THE ROLE OF AGE AND EMOTIONAL VALENCE IN WORD RECOGNITION: AN EX-GAUSSIAN ANALYSIS

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Abstract: The aim of this work is to evaluate the roles of age and emotional valence in word recognition in terms of ex-Gaussian distribution components. In order to do that, a word recognition task was carried out with two age groups, in which emotional valence was manipulated. Older participants did not present a clear trend for reaction times. The younger participants showed significant statistical differences in negative words for target and distracting conditions. Addressing the ex-Gaussian τ parameter, often related to attentional demands in the literature, age-related differences in emotional valence seem not to have an effect for negative words. Focusing on emotional valence for each group, the younger participants only showed an effect on negative distracting words. The older participants showed an effect regarding negative and positive target words, and negative distracting words. This suggests that the attentional demand is higher for emotional words, in particular, for the older participants.

Key words: word recognition, emotional valence, ex-Gaussian components

In recent years, the scientific community has increased its interest in the influence that emotion can exercise on cognitive processes such as memory and attention (Bradley, Greenwald, Petry, & Lang, 1992; Schmidt, 2012; Schmidt & Saari, 2007). Moreover, the literature shows a robust effect of emotional valence on memory. As indicated by Ferré (2003), the emotional effect on memory has been repeatedly proven using several types of stimuli.

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Focusing on the effect of emotional content on word recognition, the evidence shows more interference in emotionally valent (positive or negative) than neutral conditions for university students (Anderson, 2005; Dresler, M´eriau, Heekeren, & van der Meer, 2009; Pratto & John, 1991). On the other hand, emotional words are better remembered than neutral ones (Altarriba & Bauer, 2004; Brierley, Medford, Shaw, & David, 2007; Buchanan, Etzel, Adolphs, & Tranel, 2006; Ferré, 2003; Ferré, García, Fraga, Sánchez-Casas, & Molero, 2010; Herbert, Junghofer, & Kissler, 2008; Herbert & Kissler, 2010; Kensinger, 2008; Kensinger & Corkin, 2003; Kissler, Herbert, Peyk, & Junghofer, 2007; Schmidt & Saari, 2007). However, with aging, it seems that negative memories vanish more easily than positive memories (Abrisqueta-Gomez, Bueno, Oliveira, & Bertolucci, 2002; Berntsen & Rubin, 2002; Emery Hess, 2008); a clear dierence as compared to younger participants in the literature. Mather and Cartensen (2003) explained this by claiming that older participants try to improve their well-being in terms of memory. Another explanation offered by Gross et al. (1997), proposes that people learn to regulate their negative emotions better as they get older.

Regarding the role of attention in the field of memory, the effect of emotion on memory may be mediated by attentional demands. Reisberg and Heuer (1995) argued that attention might be higher (as opposed to neutral) during the encoding process for emotional stimuli. Research reviewed above is based on reaction time data. They are typically analyzed using ANOVA (ANalysis Of VAriance). An alternative strategy (in terms of statistical analysis) to deal with this variable is by its characterization: one option being an ex-Gaussian distribution fit. Luce (1986) has argued that the ex-Gaussian function provides a good fit to multiple empirical response time distributions. The ex-Gaussian function is the combination of two functions; a Gaussian (normal) and an exponential distribution. Several authors (Lemus-Zúñiga, Navarro-Pardo, Moret-Tatay & Pocinho, 2015; Moret-Tatay, Irigaray, Oliveira, & Argimon, 2015; Moret-Tatay et al., 2014; Moret-Tatay et al., in press; Navarro-Pardo, Navarro-Prados, Gamermann, & Moret-Tatay, 2013) have discussed the benefits of this approach in terms of statistical analysis. The ex-Gaussian distribution is characterized by three parameters, μ, σ and τ. The τ parameter is particularly interesting, as some have argued that it represents specific related cognitive processes such as attention. The study of Leth-Steensen, King Elbaz and Douglas (2000) is particularly relevant in this context. The research authors found differences in τ parameter between children with ADHD and controls. They proposed several interpretations for this parameter, from a defective effort control mechanism role to developmental delay or processing problems. However, Matzke and Wagenmakers (2009) argued that the relationship of the ex-Gaussian distribution parameters to specific cognitive processes was not straightforward after a study of simulation. Further research along these lines is necessary. Nevertheless, there is a clear advantage of the ex-Gaussian distribution fit in that it allows the inclusion of all data without employing trimming or cut-off techniques which could leave interesting data out from a study.

The aim of the current study is to examine the roles of emotional valence and age in word recognition, in terms of ex-Gaussian components. To achieve this, a word recognition task was carried out with older and younger participants. Stimuli were derived using a B-Pal, or Busca Palabras (Davis & Perea, 2005): a tool for deriving psycholinguistic properties of words. It is a Spanish language version of an earlier English language instrument (Davis, 2005). For our purposes, it provides information about emotional valence of words, among other aspects. We were interested in emotional valence, in terms of positive, negative and neutral. Reaction times were analyzed through the traditional analysis of variance and an alternative strategy: an ex-Gaussian distribution fit. It is expected that the ex-Gaussian modeling of the distribution of reaction time data will offer a superior description and will allow for more straightforward interpretation of the results.

Method

Participants

A sample of 33 university students took part in experiment 1 (28 women and 5 men, with an average age of 21.15 years and *SD* = 1.60); while a sample of 33 senior university students took part in experiment 2 (29 women and 4 men, with an average age of 65.39 years and *SD* = 5.20). All the participants had normal or corrected to normal vision, were native Spanish speakers and did not report cognitive or neurological disorders.

Materials

The stimuli employed were a selection of words from the Busca Palabras database (Davis & Perea, 2005). A total of 90 words were divided into three sets of 30 stimuli, based on their scores on emotional valence (positive, negative or neutral); see Table 1. Employing the same classification as Moret-Tatay et al. (2014), stimuli rated 4 or lower were considered negative, rated 4 to 6 to be neutral, and rated above 6 to be positive. From the 90 words selected, 45 words were designated as target (and appeared in the first and second block) and the other 45 as distractors (and appeared only in the second block).

Procedure

Participants were tested in a quiet room, in groups of three or four. The presentation of stimuli and recording of response times were controlled by a Windows operating system through the DMDX software (Forster & Forster, 2003). The experiment consisted of two phases. In the first phase, 45 target stimuli were randomly presented (divided into 15 stimuli for each of the three valence categories) with short exposures of 2 seconds each. In the second phase (15 minutes after the participants were distracted by performing Stroop tasks), 45 target stimuli plus the 45 distracting stimuli were randomly pre-

Table 1 *Average valence for the selected words in the different sets (standard deviation in parenthesis)*

		Neutral	Negative	Positive
Valence	Target	4.77 (0.20)	2.86 (0.62)	6.62 (0.53)
	Distracting	4.89 (0.40)	2.84 (0.78)	7.20 (0.62)

sented. Each word was presented until the participant gave a response or 2000 ms passed. The participants were instructed to press a button (labelled ”Yes”) if the stimulus was a target stimulus, and press another button (labelled ”No”) if the stimulus was a distractor stimulus. The participants were also instructed to respond as quickly as possible while maintaining a reasonable level of accuracy. The session lasted approximately 30 minutes.

Statistical Design and Data Analysis

Valence (neutral, negative and positive) was manipulated as within group variables. Two different analysis procedures were carried out: a classical ANOVA and a fitting of the data to an ex-Gaussian distribution function. The ex-Gaussian distribution fit was carried out by data sets, which were distributed in intervals in order to create a histogram. Differences between parameters from the ex-Gaussian distribution fit were analyzed regarding their uncertainties (errors) as confidence interval lengths for each parameter.

Results

The statistical analysis was performed using SPSS 20. Table 2 presents the average reaction times (ms), error rates and standard deviation for each group of words, and for each age group.

In the ANOVA for latency analyses, RTs less than 250 ms and over 1800 ms were excluded (less than 2% of the data set). The 1800 ms cut-off point was adopted for consistency with earlier studies in the field (Moret-Tatay & Perea, 2011; Perea, Moret-

Table 2 *Response time averages (ms), error rate and standard deviation (SD) for different experimental conditions*

Images	Neutral	Negative	Positive
Younger			
Target	847.13	822.99	841.07
SD	112.22	92.53	137.60
Errors	24%	26%	26%
Distracting	937.29	897.83	932.68
SD	116.81	129.84	152.16
Errors	26%	16%	14%
Older			
Target	923.65	923.24	888.78
SD	176.24	177.02	144.02
Errors	23%	32%	21%
Distracting	1029.72	1006.72	1022.23
SD	197.47	209.50	199.33
Errors	28%	26%	33%

Tatay, & Panadero, 2011; Perea, Panadero, Moret-Tatay, & Gómez, 2012). A mixed 2 X 2 X 3 ANOVA was conducted, with valence a repeated measure and both age group and target/distractor as independent subject factors. The ANOVA was also carried out on both older and younger participants' correct RTs.

The ANOVA of the global data set showed that dierences in emotional valence were close to but did not reach statistical significance, $F_{(2,128)} = 2.63$; $MSE = 6018.46$; $\eta^2 = 0.04$; $p = 0.08$. In the case of distracting and target conditions, target stimuli were processed faster ($M = 874.48$ ms) than distractors ($M = 971.08$ ms), and these differences reached statistical significance: $F_{(1,64)} = 41.30$; $MSE = 22364.27$; $\eta^2 = 0.39$; $p < 0.05$. It is concerning that the analyses of variance revealed significant differences in variability of response times between younger and older participants. Homogeneity of variance across populations is one of the assumptions of analysis of variance. Therefore, a violation of this assumption calls into question any conclusions drawn from this analysis. This is why ANOVA for both groups was conducted separately.

For younger university students, the ANOVA on the latency data showed that dierences in valence were statistically significant, $F_{(2,64)} = 4.43$; $MSE = 4316.57$; $\eta^2 = 0.12$; $p < 0.05$. The neutral stimuli ($M = 892.21$ ms) were processed slower than the positive ones ($M = 886.84$ ms) which, in turn were processed slower than the negatives ones ($M = 860.41$ ms). In the case of distracting and target conditions, differences also reached statistical significance: $F_{(1,32)} = 23.83$; $MSE = 15195.46$; $\eta^2 = 0.42$; $p < 0.05$. Target stimuli were processed faster ($M = 837.06$ ms) than distractors ($M = 922.60$ ms). Any interaction or error differences did not reach statistical significance ($F < 1$).

The ANOVA of the latency of the older participants' data, for valence, did not reach the significance level ($F < 1$). In the case of distracting and target conditions, these dierences reached statistical significance: $F_{(1,32)} = 19.42$; $MSE = 29533.88$; $\eta^2 = 0.38$; $p < 0.05$. Target stimuli were processed faster ($M = 911.89$ ms) than distractors ($M = 1019.56$ ms). Any interaction or error differences did not reach statistical significance ($F < 1$).

Secondly, we proceeded to characterize the reaction times using an ex-Gaussian distribution fit. The distribution is completely characterized by the three parameters μ, σ and τ. The parameters μ and σ are the average and standard deviation of the Gaussian component, while τ is the parameter that characterizes the exponential component. One should bear in mind that μ and σ are not the average and standard deviation of the ex-Gaussian distribution, which should be calculated via the three parameters that describe the distribution: $M = \mu + \tau$.

To fit the distribution is to find the optimal values for the parameters μ, τ and σ that best describe the experimental data. For this purpose, we used the fitting function of the open-source software Gnuplot. With this software, the fit of any mathematical function to any data set can be obtained straightforwardly by a single function call, but given the amount of data in the present work, the need to prepare the data (distribute it in intervals) and the fact that many different data sets had to be fitted, a python script was employed. This script automatically reads a set of data (reaction times), groups this data in intervals, creating a histogram and interacts with the Gnuplot software in order to fit an ex-Gaussian function to the data points. Both, distributions fits and graphics, were carried out by the command-line program GNU plot 4.2 (via the python script published in Navarro-Pardo et al., 2013). The Gnuplot software employs the Levenberg-Marquardt algorithm, also known as dumped least-square method (Marquardt, 1963), in order to find the optimal parameters that minimize the square of the difference between a given data set (x_i and y_i) and a target function which depends on some parameters. The algorithm is an interactive procedure that readjusts the set of parameters in each interaction. First of all one should define a goodness of fit function, in order to reflect the quality of the fit. The goodness of fit can be evaluated through the residual variance (the most widely used method in behavioral sciences, χ^2/degrees of freedom). Smaller values are preferable and show a better fit. Table 3 shows the different parameters obtained by the fitting procedure and Figures 1 and 2 show the graphical representation of the histograms together with their fit, for each condition.

If we focus on the uncertainties (errors – defined as a confidence interval length for each parameter) from Table 3, we can compare the parameters for the different condi-

Table 3 *μ, σ and τ parameters with their uncertainty in parenthesis (error), dof (degrees of freedom) and the goodness of fit by χ^2/dof for younger and older university students*

Task/Parameters	μ	σ	τ	dof	χ^2/dof
Younger					
Target					
Neutral	622.86 ± 12.34	96.17 ± 9.84	211.09 ± 17.46	26	0.63
Negative	615.48 ± 14.81	86.55 ± 12.02	194.42 ± 20.74	21	1.01
Positive	593.41 ± 9.05	77.80 ± 7.72	232.38 ± 14.89	23	0.45
Distracting					
Neutral	663.06 ± 23.53	109.42 ± 17.56	289.18 ± 41.94	27	1.37
Negative	681.14 ± 13.57	98.07 ± 11.17	210.38 ± 19.39	28	0.89
Positive	691.57 ± 18.63	98.79 ± 15.96	222.12 ± 27.36	25	1.59
Older					
Target					
Neutral	650.90 ± 18.12	126.63 ± 13.85	265.63 ± 27.79	25	0.75
Negative	688.87 ± 39.34	175.28 ± 28.15	184.63 ± 47.39	27	1.44
Positive	607.34 ± 15.66	91.34 ± 13.79	282.97 ± 27.92	27	1.04
Distracting					
Neutral	722.78 ± 25.91	131.42 ± 23.26	345.89 ± 45.22	27	1.16
Negative	798.02 ± 39.27	147.29 ± 26.78	144.35 ± 45.89	27	1.90
Positive	818.08 ± 51.88	189.21 ± 34.32	164.01 ± 62.59	26	1.60

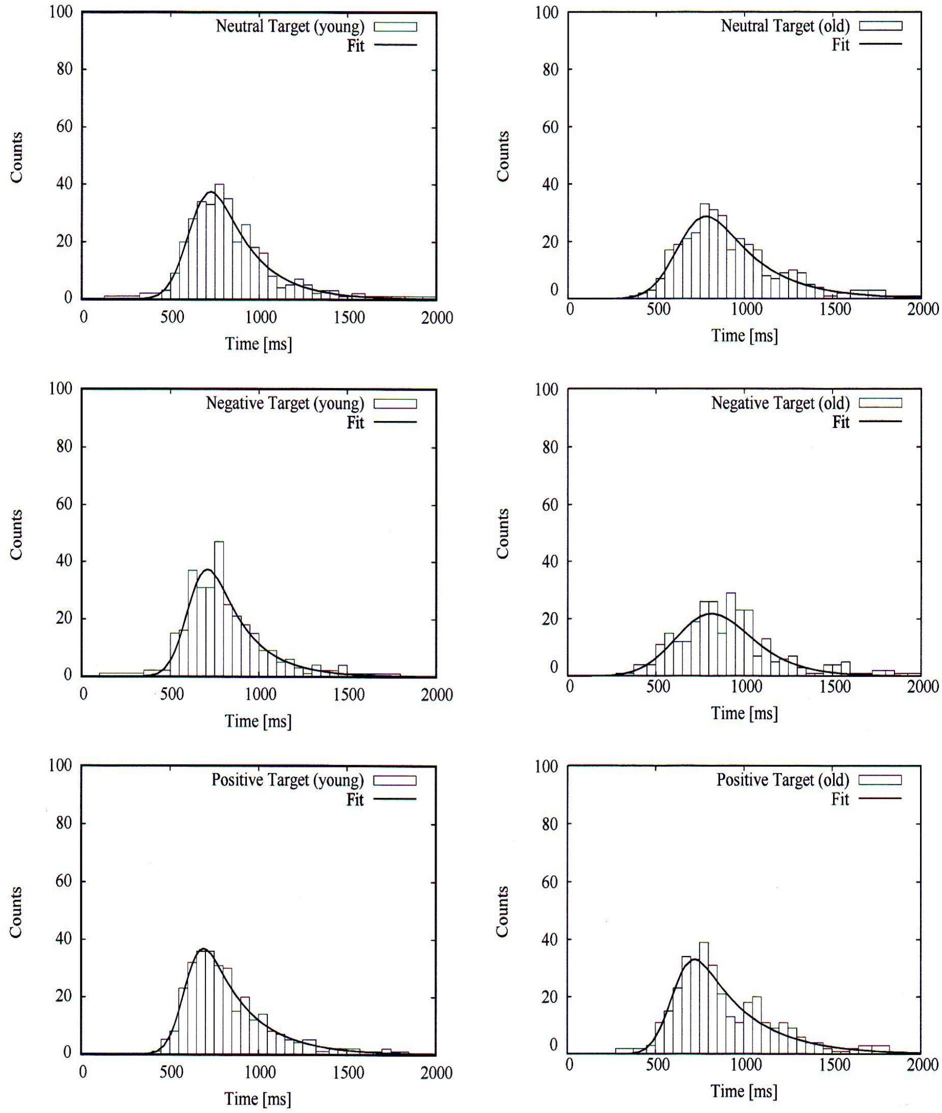

Figure 1. Emotional word recognition graphics for younger and older university students in the target condition

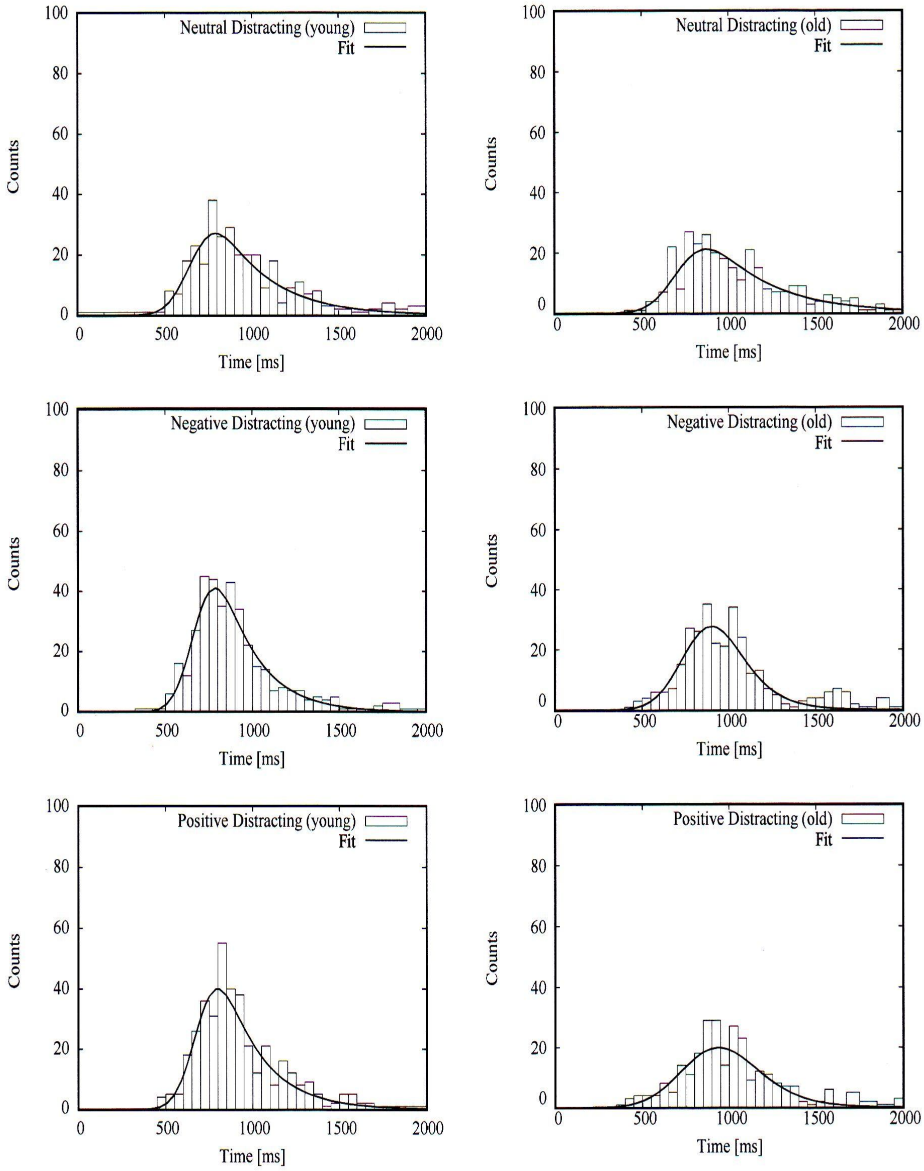

Figure 2. Emotional word recognition graphics for younger and older university students in the distracting condition

tions. If we compare the τ parameter differences in conditions by age, we find differences in positive targets between younger and older participants. Here, the differences between older and younger participants in this condition (50.59) were higher than the uncertainties sum (42.81). Furthermore, it is also possible to find differences in the neutral target condition between younger and older participants for τ parameter. In this case, the differences between older and younger participants in this condition (54.54) were also higher than the uncertainties sum (45.25).

Moving on to the differences between levels of emotional valence, the τ parameter seems not to have special properties for the younger group, except between the negative and neutral distracting conditions (78.8), which was higher than the uncertainties sum (61.33). Older participants showed a difference between the negative and neutral target conditions (81), which also was higher than the uncertainties sum (75.18). Nevertheless, the role of valence was clear for the distracting words in this group: the difference between negative and neutral condition was 201.54, and its uncertainties sum was 91.11, while the difference between positive and neutral conditions was 181.81 and its uncertainties sum was 107.81.

Discussion

The aim of the current study is to examine the roles of emotional valence and age in word recognition, in terms of ex-Gaussian components. To achieve that, a recognition task, employing a short retention interval, was carried out. This recognition task was analyzed not only by the classical analysis of variance, but also through the characterization of the reaction times via an ex-Gaussian distribution fit, which allows the analysis of the conditions in terms of parameters. The logic of this analysis is to reexamine the existing hypotheses cited in the literature in terms of ex-Gaussian parameters, and in particular, the τ parameter often related to attention.

Younger participants showed shorter RTs to negative words for target and distracting condition. Older participant RTs were shorter for neutral and negative target condition and positive distracting condition. However, the results only reached the statistical significance level for younger participant RTs. Thus, the emotional effect was clear for younger students but it was not for the older participants. During the traditional analysis some data was trimmed to minimize the effect of outliers. This is a popular technique in Cognitive Psychology. However, it is not clear where it is better to set the limit between what is noise and what is signal. An alternative could be an ex-Gaussian fit, where all data set is employed. In particular, the differences in this second analysis seemed clearer for the emotional words than in case of the traditional one.

In terms of parameters, age-related differences in emotional valence seem not to have special properties for negative words. Focusing on emotional valence for each group, the younger participants only showed an effect for the negative condition in the distracting words. This pattern was clear for the older participants. They showed an effect for negative target words, plus positive and negative distracting words.

Finally, if we interpret the τ parameter as an indicator of attentional demands, these results seem to reinforce the idea that emotional stimuli have a remarkable effect on attention, and thereby, on other processes, such as memory.

Conclusions

Several studies claim that emotional words might capture more attention than neutral ones (Algom, Chajut, & Lev, 2004; Huang, Baddeley, & Younger, 2008; Phelps et al., 1997). The RTs for distracting negative words were similar to the neutral ones in the case of the older participants. These results are consistent with Mather and Carstensen (2003), reinforcing the idea of age differences in the processing of negative and positive information (Carstensen et al., 2000). Another possible explanation (Gross et al., 1997) could be related to how people learn to regulate their negative emotions, which might be more effective for older than younger adults. Comparing word recognition to image recognition, some research (León et al., 2010; Moret-Tatay et al., 2014) found slower latencies towards negative stimuli valence employing the IAPS battery.

However, addressing the question of the ex-Gaussian components, the negative words seem not to have special properties for age. This suggests that there are no age differences for this valence. Focusing on emotional valence globally (negative and positive words), the pattern is clearer for the older than the younger group. It suggests that the role of valence has a higher effect for the older adults.

This work also presents potential limitations. There are remarkably high error rates, which indicates that the task might be difficult for participants. For future research it would be interesting to develop easier series of experiments that might also examine the role of arousal in terms of parameters, and possible interactions with valence. Future studies may include a series of experiments that would examine the role of τ parameter in the context of negative images, which would try to explain if such stimuli attract attention more readily or just hold attention for a longer period of time.

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VPLYV VEKU A EMOČNEJ VALENCIE NA ZNOVUPOZNÁVANIE SLOV: EX-GAUSSOVA ANALÝZA

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Súhrn: Cieľom práce je posúdiť vplyv veku a emočnej valencie na znovupoznávanie slov v rámci ex-Gaussových distribučných komponentov. Dvom vekovým skupinám sme administrovali test znovupoznávania slov, v ktorom sme manipulovali emočnou valenciou. U mladších respondentov sa prejavili štatisticky signifikantné rozdiely pri negatívnych slovách v experimentálnej podmienke a v podmienke s distrakciou. U starších respondentov sme v odpoveďových časoch nezistili jasnú tendenciu. Vzhľadom na ex-Gaussovský parameter τ, ktorý sa v literatúre často spája s nárokmi na pozornosť, vekovo podmienené rozdiely v emočnej valencii nemali žiaden vplyv na negatívne slová. Ak sa zameriame na emočnú valenciu v oboch skupinách, u mladších respondentov sa prejavil vplyv v negatívnych distrakčných slovách. U starších respondentov sa prejavil vplyv v negatívnych a pozitívnych cieľových slovách a negatívnych distrakčných slovách. Z toho vyplýva, že nároky na pozornosť sú vyššie pre emočne nabité slová, najmä u starších respondentov.