, suggesting that the latter could have an associative-binding deficit (e.g., Old & Naveh-Benjamin, 2008).

With regard to the analysis of the corrected familiarity estimations using the PD procedure (Table 2), the ANOVA showed significant main effects of both the repetition conditions and groups ($F_{1, 58}$ = 90.99, p<.0001, η^2_p = .61, and $F_{1,58}$ = 4.41, p<.05, η^2_p = .07, respectively), indicating that repeated stimuli give rise to more familiarity than non repeated stimuli (means of 0.58 and 0.34, respectively), and familiarity declines with age (means of 0.51 and 0.41, for young people and older people, respectively). Neither the main effect of the variable materials nor the remaining interactions were significant.

Regarding the analysis of the corrected familiarity estimations using the RK procedure (Table 2), the results agree with the estimations made with the PD procedure. Thus, the ANOVA again showed significant main effects of both the groups ($F_{1,58}$ = 29.56, p<.0001, η^2_p = .34) and repetition conditions ($F_{1,58}$ = 16.06, p<.0001, η^2_p = .22) variables, indicating again that young people use familiarity more efficiently than older people (means of 0.47 and 0.20, respectively), and repeated stimuli lead to more familiarity than non repeated stimuli (means of 0.45 and 0.25, respectively). The Group × Repetition interaction was also significant ($F_{1,58}$ = 5.67, p<.05, η^2_p = .09), as young people improved their familiarity capacity with repetition (t_{29} = 3.74, p = .001; means of 0.34 and 0.59, for non repeated and repeated stimuli, respectively), whereas older people did not (means of 0.16 and 0.23, respectively). Neither the main effect of the variable materials nor the remaining interactions were significant.

Overall, we would like to highlight that our results, both those related to overall recognition (Table 1) and those related to recollection and familiarity estimations (Table 2), coincide in general terms with findings published in the literature (e.g., Koen & Yonelinas, 2014; Prull et al., 2006), which supports our experimental procedure. Our analyses coincide in showing that repetition increases familiarity (a well-recognized fact in the literature; see Buchler et al., 2011; Kilb & Naveh-Benjamin, 2011). In addition, images and words produce similar familiarity estimations, unlike what occurs with recollection. Finally, and more directly related to the aim of our study, the recognition capacity through familiarity also declines with age, although to a lesser extent than recollection (e.g. the effect sizes for the familiarity estimations by RK and PD procedures are .34 and .07, respectively, whereas the effect sizes for the recollection estimations are .55 and .59, respectively).

Discussion

The main aim of our study was to respond to the question of whether familiarity, estimated using two different estimation processes (PD and RK) and different materials (pairs of words or images), declines with healthy aging, given the inconsistent results found in the literature (e.g. Koen & Yonelinas, 2014). Our results show, using both estimation methods and both types of materials, that both recollection and familiarity decline significantly with age (see also Parks, 2007; Wang, de Chastelaine, Minton, & Rugg, 2012), although age-related decreases in recollection were significantly larger than age-related decreases in familiarity. For this reason familiarity could compensate recollection deficits in older people (Danckert & Craik, 2013). Our results generally coincide with the findings of Koen and Yonelinas (2014) in their recent meta-analytic review, where they show that the overall recollection and familiarity effect sizes (for the comparison of the groups of young people and healthy older people) were both significant (0.75, p<0.001 and 0.27, p<0.01, respectively), suggesting that healthy aging is associated with reductions in both recollection and familiarity. However, the effect size for recollection was in the moderate-to-large range, whereas the effect size for familiarity was in the small range, as we have also found in our results. The only difference between the results found by Koen and Yonelinas (2014) and the results from the present study lies in the fact that these authors found an impairment in familiarity only in the RK procedure, but not with the PD procedure, while we found this deficit in both procedures, even though in our results the effect size of the groups variable on corrected familiarity in the PD procedure (.07, p<.05) is inferior to the effect size in the RK procedure (.34, p<.0001). The reason for this discrepancy (and the fact that our results reach statistical significance) could be that our estimations of recollection and familiarity come from data coming from the same experimental task and from the same participants, while the majority of studies reviewed in the work by Koen and Yonelinas (2014) compared these estimation methods across different tasks and different samples (samples of usually small sizes, which can involve a lack of power to reject the null hypothesis; Koen and Yonelinas, in press).

From a cognitive point of view our results show that, as far as correct recognition is concerned, young people recognize better than older people because the latter have more difficulties in encoding and remembering the contextual information (associative-binding deficit hypothesis; Old & Naveh-Benjamin, 2008). On the other hand, repetition improves recognition in both samples, which indicates that older people benefit from associative strengthening as much as young adults do (although the starting point for older people is lower). Regarding false recognition, our results show that the older people made more FA than the young people, as is well-known in literature (see e.g. McCabe, Roediger, McDaniel, & Balota, 2009, for a review). Moreover, repetition does not increase FA in young people (probably because they correctly use a controlled mechanism of "recall-to-reject"; e.g. Rotello & Heit, 2000), but it does increase them in older people. However this increase in FA by repetition in older people lies in recollection (false recollections; see McCabe et al., 2009), and not in familiarity, which cast doubts on the dual models of recognition, which are not able to explain how someone can recollect something that he/she never studied. What seems to happen here it is that repetition increases the familiarity of the two items of each pair, giving rise sometimes in older people (but not in young people) to source monitoring errors (e.g. Ferguson, Hashtroudi & Johnson, 1992).

Future research is needed to determine if the dissociations between recollection and familiarity estimates still appear in larger samples, different populations (healthy people and patients with different neurodegenerative diseases) and different estimation procedures. Morever given the growing interest in relating cognitive processes to underlying neural structures, it would be fruitful to link the present age-related differences in recollection and familiarity to underlying brain changes.

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