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Age-related Changes in Recognition and Response Criterion

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Recognition performance does not usually change along the lifespan, but the response criterion usually does, and in general, it changes from being conservative during youth to being liberal, in old age. The focus of the present study is to analyze the changes that take place, both in discrimination and response criterion, as a result of aging in two recognition tasks: one with neutral images, and the other with faces showing positive and negative emotional expressions. Two groups of participants performed both tasks: young (N = 21; age range, 17-33 years), older (N = 21; age range, 65-91 years). The analyses of several discrimination parameters (d´ and probability of recognition) and the response criterion yielded significant age differences. Thus, results indicated that the ability to discriminate of older participants was better than that of younger participants when having to recognize neutral images, and faces with negative emotional expressions. The response criterion of younger participants was always conservative, whereas older participants only showed liberal criteria in front of faces with emotional expressions. In relation to the neutral images, the response criterion of older participants was optimum, because it led to more hits, without increasing the false alarms. The results are partially explained by the tasks differential difficulty, and are discussed within the frame of Simulation theory.
Keywords: age differences, recognition, response criterion, face recognition, facial expression valence.

El rendimiento en pruebas de reconocimiento no suele variar a lo largo de la vida, pero sí lo hace el criterio de respuesta empleado que, en general, pasa de ser conservador, en la juventud, a ser liberal, al envejecer. El objetivo del presente estudio es analizar los cambios que se producen en la discriminación y el criterio de respuesta en función de la edad en dos pruebas de reconocimiento: una frente a imágenes sin carga emocional y otra frente a caras con expresiones faciales positivas y negativas. Dos grupos de participantes realizaron ambas pruebas: joven (N = 21; rango de edad de 17-33 años), mayor (N = 21; rango de edad de 65-91 años). El análisis de diferentes medidas de discriminación (d´ y probabilidad de reconocimiento) y del criterio de respuesta de los participantes en las distintas tareas experimentales arrojó diferencias significativas en función de la edad. Así, los resultados indicaron que la habilidad para discriminar de las personas de más edad supera a la de los jóvenes frente a imágenes neutras y caras con expresiones faciales negativas. En lo que respecta al criterio de respuesta, el de los jóvenes siempre fue conservador, en tanto que el de los mayores fue óptimo frente a imágenes neutras (más aciertos sin incremento de falsas alarmas) y liberal frente a las caras con expresiones faciales emocionales. Los resultados se explican en parte por la dificultad diferencial de las pruebas y se interpretan dentro del marco de la teoría de la simulación.
Palabras clave: envejecimiento, reconocimiento, criterio de respuesta, reconocimiento de caras, valencia de la expresión facial.

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The ability to recognize information previously seen or heard does not seem to significantly worsen with age or at least, it does not decline as much as the ability to recall it (for a review, see, e.g., Hess, 2005). This stable performance on recognition tasks is usually reflected in an absence of differences in discrimination parameters such as d´ as a function of age (e.g., Mitrushina, Satz, Chervinsky, & D'Elia, 1991), although at times it is accompanied by age-related changes in the response criterion (e.g., Howard, Bessette-Symons, Zhang, & Hoyer, 2006). Thus, some researchers suggest that during youth, a more conservative response criterion is used, indicated by being less inclined to report having seen a stimulus previously presented. This conservative bias in recognition might lead to more correct rejections of distractors, but also to more misses of target items. With old age, on the other hand, a more liberal response criterion tends to be adopted and people are more inclined to report having seen a stimulus; this may lead to a greater number of hits, but it also could entail more false recognitions (e.g., Howard, et al., 2006). However, there is evidence to suggest the possibility that when presented with stimuli with no emotional weight, the response criterion might be so precise as not to produce any increase in false alarms as a function of age (e.g., Simón, Ruiz Gallego-Largo, & Suengas, 2009).

With regards to processing information with emotional valence, it has been proposed that response biases would reverse direction with age: a negative bias in youth may become a positive bias in older age (e.g., Spaniol, Voss, & Grady, 2008). Socio-emotional selectivity theory suggests that the tendency of younger people to pay more attention to emotionally intense information in general and particularly when it is negative, changes in older age, when priority is given to the emotional wellbeing, partially achieved by favoring the processing of positive, as opposed to negative information (for a review, see Mather, & Carstensen, 2005). Elderly people's positive bias may not only affect the processing of laboratory materials (e.g., images or faces; Charles, Mather, & Carstensen, 2003; Mather, & Carstensen, 2003), but in a broader sense, it could lead them to: associate more positive feelings than youths with negative events (e.g., Comblain, D'Argembeau, & Van der Linden, 2005; Meléndez, Tomás, & Navarro, 2008), judge that there is greater similarity between a normal day and an ideal day (Triadó, Villar, Solé, Celdrán, & Osuna, 2009), and even favorably distort autobiographical memories (e.g., Kennedy, Mather, & Carstensen, 2004; for an exception, see St. Jacques, & Levine, 2007).

According to this framework, when processing faces, a positive bias would be reflected if elderly people exhibited more difficulties identifying negative facial expressions with no changes in their ability to identify positive ones (e.g., Calder, Keane, Manly, Sprengelmeyer, Scott, Nimmo-Smith, *et al.*, 2003; Mather, & Carstensen, 2003). A relatively common research finding is that the ability to recognize negative emotional expressions declines with age such that, for example, older participants might not discriminate well between faces displaying anger, disgust and fear (e.g., Keightley, Winocur, Burianova, Hongwanishkul, & Grady, 2006). But it should be taken into account that there is only one unquestionably positive facial expression, the prototypical pattern of happiness, while there are at least four negative ones (anger, disgust, fear, and sadness). Therefore, the difficulty described above always occurs between negative emotions, since there are no different types of positive facial patterns between which to differentiate.

Nevertheless, not all researchers have found a positive memory bias in old age. On the contrary, some have found results to indicate that processing emotional information (positive or negative) does not vary with age (e.g., D´Argembeau, & Van der Linden, 2004; Denburg, Buchanan, Tranel, & Adolphs, 2003). Those authors have criticized Socio-emotional theory on the basis that some of its supporting data comes from studies where the method of stimuli presentation could have attenuated the processing of negative information (Denburg, *et al.*, 2003; Grühn, Smith, & Baltes, 2005).

From a different perspective, Simulation theory proposes that facial expressions are understood by "simulating" the gesture and through personal identification with the underlying emotion experienced (e.g., Suzuki, Hocino, Shigemasu, & Kawamura, 2007). This theory attributes the age-related deficit in processing negative facial expressions to having decreased personal experience with negative emotions. However, there is no agreement on this subject, and some studies have suggested that with age, there is in fact a greater ability to differentiate between positive and negative emotions, while the experience of the latter is not only more complex than during youth (Ready, Carvalho, & Weinberger, 2008), but in instances such as responding with sadness to a pertinent emotional situation, it actually increases with age (e.g., Kunzmann, & Grühn, 2005). In light of this, it could be possible that the greater personal experience of negative emotions would lead elderly participants to a more precise identification of negative facial expressions (e.g., Goldman, & Sripada, 2005).

There is evidence to suggest a possible relationship between the emotional nature of the information presented and the response criterion with which it is approached. Thus, Comblain, D'Argembeau, Van der Linden, and Aldenhoff (2004) suggest that at any age, a more conservative response criterion is activated when processing neutral information than when the information is emotionally charged, whether positively or negatively, in which case, a more liberal criterion is adopted. It has also been suggested that elderly people generate the most false alarms when the information to be recognized has emotional weight (e.g., Kapucu, Rotello, Ready, & Seidl, 2008).

In the present study, all participants completed two recognition tasks with two different types of visual stimuli: neutral images and faces with positive and negative facial expressions. We chose to use this type of stimulus because participants' performance on tasks using visual materials is usually better than with verbal materials (e.g., Janowsky, Carper, & Kaye, 1996). Also, we opted for an incidental procedure; in other words, we did not give specific instructions to remember the information or prior warning about the recall/recognition test that would follow because several authors have suggested that those conditions favor elderly participants' performance, unlike situations where recall is intentional (e.g., Old & Naveh-Benjamin, 2008). In addition, as suggested by Comblain, *et al.* (2004), it might be of greater interest to study different age groups using incidental paradigms because they provide more information about everyday memory performance, which rarely involves conscious memory processing.

As for the study's objectives, by comparing performance on the two tasks, we tried to determine whether or not the response criterion changes with age independently of the information to be recognized, or if it only varies when presented with information with a clear emotional valence. The results would also allow us to establish whether or not, as Socio-emotional theory posits (e.g. Mather, & Carstensen, 2003), aging makes negative stimuli more difficult to identify than positive or neutral ones, or if, according to an alternative interpretation of the Simulation theory, elderly people better recognize negative facial expressions due to the increased frequency of negative personal experiences that comes with age (Kunzmann, & Grühn, 2005).

On the basis of the evidence documented in the previously outlined studies, we proposed various hypotheses concerning Task 1, which examined free recall, recognition, and evaluation of neutral images. On the one hand, we expected that younger participants would remember more information than older ones. As far as recognition, we hypothesized there would be no differences as a function of age in the ability to discriminate, but that there would be differences in the response criterion such that young people would be more conservative. Last, we anticipated that elderly people would judge the images as more appealing than their young counterparts. We also proposed various hypotheses about Task 2, which explored recognition, discrimination of facial expressions, and evaluation of the appeal of faces. We did not expect differences as a function of age in the ability to recognize faces, although we did anticipate differences in discriminating facial expressions. Our hypothesis, departing from Socio-emotional theory, was that elderly participants would better discriminate negative facial expressions due to having had their own emotional experiences reminiscent of some of them. With respect to the response criterion, we expected that it would be more conservative in youth and more liberal in old age. Finally, we anticipated that elderly people would judge the faces presented as more appealing than the young people would.

Method

Participants

Forty-two people voluntarily participated in the study, of whom 21 were young adults (20 women and 1 man) ranging in age from 17 to 33 years old ($\overline{X}$ = 19.81 years, *SD* = 3.67) who had an average of 14.81 years of education (*SD* = 1.40). The other 21 were elderly adults (20 women and 1 man) ranging in age from 65 to 91 years old ($\overline{X}$ = 77.33 years, *SD* = 7.85) with a mean of 9.38 years of education (*SD* = 1.65). The youths were fist-year students in the Psychology Department at the Universidad Complutense de Madrid. The elderly adults came from two senior clubs in Madrid (Altamira and Nuestra Señora de Monserrat) and were selected because the health professionals responsible for them indicated they did not suffer from any illnesses that could reduce cognitive performance. This was reflected by their scoring over 26 on the Spanish adaptation of the *Mini-Mental State Examination* (Folstein, Folstein, McHugh, & Fangiang, 2001) by Lobo, Saz, Marcos, and Grupo ZARADEMP (2002) and by their active participation in the academic courses and cultural programs the two institutions offer.

Task 1 – Images without Emotional Weight

Materials

The stimuli consisted of 100 color photographs of elements representative of different categories (clothing, animals, foods, everyday utensils, modes of transportation, and furniture) taken from the Internet (for examples, see Appendix A). All images selected met the requirement that three judges independently considered them clearly recognizable, easily labeled, and rated them with 4 on a scale from 1 (*very disagreeable*) to 7 (*very agreeable*). From that point on, we considered all the images to be neutral and without emotional weight. During the acquisition phase, 50 images were presented, whereas all 100 were presented in the recognition phase. In both cases, the stimuli were counterbalanced such that each participant was presented with a different sequence.

Procedure

The procedure employed in Task 1 was similar to that of Simón, *et al.* (2009). In the acquisition phase, a series of 50 images was presented at a rate of one every five seconds. The elderly participants completed the task individually and the images formed the pages of an A4 sized notebook. Young participants completed the task in small groups and the images were projected through a computer onto a screen. The instructions consisted of simply observing

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the images attentively, without specifically indicating they would need to be remembered. Later, the experimenter gave a brief, three-minute talk about current events. Next, they completed the free recall task in which they were asked to name all the images they remembered from the series they just saw. Subsequently, they completed the recognition task, which involved presenting 100 images (the 50 presented initially and 50 distracters). They were asked to indicate if they had previously seen each stimulus or not. Finally, the initial 50 images were again presented and participants were asked to evaluate the appeal of each on a Likert-type scale ranging from 1 (*very disagreeable*) to 7 (*very agreeable*).

Task 2 – Faces with Positive and Negative Emotional Expressions

Materials

The stimuli included 48 color photographs of faces from the group of NimStim Emotional Face Stimuli (Tottenham, Borscheid, Ellersten, Marcus, & Nelson, 2002). Figure 1 depicts a schema of Task 2 and includes some examples of the faces employed as stimuli. The 48 photographs presented 24 different faces with two different facial expressions each (positive, negative). They were organized into 4 subgroups of 12 different faces, which were counterbalanced so that each participant would see 3 subgroups, for a total of 36 different photographs [(12 different faces during the acquisition phase, 2 different expressions each for the recognition phase = 24 photos) + 12 new faces / distractors in the recognition phase]. Thus, 12 different faces were presented in the acquisition phase: 6 men and 6 women; from each, 3 had negative facial expressions (fear, anger, sadness, disgust) and 3 had positive facial expressions (happiness, surprise). During the recognition phase, 36 faces were presented: the 12 initial faces (so the face and facial expression coincided); 12 faces that had been presented, but with a different facial expression (positive or negative; coincidence of face, but not of facial expression); and 12 entirely new ones (6 men and 6 women; 6 with positive facial expressions and 6 with negative ones).

Procedure

All participants completed this task individually. In the acquisition phase, a series of 12 photographs of faces was presented, which comprised the pages of a size A4 notebook, at a rate of one every five seconds. The instructions consisted of simply observing the faces and their respective facial expressions attentively, there were no specific directions to remember them. Next, the experimenter gave a brief talk on current events for three minutes. Later, participants performed the recognition test,

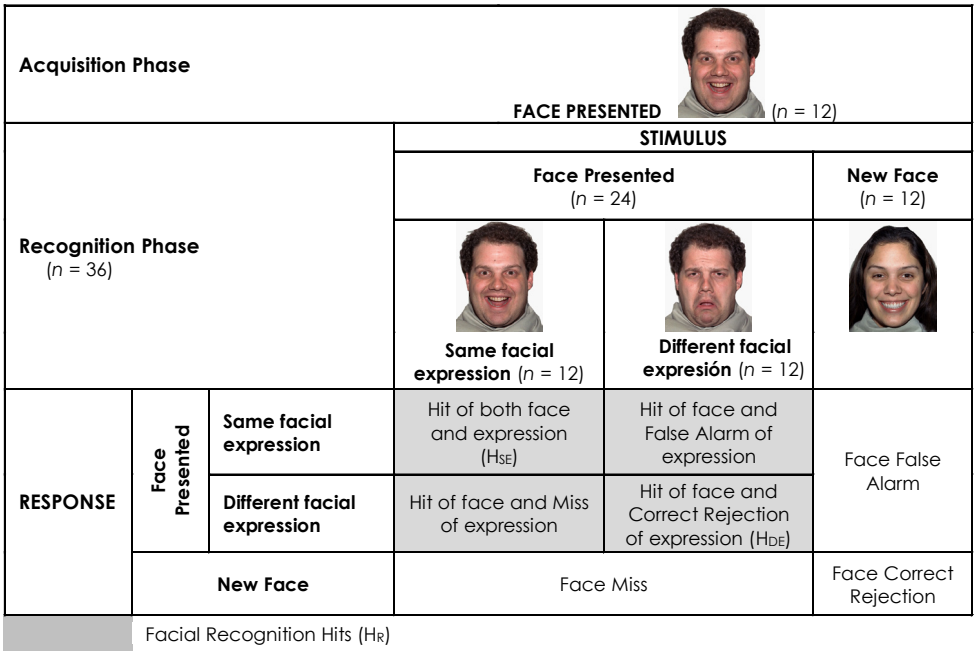

Figure 1. Schema of face and facial expression recognition tests, with some examples of stimuli used in Task 2 (faces with positive and negative emotional expressions), selected from the group of NimStim Emotional Face Stimuli (Tottenham, Borscheid, Ellersten, Marcus, & Nelson, 2002).

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outlined in Figure 1. Participants were presented with 36 photographs: 12 identical to those presented previously (face and facial expression coincided), 12 presented the same face with a different facial expression (positive or negative; face coincided, facial expression did not) and 12 faces that had not been previously presented (6 men and 6 women; 6 positive and 6 negative facial expressions). When presented with each photograph, participants were asked to indicate first if they had seen the face previously or not (facial recognition) and in the case of an affirmative response, whether or not they had seen the face before with the same facial expression, or a different one (identifying the facial expression). Finally, they were again presented with the 36 faces that comprised the recognition test and were asked this time to evaluate the faces' appeal on a Likert-type scale from 1 (*not at all agreeable*) to 5 (*very agreeable*).

All participants performed both tasks (images without emotional weight and faces with emotional expressions) and the order was counterbalanced over two different days in order to minimize the effect of building expectations and to maintain the study's incidental nature. The young people took the tasks in written form and the elderly, orally. These procedural differences were intended to minimize fatigue for the elderly participants.

Data Analysis

The level of significance was fixed at .05. Whenever a design of independent measures was used, the following parametric assumptions were tested: normal distribution (using the Shapiro-Wilk test) and equality of variance (using the Levene test). If the data distribution was normal, a parametric analysis (ANOVA) was performed; if the data were not normally distributed, a transformation was applied toward achieving normal distribution. If, after the transformation, they became normally distributed or did not stray much from normal distribution, an ANOVA was applied as well, given that the size of the groups (n = 21) was the same. If not, the corresponding non-parametric analysis was performed. When the assumption of equality of variance was not met, the Brown-Forsythe correction was applied. When using a repeated measures design, the assumption of sphericity was tested as well. When that assumption was not met, a multivariate or univariate contrast was performed using the Greenhouse-Geisser correction. The Bonferroni test was utilized to make *a posteriori* comparisons.

Results

Task 1 – Images without Emotional Weight

Free Recall

To study the effect of age on the quantity of images recalled, a one-factor ANOVA was performed with age (young, older) as the between-subjects factor. The results revealed a significant main effect for age, F (1, 40) = 57.29, p = .001, η^2 = .89, $1\text{-}\beta$ = 1.00, which suggests that as a group, youths remembered more images ($\overline{X}$ = 25.24, SD = 3.82) than their older counterparts ($\overline{X}$ = 16.14, SD = 3.97).

Recognition

The upper part of Table 1 displays the descriptive statistics of the two groups' (young, older) scores for recognition on Task 1.

Table 1
Dependent variables used to evaluate stimulus recognition in Task 1 (images without emotional weight) and Task 2 (faces with positive and negative emotional expressions) as a function of age group (young, older): Mean (standard deviation)

	Age Group	*d*'	Probability of Recognition	Response Criterion	P(H)	P(FA)
Task 1	Young	3.49 (.54)	.93 (.06)	2.44 (2.15)	.93 (.06)	.04 (.03)
	Older	3.63 (.79)	.94 (.08)	1.29 (1.07)	.95 (.07)	.05 (.07)
Task 2	Young	1.62 (.81)	.63 (.22)	1.50 (.90)	.72 (.15)	.19 (.15)
	Older	1.55 (.63)	.71 (.17)	1.02 (.82)	.79 (.12)	.27 (.16)

Note: P(H) = Probability of Hits; P(FA) = Probability of False Alarms.

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We estimated participants' ability to discriminate between the images presented and the distracters through two measures: *d'* ($z_{p(H)}$-$z_{p(FA)}$) and *probability of recognition* [p(H)-p(FA)]/[1-p(FA)] where p(H) and p(FA) are the respective proportions of hits and false alarms. The *Mann-Whitney U* test indicated there were no significant differences as a function of age in *d'* ($p > .05$), though there were significant differences in *probability of recognition* [$U = 152.00$, $p(unilateral) = .04$]. Thus, the older group discriminated significantly better between the information initially presented and the distracter (*mean rank* = 24.76) than the youths (*mean rank* = 18.24). The left column in Figure 2 displays the *probability of recognition* for both groups on this task.

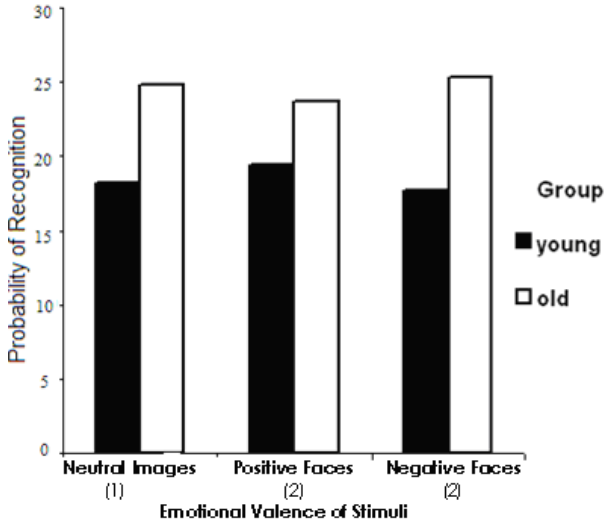

Figure 2. *Probability of recognition* (calculated as [p(H)-p(FA)]/[1-p(FA)], where p(H) is proportion of hits, and p(FA) is the proportion of false alarms) as a function of age group (young, old) in Task 1 (1): Images without emotional weight; and in Task 2 (2): Faces with positive and negative emotional expressions.

Response Criterion, Hits and False Alarms

We calculated the participants' response criterion, $f[z_{p(A)}]/f[z_{p(FA)}]$, where $f[z_{p(H)}]$ and $f[z_{p(FA)}]$ correspond to the ordinate values for the probability of hits and false alarms in a normal distribution. A one-factor ANOVA was performed with age (young, older) as the between-subjects factor, which revealed significant differences between the two groups [*Brown-Forsythe* (1, 32,22) = 4.77, $p = .04$, $\eta^2 = .11$, $1\text{-}\beta = .57$]. This result showed that the young group's response criterion turned out to be significantly higher, that is, more conservative, than the older group's, who had a more liberal response criterion.

To go into greater depth on this aspect, the *Mann-Whitney U* test was applied to the proportion of hits and false alarms. Results indicated significant differences as a function of age in the proportion of hits [$U = 149.50$, $p(unilateral) = .03$] and therefore also misses, but not in the proportion of false alarms and therefore, correct rejections. In other words, the older group achieved significantly more hits (*mean rank* = 24.88) than the youths (*mean rank* = 18.12) such that the latter had significantly more misses (*mean rank* = 24.88) than the older participants (*mean rank* = 18.12).

Evaluating Images

To analyze whether or not there were differences in participants' evaluations of images, a one-factor ANOVA was performed with age (young, older) as the between-subjects factor. Results demonstrated a significant main effect for age, F (1, 33) = 17.31, $p = .001$, $\eta_p^2 = .34$, $1\text{-}\beta = .98$, thus indicating that older participants ($\overline{X} = 4.80$, $SD = .20$) judged the images as more agreeable than younger ones ($\overline{X} = 3.72$, $SD = .18$).

Task 2 – Faces with Positive and Negative Facial Expressions

Face Recognition

The lower part of Table 1 displays the two groups' (young, older) descriptive statistics for the dependent variables analyzed pertaining to facial recognition. We estimated participants' ability to discriminate between the faces presented and the distractors through two measures, *d'* and *probability of recognition,* which were already defined in the section on Task 1. A one-factor ANOVA was performed with age (young, older) as the between-subjects factor for each measure and the results indicated no significant differences between the groups ($p > .05$). Thus, younger and older participants were equally accurate when discriminating between new faces and previously presented ones.

Response Criterion, Hits and False Alarms in Face Recognition

The *Mann-Whitney U* test determined there were significant differences in *response criterion* [$U = 139.00$, $p(unilateral) = .02$] between the younger group (mean rank = 25.38) and the older one (mean rank = 17.62). The young group employed a more conservative response criterion,

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while the older group's criterion was more liberal. This was supported by the results of the *Mann-Whitney U* tests that indicated significant differences as a function of age in the proportion of hits [U = 158.50, p(*unilateral*) = .05] and false alarms [U = 146.50, p(*unilateral*) = .03]. In this way, older participants (*mean rank* = 24.52) got more hits than the youths (*mean rank* = 18.48), but simultaneously made more false alarms (*mean rank*: *young* = 17.98; *older* = 25.02).

Discriminating Same-Different Facial Expressions

Figure 1 presents a schema depicting the dependent variable used in the analysis of the ability to discriminate facial expressions: *Discrimination*. This variable has two levels: Discrimination of same expression = (H_{SE} / H_R) and discrimination of different expression = (H_{DE} / H_R), where H_{SE} (same expression hits) is the number of times participants correctly indicated the face had the same expression as when it was initially presented; H_{DE} (different expression hits) is the number of times participants correctly indicated that the face had a different expression than the one initially presented; and H_R (recognition hits) is the number of times participants correctly recognized the face as initially presented, independently of its expression.

A mixed-model ANOVA was performed with age (young, older) as the between-subjects factor and *Discrimination* (same expression, different expression) as the within-subjects factor. No significant effects of age were found although there was a main effect of *Discrimination, F* (1, 40) = 13.02, p = .001, η_p^2 = .25, *1-*β = .94. In general, participants were better at discriminating faces that appeared in the recognition test with the same expression as when they were initially presented ($\overline{X}$ = .43, *SD* = .09) than those that appeared with a different expression ($\overline{X}$ = .35, *SD* = .08). The interaction between age and *Discrimination*, illustrated in Figure 3, almost achieved statistical significance, F (1, 40) = 3.61, p = .06, η_p^2 = .08, *1-*β = .46. The *a posteriori* comparisons [t(1, 20) = 3.62, p = .002] showed that only the older participants were significantly better at discriminating faces that appeared in the recognition test with the same expression as before ($\overline{X}$ = .46, *SD* = .90) than those that appeared with a different expression ($\overline{X}$ = .33, *SD* = .98).

Response Criterion, Hits and False Alarms When Discriminating Same-Different Facial Expressions

The results of the *Mann-Whitney U* test revealed no significant differences between the young and older groups in terms of their response criteria used to discriminate faces, which appeared in the recognition task with either the same or a different facial expression than the one initially presented (p > .05). The results of the one-factor ANOVA (young, older) did, however, yield significant differences between the two groups in hit rate when the faces had the same facial expression in the acquisition and recognition phases, *F (1, 40) = 4.51, p = .04,* η^2 = .10, *1-*β = .54. That is to say, older participants had more hits than young ones ($\overline{X}$ = .73, *SD* = .15) when determining whether or not a face had the same expression when it was initially presented. Conversely, the young group (see note 1) had more misses; that is, though the face did have the same expression, they tended to say it was different from when initially presented. With regards to the incidence of false alarms when discriminating whether or not a facial expression coincided with the one initially presented, no significant differences were found between the two groups (p > .05).

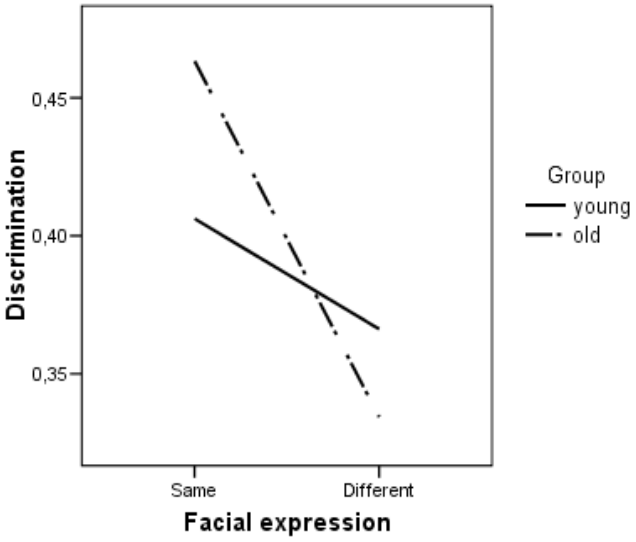

Figure 3. Discrimination of facial expression (same expression, different expression) as a function of age group (young, old) in Task 2 (faces with positive and negative emotional expressions).

Discrimination as a Function of Facial Expressions' Emotional Valence (Positive, Negative)

Table 2 displays the descriptive statistics corresponding to the dependent variables analyzed for each group (young, older) concerning face discrimination as a function of the emotional valence (positive, negative) of the facial expression.

To evaluate participants' differential performance when presented with faces expressing positive and negative emotions, we analyzed *d′* and *probability of recognition*

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Table 2
Dependent variables used to evaluate stimulus recognition in Task 2 (faces) as a function of the emotional valence of the facial expression (positive, negative) and age group (young, older): Mean (standard deviation)

Facial Expression	Age Group	*d'*	Probability of Recognition	Response Criterion	P(H)	P(FA)
Positive	Young	1.79 (.67)	.77 (.20)	.25 (.09)	.82 (.17)	.18 (.19)
	Older	1.72 (.66)	.83 (.23)	.29 (.08)	.87 (.16)	.26 (.19)
Negative	Young	1.58 (.84)	.66 (.31)	1.14 (.43)	.76 (.19)	.20 (.16)
	Older	1.68 (.70)	.83 (.25)	.76 (.35)	.89 (.14)	.29 (.18)

Note: P(H) = Probability of Hits; P(FA) = Probability of Falses Alarms.

for each group of stimuli. Our analyses of participants' ability to discriminate faces with negative expressions indicated there were no significant differences in *d'* ($p > .05$), but there were significant differences in *probability of recognition* as a function of age [$U = 140.50$, p(*unilateral*) = .02]. As Figure 2 conveys, older participants (*mean rank* = 25.31) discriminated faces with negative expressions significantly better than young participants (*mean rank* = 17.69). As for faces with positive expressions, results from a one-factor ANOVA and the *Mann-Whitney U* test applied, respectively, to *d'* and *probability of recognition* indicated there were no significant differences as a function of age ($p > .05$).

Response Criterion, Hits and False Alarms as a Function of Facial Expressions' Emotional Valence (Positive, Negative)

To study the influence of the emotional valence of facial expressions, positive or negative, on participants' response criteria, a mixed-model ANOVA was performed with age (young, older) as the between-subjects factor and emotional valence (positive, negative) as the within-subjects factor. Results indicated that emotional valence had a significant effect, $F(1, 40) = 109.74$, $p = .001$, $\eta_p^2 = .73$, $1\text{-}\beta = 1.00$, given that participants were found to employ higher, that is, more conservative response criteria when dealing with negative facial expressions ($\overline{X} = .95$, $SD = .43$) as compared to positive ones ($\overline{X} = .27$, $SD = .09$). A significant effect of age was also found, $F(1, 40) = 8.78$, $p = .005$, $\eta_p^2 = .18$, $1\text{-}\beta = .82$, such that youths exhibited a higher, more conservative response criterion ($\overline{X} = .70$, $SD = .54$) than older participants ($\overline{X} = .53$, $SD = .35$). The interaction between the two variables (age and emotional valence) was also significant, $F(1, 40) = 10.06$, $p = .001$, $\eta_p^2 = .20$, $1\text{-}\beta = .87$. Subsequent analyses demonstrated that though there were no significant differences as a function of age when discriminating positive facial expressions ($p > .05$), there were when the facial expressions were negative: young participants, in this case, adopted a significantly higher, more conservative response criterion than the elderly participants, $t(1, 40) = 3.14$; $p = .003$. Furthermore, both young, $t(1, 20) = -8.9$; $p = .001$, and older, $t(1, 20) = -5.69$; $p = .001$, participants employed significantly higher response criterion values (more conservative) when presented with negative facial expressions than positive ones. Figure 4 conveys this interaction between the facial expression's emotional valence (positive, negative) and participants' age (young, older) in the response criterion.

With the aim of examining participants' differential accuracy when presented with faces with positive and negative expressions, we analyzed the respective probabilities of hits and false alarms for each group of stimuli. Concerning faces with negative emotional expressions, results from *Mann-Whitney U* tests indicated significant differences as a function of age both for hits [$U = 131.50$, p(unilateral) = .01] and false alarms [$U = 159.00$, p(*unilateral*) = .05]. Older participants (*mean rank* = 25.74) had significantly more hits when discriminating faces with negative emotional expressions than young participants did (*mean rank* = 17.26), but they also made significantly more false recognitions (*mean ranks: older* = 24.43; *young* = 18.57). The corresponding *Mann-Whitney U* tests indicated that when presented with positive facial expressions, there were no differences as a function of age in probability of hits and false alarms ($p > .05$).

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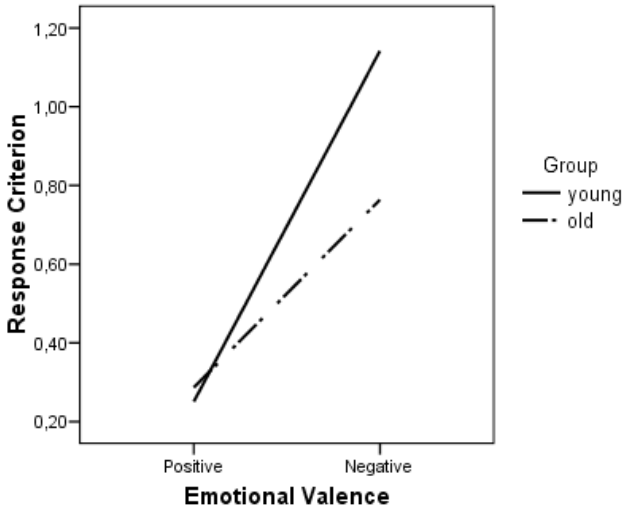

Figure 4. Response Criterion as a function of the emotional valence of the facial expression (positive, negative) and age group (young, old) in Task 2 (faces with positive and negative emotional expressions).

Judging Faces' Appeal

To analyze whether or not participants judged the faces' appeal as a function of their facial expressions, a mixed-model ANOVA was performed with age (young, older) as the between-subjects factor and the facial expression's emotional valence (positive, negative) as the within-subjects factor. The only significant effect found corresponded to the type of expression, $F\ (1, 40) = 176.90$, $p = .001$, $\eta_p^2 = .82$, $1\text{-}\beta = 1.00$. That is, participants considered faces with positive expressions more agreeable ($\overline{X} = 3.21$, $SD = .58$) than those with negative expressions ($\overline{X} = 1.86$, $SD = .4$). The effect of age and its interaction with emotional valence did not turn out to be significant ($p > .05$).

Performance on Both Tasks

In order to analyze whether or not the relationship between participants' performance on Task 1 (images without emotional weight) and Task 2 (faces with positive and negative emotional expressions) was a function of age, we calculated linear correlations between different indicators used in both tasks. Specifically, for each group, we calculated the correlations between variables that were of interest either because they had shown significant differences as a function of age in prior analyses (e.g., recall), or dealt with variables referring to the same characteristics in both tasks (e.g., *d'*). Table 3 presents scores on Task 1, which were correlated with those on Task 2.

As Table 4 depicts, no correlation turned out to be significant for the young group, but three were for the elderly group. In other words, for the young group, there was no linear relationship between performance on Task 1, recognizing neutral images, and performance on Task 2, recognizing faces with emotional expressions. For the older group, on the other hand, there were significant correlations between recall performance on the first task and their response criteria when recognizing positive facial expressions, between their response criteria when presented with neutral images and the probability of hit when presented with faces, and between their evaluations of stimuli on the two tasks. Therefore, for the older participants, it is possible to state that there is a percentage of variance in common between certain measures of performance on Tasks 1 and 2.

Discussion

At the outset of the present study, our objectives were, on the one hand, to examine the effects of age on response criterion in visual recognition tasks with materials of different emotional weight, in light of the abundant bibliography connecting these two aspects (e.g., Comblain, *et al.*, 2004; Kapucu, *et al.*, 2008). Second, we wished to contrast the Socio-emotional theory approach (e.g. Mather,

Table 3
Variables from Task 1 (images without emotional weight) and Task 2 (faces with positive and negative emotional pressions) between which the correlation was calculated for each age group (young, older)

Task 1	Task 2
Measures of recognition accuracy: d', Probability of Recognition	Measures of recognition accuracy: d', Probability of Recognition
Measures of Image Evaluation	Measures of Face Evaluation
Response Criterion, Probability of Hits, and Probability of False Alarms	Response Criterion, Probability of Hits, and Probability of False Alarms
Recall	d', Probability of Recognition, Evaluation, Response Criterion, Probability of Hits, and Probability of False Alarms

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Table 4
Variables from Task 1 (images without emotional weight) and Task 2 (faces with positive and negative emotional expressions) whose correlations were significant (in older group only)

		Young		Older	
Task 1	Task 2	*r*	*p*	*r*	*p*
Recall	Response Criterion for Positive Facial Expression	.16	.49	.45*	.04
Response Criterion for Images	Probability of Hits, Negative Facial Expression	-.40	.07	-.49*	.03
Average Evaluation of Images	Average Evaluation of Faces	.35	.12	.47*	.03

Note: *r* is Pearson's correlation coefficient; *p* is probability.

& Carstensen, 2003) to an alternative interpretation of the Simulation theory (Kunzmann, & Grühn, 2005) when explaining our results.

Our first hypothesis proposed that older participants would recall fewer images than young people and the results from Task 1 confirmed this aspect. This is consistent with the accrued evidence about the effects of aging on free recall paradigms (e.g., Davis, Trussell, & Klebe, 2001). Possible explanations for this memory decline as a function of age are summarized, for example, in the conclusions of Luo, Hendriks, and Craik (2007), who consider recall an activity with costly cognitive demands to working memory because it requires a large quantity of self-initiated processing, which is very much affected by age. These authors stated that, after years of research and debate intended to discern whether the origin of memory decline with old age stems from its effect on encoding or retrieval processes, it should be concluded that aging significantly influences "both" phases of information processing (Luo, *et al.*, 2007).

Recognition

If the results of the two task here presented seem to indicate anything with clarity, it is that, as illustrated in Figure 2 and as we posited in our second hypothesis, recognition of visual materials does not only not diminish with age, but actually "improves" in some cases. In both tasks, when presented with neutral images as well as faces expressing emotions, all discrimination parameters measured produced results in which there were no differences between age groups, or if there were any, they favored elderly participants. There are additional studies that had found that under certain circumstances (e.g., incidental paradigms, visual materials), older people perform as well as or better than young people on recognition tasks (e.g., Keightley, *et al.*, 2006; Simón, *et al.*, 2009).

With that in mind, it should be mentioned that elderly participants, but not their young counterparts, were better at discriminating faces that appeared on the recognition test with the same facial expression as when they were initially presented, than faces that appeared with a different expression. This result could indicate a certain lack of flexibility, which some authors have cited as a characteristic of memory functioning in old age (e.g., Bishara, & Jacoby, 2008). This limitation in flexibility would lead elderly people to better register the literal facial expression, but not the identities behind the faces. The young group, on the other hand, exhibited a more flexible performance by identifying equally well faces with the same and different emotional expressions, which may suggest that they achieved a better understanding of the underlying identities of the faces. Various authors have asserted that aging fundamentally affects extracting identity and not so much identifying emotional expressions (e.g., D'Argembeau, & Van der Linden, 2004).

Discriminating Positive and Negative Emotional Facial Expressions

Regarding the emotional valence of stimuli, results supported our hypotheses showing that older participants better discriminated neutral images and faces with negative emotional expressions than young ones. There was no difference when it came to recognizing positive expressions. This result does not agree with the prediction from Socio-emotional selectivity theory, about better performance of older people when presented with positive information (e.g., Charles, *et al.*, 2003; Mather & Carstensen, 2005). It does, however, partially support the findings from other studies that have concluded that at any age, negative words or images are remembered better than positive ones (Grühn, *et al.*, 2005; Denburg, *et al.*, 2003).

The disparity between the results of this and other studies could be explained partly by differences in methodology, given that some studies whose results have indicated poorer recognition of faces with negative expressions used intentional processing paradigms (e.g., D´Argembeau, & Van del Linden, 2004), or presented pairs of faces (e.g., Mather, & Carstensen, 2003), whereas here we applied an incidental paradigm and presented the faces individually.

It is possible that older people were better at recognizing negative facial expressions because, although the faces

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were all presented for the same amount of time, participants' effective processing time would have been greater for negative expressions, since faces with positive expressions seem to be more quickly identified and processed. Thus, some researchers argue that happy faces' more automatic processing causes them be registered with less attention than those that convey negative emotions, to the detriment of later recognition (e.g., Grady, Hongwanishkul, Keightley, Lee, & Hasher, 2007). In addition to that, when photographs are shown individually, as in the case of Task 2, participants of all ages look at the sad and angry faces longer than happy ones (Mather, & Carstensen, 2003). Perhaps, for that reason, greater initial attention to the negative expressions is what leads to better recognition later on, but the methodology employed in this study does not allow us to evaluate this aspect.

Simulation theory places particular emphasis on the existence of a connection between experience and recognition of facial expressions. In other words, the other's emotional state is recognized by simulating an analogous state in ourselves (e.g., Goldman, & Sripada, 2005). Some supporters of this theory defend parallel assumptions to Socio-emotional theory in the sense that growing old involves a search for emotional wellbeing, which could lead to a reduction in the experience of negative emotions and consequently, a decreased understanding of them (e.g., Suzuki, *et al.*, 2007). Nevertheless, there have been substantial data to the contrary that suggest that if anything increases in old age, it is the experience of negative events, at least in terms of illness and the death of loved ones, which lead emotions such as sadness to be experienced with greater intensity and frequency than in youth (e.g., Rodríguez-Testal, & Valdés, 2003). Charles (2005), to that effect, demonstrated that elderly participants experience a greater diversity and intensity of negative emotions than young people when watching films depicting different social injustices. For those reasons, we believe that a reinterpretation of Simulation theory applies to these results, given that the frequent experience of negative emotions when growing old could explain better recognition of their expressions in other people.

The Response Criterion

The data we collected support the proposed hypothesis by suggesting that aging does, in fact, bring about changes to the response criterion, yet those changes only lead to the generation of false recognitions when discriminating information with emotional weight. When the information is neutral (Task 1), on the other hand, we found that older participants' response criteria are more precise than young people's. Therefore, they not only achieved more hits when identifying the images presented, but they did not incur in more false alarms. Young people, as other studies have reported, exhibit a more conservative response criterion which, though it does lead them to correctly reject information they have not seen, also leads them to make more misses (e.g., Howard, *et al.*, 2006).

When presented with materials of marked emotional valence, such as the faces in Task 2, young people's response criterion continues to be conservative and this leads them to a habitual pattern of correctly rejecting faces they have not seen previously, while also missing some they have seen. However, older participants, who continue to have a more liberal response criterion than young people, do commit in this case more false alarms. To put it another way, compared to their performance when recognizing neutral images, when trying to discriminate faces with positive and negative expressions, older participants get more hits than young ones, reporting they had seen the faces before, but they also make more false alarms by erroneously identifying facial expressions they had not seen previously. The effect of "false recognition" in old age has been verified in diverse contexts (for a review, see, e.g., Schacter, Koutstaal, & Norman, 1997): facial recognition (e.g., Rhodes, Castel, & Jacoby, 2008), word recognition (e.g., Jacoby, Bishara, Hessels, & Toth, 2005), and even when acting as eye witnesses, trying to recognize someone in a line-up (e.g., Searcy, Bartlett, Memon, & Swanson, 2001).

We also observed that the response criterion differed for positive and negative facial expressions in that all participants adopted a more conservative criterion when presented with faces expressing negative emotions. This result does not clearly support the findings of other studies, which have not always found differences in the response criterion between positive and negative images (e.g., Charles, *et al*., 2003). This result seems to agree with the notion commented on earlier, that faces that convey positive emotions are more easily identified, which would allow them to be responded to using a more liberal criterion at any age. Meanwhile, pausing for more time when processing faces that show negative emotions could be related to adopting a more cautious criterion when confronted with them.

Why did elderly participants abandon their optimal response criterion in Task 1 to adopt a more liberal one in Task 2? One possible explanation is the differential difficulty of the two tasks. The discrimination was easier in Task 1 where all the stimuli were different, while it became more complicated in Task 2, where the same face appears with two different expressions. Many studies have suggested increasing the difficulty of a task as one of the variables that elicits the most differences as a function of age (for a meta-analysis, see Ruffman, Henry, Livingstone, & Phillips, 2008). Therefore, it is possible that the increased difficulty of the discrimination forced a change in older participants toward employing a more liberal response criterion that also generated more false alarms.

We would like to argue that in old age, making false recognitions as the task becomes more complex may actually be a metamemory strategy, suggesting an

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understanding of the fallibility of one's own memory. Older people may be more conscious of frequently forgetting things so when asked to determine whether or not they have seen something before, they may say they have in spite of their doubts, figuring that in all likelihood they have, judging from the frequency with which these "slip-ups" occur in their everyday lives (Cavanaugh, 1989). We have no data to support this justification, but we would guess this is a possible explanation for the tendency to adopt liberal response biases when aging, as the demands of the task itself increase.

Why young people's response criterion is conservative remains to be explained. Perhaps, opposite to the reasoning about the elderly, not remembering information is so infrequent during youth, both in terms of content and in the context of acquisition, that they come to overestimate their memory. Thus, when faced with the uncertainty of having previously viewed a given stimulus, they respond that they had not, figuring that if they had seen it, surely they would remember it.

Evaluations of Stimuli

Though we expected that elderly participants would consider the stimuli more agreeable than young people, the results only support that hypothesis in Task 1. As other researchers have observed (e.g., Mather, & Knight, 2005), when presented neutral images, elderly people judge them to be more agreeable than young people, which could to some extent explain the fact that they performed better on the recognition test. That is to say, the appeal of images could have acted as a motivational and volitional mediator for older participants and positively influenced their performance (e.g., Mateos, Meilán, & Arana, 2002).

The results from Task 2 do not support the hypothesis that elderly people would judge the young faces used as stimuli as more attractive than young people would. Participants considered the faces with a positive expression more appealing than those that showed a negative expression, but differences as a function of age did not occur. This result is somewhat surprising because it does not coincide with the results from Task 1 and because, in other studies, participants' age has influenced their evaluations of the appeal of different faces (Ebner, 2008).

The Relationship between the Two Tasks

The fact that several different measures taken in the older group are correlated, and in the case of the young group, they are not, could indicate that the former went about the two tasks with the same type of strategy, while the latter applied different strategies according to the demands of the task. This result is in agreement with those from other studies and would allows us, though only for the elderly participants, to predict performance on one task based on their performance on the other (e.g., Keightley, *et al*., 2006). Some researchers explain these kinds of results within the framework of the hypothesis of dedifferentiation, or neointegration, during the process of intellectual aging and argue that many indicators of cognitive performance become intercorrelated with age, which demonstrates a decrease in cognitive resources and an increased homogeneity across different abilities, compared to the characteristic diversity of youth (e.g., Lindenberger, & Baltes, 1997).

Limitations

One limitation of the present study was the use of photographs of young people as stimuli. We do not know the impact that this factor may have had on our results, but we must point out that, for example, Anastasi and Rodhes (2006) and Firestone, Turk-Browne, and Ryan (2007) proposed that older participants better recognize the faces of people their own age. However, authors are not in unanimous agreement on this matter. Studies by Ebner and Jonhson (2009) demonstrated that participants of all ages recognize young faces better than elderly ones, perhaps because facial aging adds objective difficulties to the discrimination. In any case, we wish to reiterate that in the present study, in spite of observing young faces, elderly participants recognized faces better than young participants, at least when they portrayed negative expressions.

Another aspect of this study that has traditionally been considered a limitation to research on aging is that there is usually a difference in educational level, measured by number of years of education, between young and elderly participants. Nevertheless, there is disagreement about the influence of academic education on memory performance. On one side, authors such as Keightley *et al*. (2006) have shown that when years of education are introduced as covariance in analyses of facial discrimination, the results are the same. In other words, education does not explain the differences obtained. On the other hand, studies such as Tractenberg, Aisen, and Chuang (2005) have found that years of formal education do explain part of the variance in recall measures in adult and elderly populations. Bearing in mind these opposing results, we insist that in the present study, in spite of the clear difference between the two groups in years of academic education, the less educated elderly participants were better at recognizing objects and faces with negative expressions than the young, college-age participants.

Conclusions

Our results indicate that older people can discriminate visual information without emotional weight even better than youths. They also surpass them when discriminating faces that exhibit negative facial expressions, perhaps because of having more experience and personal identification with

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their underlying feelings. With regards to the response criterion, young people are always more conservative in this way, while older people exhibit an optimal criterion when presented with neutral information and become liberal only when the information implies emotional weight. Finally, we must consider the possibility that the change in response criterion is actually part of a strategy to compensate for memory decline, which is widely reported by elderly people in a variety of contexts.

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APPENDIX A

EXAMPLES OF IMAGES USED AS STIMULI IN TASK 1 – IMAGES WITHOUT EMOTIONAL WEIGHT.

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