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Effects of Presentation Side and Emotional Valence on Auditory Recognition in Younger and Older Adults

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Abstract: (1) Background: It is well-established that older persons compared with younger persons show a bias toward positive valence (a positivity effect), together with less pronounced hemispheric asymmetries, but these topics have been scarcely explored in auditory modality. (2) Methods: We presented auditory stimuli with positive, neutral, or negative emotional valence dichotically to 20 younger and 20 older participants and asked them to memorize the stimuli. In a following session, stimuli were presented binaurally, and participants had to decide whether they were new or already presented in the left/right ear. (3) Results: A higher performance by younger compared with older listeners emerged, but neither the expected Right Ear Advantage nor the positivity effect was confirmed. New stimuli were correctly categorized more frequently if they had neutral valence, whereas stimuli already presented were better recognized with negative rather than neutral or positive valence, without any age difference. (4) Conclusions: These results reveal no hemispheric asymmetries and no age difference in a memory task for auditory stimuli and suggest the existence of a bias to better encode negative content, possibly due to the crucial role of negative stimuli in everyday life.

Keywords: hemispheric asymmetries; right ear advantage (REA); age; auditory recognition; positivity effect

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1. Introduction

The left-hemispheric superiority for language is the first and strongest hemispheric asymmetry described in the field of neuropsychology [1–3], and it is attributed to both anatomical and functional cerebral asymmetries [4]. The most exploited behavioral paradigm used to test asymmetries in the auditory modality is the Dichotic Listening paradigm (DL; see [5,6]), namely the simultaneous presentation of two different inputs in two ears [7], by means of which the so-called Right Ear Advantage (REA; [8]) has been widely confirmed. In fact, when participants are asked to report which of the two stimuli presented via headphones is heard better, they are more likely to report the stimuli presented to the right ear [9–12]. This bias has also been confirmed by neuroimaging studies [13,14] and even in the absence of perceptual stimuli: when asked to imagine hearing auditory content in one ear, participants reported imagining it mostly in the right ear [15–17]. The bias is explained by the left-hemispheric superiority for language, in turn due to the aforementioned anatomical and functional specialization of the left—over the right—temporal cortex for linguistic processing. Indeed, a modulation of the REA has been shown during bilateral, but not unilateral, temporal cortex stimulation [9], showing the importance of the hyper- vs. hypo-activity of the left vs. right side of the brain. The link between an REA and functional asymmetries is evident also in clinical conditions: an atypical REA is present in dyslexia [18], in depression [19], and in auditory hallucinations [20–23], so the REA is considered a marker of typical cerebral asymmetry [6,24]. Moreover, recent studies also described an alteration of the left/right asymmetries in anxiety, in depression, and in mixed (anxiety and depression) conditions, with both pure tones and musical pieces [25,26]. It is important to notice that, while the REA is considered a stable marker of language asymmetrical processing in the brain, no clear-cut evidence has emerged for non-verbal stimuli. According to the models proposed, in fact, the left-hemispheric superiority for language is at the basis of the REA, but hemispheric asymmetries for non-linguistic stimuli are more controversial, with some evidence suggesting a right-hemispheric superiority for sound processing (corresponding to a Left Ear Advantage at a behavioral level; see [6,27,28]) as well as for voice gender categorization [29,30]. Meanwhile, some studies fail to show clear asymmetry (e.g., [31]), with others confirming a REA also for complex tones (e.g., [32]).

Despite having been widely described in healthy and clinical populations, these asymmetries have been less explored in the aging population. This scarcity of evidence is surprising considering that hemispheric asymmetries in the elderly receive attention, with most studies revealing a reduction in asymmetry with increasing age [33,34]. According to the HAROLD (Hemispheric Asymmetry Reduction in OLDer adults) model [35], strong bilateral hemispheric activity in the elderly should be due to an increasing difficulty in recruiting lateralized mechanisms, and it could be considered a kind of compensatory mechanism of the aging brain. Nevertheless, the REA is so resistant a bias that it has also been confirmed in aging, showing more resilience with respect to other lateralized cognitive and perceptual biases [36,37] or even revealing an unexpected stronger behavioral asymmetry in older rather than in younger persons [38]. However, with non-speech stimuli, a Left Ear Advantage was described in young listeners [39], but a different study using pure tones confirmed the REA in younger but not in older adults [40].

Another important issue involving the lateralized human brain concerns the emotional valence of the stimuli: according to the Right Hemisphere Hypothesis (RHH; [41–44]), the right hemisphere would be superior to the left hemisphere in processing all emotional stimuli; however, the Valence Hypothesis (VH; [45–47]) posits that the left/right hemispheres are specialized in processing positive/negative emotional valence, respectively. The dispute between these two pivotal theories is still open, with data supporting either the first [48,49] or the second model [15,50,51], or even both [52–56]. Again, the argument surrounding the effects of aging on the laterality for emotional valence is controversial, and different studies suggest the absence of changes across one’s life span for the processing of facial emotions [57,58], as well as in the accuracy and laterality in recognizing positive emotions [59]. Nevertheless, a decline with age in recognizing negative and neutral (but not positive) expressions supports the so-called “positivity effect” [60]. Such an age-related bias consists of less accurate performance in recalling negative compared to positive events in the elderly [61]. According to the “socioemotional selectivity theory”, this would be due to the fact that when the temporal horizon of an individual is limited, they would be strongly oriented toward positive experiences, trying to avoid negative emotions [62]. Furthermore, this would happen the more that life expectancy was perceived as limited [63–65]. Indeed, the positivity effect would result in a lower impact of negative information, especially on attention and memory processes, in older rather than in younger adults [66,67]. However, not all results confirm this effect: it has been found, for instance, that older adults who listened to stories read with a neutral prosody remembered more words than those who listened to the same stories with either positive or negative prosody [68].

Starting from this unresolved framework concerning perception, memory, emotional valence, and hemispheric asymmetries across ages, we exploited the consolidated paradigm of dichotic listening in a memory task for emotional auditory stimuli, comparing younger and older listeners. Specifically, we hypothesized that (i) younger participants would show overall higher recognition accuracy compared with older listeners (i.e., a classical age effect on memory) and that (ii) older listeners would perform better in recognizing stimuli with positive compared to negative valence (i.e., the positivity effect). Furthermore, due to contrasting evidence collected mainly in the visual modality, and due to the scarcity of evidence in the auditory domain, we wanted to shed light on the possible changes in hemispheric asymmetries for auditory stimuli across ages: in this view, this study should be considered as exploratory in the memory auditory domain, since, to our knowledge, no previous studies have investigated laterality biases for emotional auditory stimuli. As a tentative hypothesis, we expected to find (iii) a reduced laterality bias in the elderly (e.g., a reduced REA), as suggested by the HAROLD model [35], and thus no difference in the recognition of stimuli presented in the left vs. right ears in older adults—different from the younger group in which a better performance for stimuli presented in the right rather than in the left ear is expected (REA).

2. Materials and Methods

2.1. Participants

A sample of 40 healthy participants took part in the study as volunteers, including 20 participants between 23 and 35 years of age (younger adults: YA, mean age $\pm$ standard error: 29.4 $\pm$ 0.65 years) and 20 participants between 60 and 82 years of age (older adults: OA, 66.4 $\pm$ 1.48 years). All participants but one (in the YA group) were right handers, as assessed by means of the Edinburgh Handedness Inventory [69], in which a score of -100 corresponds to a completely left preference and a score of +100 corresponds to a completely right preference (YA: 63.2 $\pm$ 6.36; OA: 60.77 $\pm$ 6.23). All participants declared having a normal hearing threshold and be free from psychiatric and neurological disorders. Additionally, they provided signed consent to take part in the study.

2.2. Stimuli

Stimuli were selected from the International Affective Digitized Sounds (IADS; [70]), a database of auditory recordings categorized according to pleasure (valence), rated on a 9-point Self-Assessment Manikin scale (SAM), ranging from a smiling, happy figure to a frowning, unhappy figure. A total set of 72 stimuli were selected, excluding those with linguistic content: 24 stimuli with positive valence (M $\pm$ SD of pleasure rating: 7.04 $\pm$ 1.7), 24 stimuli with neutral valence (pleasure rating: 4.66 $\pm$ 1.71), and 24 stimuli with negative valence (pleasure rating: 2.43 $\pm$ 1.6). A white noise stream (WN) was also created by using GoldWave v5.25 software (GoldWave Inc., St. John's, Newfoundland, Canada). All stimuli were modified by inserting a linear fade in, lasting 50 ms, and a linear fade out, lasting 70 ms. They were presented at 60 dB and lasted 6 s.

2.3. Procedure

Participants were tested in isolation in a silent room. They were asked to sit in front of the computer screen, to wear headphones, and to gaze at a fixation cross presented in the center of the screen for the whole duration of the task. They were informed that the task was composed of two sessions: the first was a passive session, and the second was an active session. In the first session, 12 stimuli for each emotional valence were randomly presented, half in the left ear and half in the right ear, during the simultaneous presentation of WN in the contralateral ear (6 positive—left ear, 6 positive—right ear, 6 neutral—left ear, 6 neutral—right ear, 6 negative—left ear, 6 negative—right ear), for a total of 36 trials. In each trial, after 1 s, in which only the cross was present, an auditory stimulus was delivered (duration: 6 s) and the participant was asked to focus on each audio trace, trying to ignore WN presented in the contralateral ear. In the second session, 72 stimuli were presented binaurally and without WN (i.e., audio trace presented in both ears simultaneously), including 24 stimuli for each valence. In each trial of this session, a central fixation cross was presented for the whole duration, and each auditory stimulus lasted 6 s. Participants were instructed to categorize each stimulus as either "New" (not presented in the first passive session), "Old-Left" (already presented in the left ear during the first session), or "Old-Right" (already presented in the right ear during the first session).

Namely, participants were asked to respond by using the right hand, pressing the key "k" if the stimulus had not been previously presented (i.e., new), and to press the keys "j" or "l" (left or right key with respect to "k") if the stimulus had already been presented in the left or right ear, respectively. After the response was recorded, a 1 s inter-stimulus interval preceded the following trial.

The task was controlled by means of E-Prime software (Psychology Software Tools, Inc., Pittsburgh, PA, USA). The order of the stimuli was completely randomized within and among participants in both sessions. Before the beginning of the task, four trials were presented to allow participants to familiarize themselves with the paradigm. After the end of the task, participants were invited to complete the Edinburg Handedness Inventory, and then they were debriefed. The whole procedure lasted about 20 min, was carried out in accordance with the principles of the Declaration of Helsinki, and approved by the Institutional Review Board of Psychology of the Department of Psychological, Health and Territorial Sciences—University "G. d'Annunzio" of Chieti-Pescara (protocol number: IRBP/22005).

3. Results

A first analysis of variance (ANOVA) was carried out by using Group (YA, OA) as the between-subjects factor; Trial (Old, New) and Valence (Negative, Neutral, Positive) were used as the within-subjects factor. The proportion of correct responses (accuracy) was used as the dependent variable (see Figure 1), and, when needed, post hoc comparisons were carried out by using the Duncan test (as in previous dichotic listening paradigms; see [30,71]).

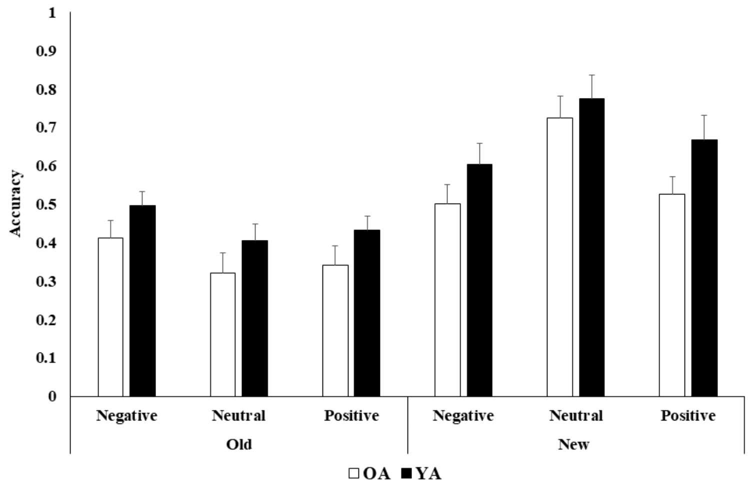

Figure 1. Interaction among Group (OA, YA), Valence (Negative, Neutral, Positive), and Trial (Old, New) on the proportion of accuracy. Bars represent standard errors.

The ANOVA revealed a significant main effect of Trial (F(1,38) = 28.62, $p < 0.001$, $\eta p2 = 0.43$), with a better performance for new (0.63 ± 0.04) compared with old (0.41 ± 0.03) stimuli. Additionally, the main effect Group reached significance (F(1,38) = 4.11, $p = 0.049$, $\eta p2 = 0.10$), with YA (0.56 ± 0.04) outperforming OA (0.47 ± 0.03). The main effect of Valence was significant (F(2,76) = 5.82, $p = 0.004$, $\eta p2 = 0.13$) and post hoc comparisons showed a better performance for neutral (0.56 ± 0.04) compared with both positive (0.49 ± 0.04, $p = 0.002$) and negative (0.50 ± 0.03, $p = 0.010$) stimuli.

The interaction between Trial and Valence was significant (F(2,76) = 22.91, $p < 0.001$, $\eta p2 = 0.38$; see Figure 2). Post hoc comparisons confirmed that, for each valence, the performance was better for new compared with old stimuli (negative: $p = 0.002$; neutral and positive: $p < 0.001$), and that, for new trials, stimuli with neutral valence were recognized with a higher accuracy than those with positive and negative valence ($p < 0.001$ for both comparisons). Concerning old trials, however, performance was better for negative valence stimuli than for both neutral (p = 0.005) and positive valence stimuli (p = 0.032).

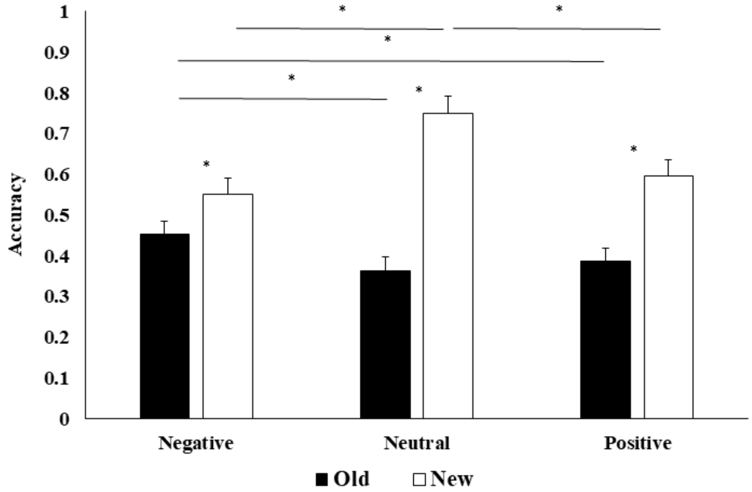

Figure 2. Significant interaction between Trial (Old, New) and Valence (Negative, Neutral, Positive) on the accuracy of the whole sample. Bars represent standard errors, and asterisks show significant comparisons ($p < 0.05$).

To test the effect of laterality, a second ANOVA was carried out only on the stimuli already presented in the encoding phase ("new" trials were excluded), using Group (YA, OA) as the between-subjects factor, and Valence (Negative, Neutral, Positive) and Ear (Left, Right) as the within-subjects factor. The proportion of correct responses (accuracy) was used as the dependent variable (see Figure 3).

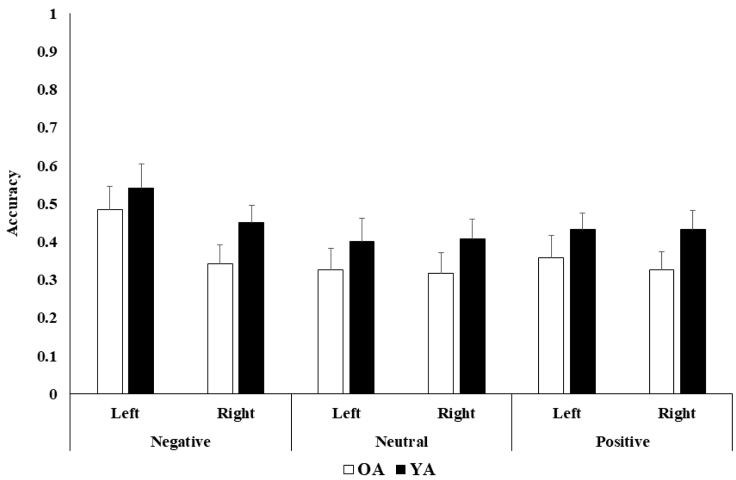

Figure 3. Proportion of accuracy in the interaction among Group (OA, YA), Valence (Negative, Neutral, Positive), and Side (Left, Right). Bars represent standard errors.

Only the main effect Valence was significant ($F(2,76) = 4.36$, p = 0.016, $\eta p2 = 0.10$), and post hoc comparisons showed better performance for more negative (0.45 $\pm$ 0.03) than neutral (0.36 $\pm$ 0.03, p = 0.008) and positive stimuli (0.39 $\pm$ 0.03, p = 0.041), confirming the results of the previous ANOVA. Importantly, Ear was not significant as a main effect, nor did it interact with the other factors.

4. Discussion

In this study, we aim at disentangling the complex relationship between emotional valence, memory, functional asymmetries, and aging. Starting from previous evidence, we hypothesize the following: (i) higher recognition accuracy in the younger listeners than in the older listeners, (ii) a positivity effect in the older participants, and (iii) a possible reduction in left–right asymmetry in the older participants compared with the younger participants, as suggested by the HAROLD model [35], with better recognition for stimuli presented in the right ear only in the younger group (Right Ear Advantage).

The results confirmed the first hypothesis, showing better performance by the younger participants compared with the older participants. It must be noted in this regard that the overall performance of both groups is relatively low (the accuracy level is 56% for younger and 47% for older participants). This evidence suggests that the task was complex for the whole sample but also shows a significant difference between the two age groups, revealing that, with increasing age, the cognitive effort required to correctly categorize old/new auditory stimuli becomes higher, leading to lower overall performance. Moreover, the same analysis also showed that, overall, participants' performances were better at correctly categorizing stimuli as not previously presented (i.e., new) than at correctly recognizing stimuli as already presented (i.e., old). This result highlights the different complexities of the two cognitive procedures, with correct recognition of the previously presented stimuli requiring a mnemonic processing, which could be more challenging than the "absence" of recognition needed to correctly categorize new stimuli, which are not familiar nor memorized—for an in-depth discussion, see [72]. Importantly, age did not affect each of the two tasks in a different way, the interaction between Group and Trial not being significant, revealing a similar effect of aging on the recognition of both kinds of stimuli (i.e., already presented and not previously presented).

Surprisingly, age did not affect the recognition of stimuli with different emotional valence, thus preventing us from confirming the expected positivity effect (second hypothesis of the present study). In fact, emotional valence was significant as the main effect, but post hoc comparisons showed that neutral stimuli were better recognized than stimuli with both positive and negative emotional content. Even if this result does not confirm the expected positivity effect [60,64,73], it confirmed the previous results exactly, showing better performance in remembering words pronounced with neutral rather than with emotional prosody [68]. Importantly, the significant interaction between old/new stimuli and valence revealed that this pattern held true only for stimuli not previously presented (new). Indeed, when participants had to categorize stimuli already presented (old), they better recognized them when they contained negative rather than neutral and positive valence.

The second analysis aimed at shedding light on the effect of functional laterality on memory and valence. The third hypothesis of the present study (a reduced REA in elderly participants in a memory task) was exploratory, due to the scarcity of evidence in this domain: on the one hand, the HAROLD model suggests a reduction in hemispheric asymmetries with aging [35]; on the other hand, a stronger REA has been described in aging [38]. Importantly, since non-verbal stimuli are used here, a Left Ear Advantage could also be found, as evidence concerning laterality biases for non-linguistic stimuli remains unclear (see [6,27–32]). Surprisingly, however, no asymmetry emerged, and the side of presentation affects the results neither in the younger nor in the older group. We must underline that, in the present study, the task was divided into two sessions and the aforementioned models of functional asymmetries were proposed for perceptual tasks. We hypothesize that when a memory recognition task is required, the possible hemispheric asymmetries found in the perceptual domain are not crucial, which let us to speculate that memory processes are so complex (and relatively slow) that possible cerebral specialization is not crucial in the performance of the participants, regardless of age. Moreover, it must be stressed that the REA effect has been ascribed to a left-hemispheric superiority for language and that, in the present paradigm, we decided to exclude linguistic stimuli. The possible hemispheric asymmetry for non-linguistic stimuli is controversial: an REA has been recently described in younger adults but not in older adults by presenting pure tones [40]; however, a Left Ear Advantage was also described when stimuli are not linguistic [39], and this point can be one of the reasons for the absence of asymmetries found here.

To conclude, the present study does not confirm neither the positivity effect in older adults nor the expected laterality bias for auditory stimuli in a memory recognition task. It shows, instead, that emotional valence is a crucial feature modulating recognition performance for auditory stimuli. The main finding of the present study is the different pattern of results that emerged for stimuli not presented in the dichotic procedure (i.e., new stimuli) and for stimuli already presented in the dichotic session (i.e., old stimuli). When stimuli were new, in fact, the performance was better when emotional valence was not present: neutral stimuli were better recognized as new compared with both negative and positive ones. This evidence paradoxically highlights the importance of valence in this task: recognizing a stimulus as new is more difficult when it must be processed for two different characteristics, its content and its valence. This means that when only one feature (content) is enough to categorize it as "new", without the need for an emotional recognition, the task is easier and thus is carried out better. When the stimulus is presented with negative or positive valence, besides its content, its valence must be processed, too, to correctly state that it has been not previously presented; however, in this case, two features must be encoded, making the task more difficult. So, we can conclude that a double encoding (two features) is more challenging from a cognitive point of view than the encoding of only one feature (content), leading to lower performance. Nevertheless, the fact that no age difference emerges in this regard suggests that increasing age does not impact the dual encoding required here. A similar result has been described in a study examining how emotional prosody affects verbal memory at different ages [68]: in that study, younger and older participants were presented with linguistic stimuli containing neutral emotional valence but pronounced with either neutral, positive, or negative prosody. Then, in a second session, participants were asked to recognize target words. Similar to the present results, the study showed higher performance by younger participants compared with older participants and overall better performance for words presented with a neutral prosody compared with those presented with both positive and negative prosody. Moreover, the interaction between the two effects revealed that this latter result was significant only for the older group (no difference emerged for younger participants according to valence). It must be considered that in the study by Fairfield and colleagues [68], linguistic stimuli were used, whereas in the present study, we specifically avoided including linguistic stimuli and selected non-linguistic audio tracks. This choice allowed us to exclude the possible differences between age groups according to linguistic memory processes (which could change across ages; see [74]). As a result, we did not find differences between the younger and older participants, confirming that the age differences previously described could be ascribed to language-specific mechanisms instead of overall memory differences at different ages.

Nevertheless, it can appear surprising that the results for "old" stimuli are quite different from those just described for "new" stimuli, with better performance when stimuli are negative than both neutral and positive, again regardless of age. This "negativity bias" is specific only for stimuli already presented, which must be recognized as such. We can figure out that, in this case, the emotional valence of the stimulus is a further feature that helps participants to correctly categorize the stimulus. Compared to results by Fairfield et al. [74], this evidence is in line with the results they found only in older participants, whereas, in the present study, no age differences emerged in this respect. We speculate that, similar to the previous result, in this case, the main difference between our results and those previously described is the specific stimuli used: the linguistic stimuli required semantic processing, in addition to low-level and emotional processing, and this can lead to differences across age groups. However, non-linguistic stimuli extracted from the IADS used in the present study (e.g., sound of an alarm, sound of a bell, sound of a winning slot machine) allowed us to delete linguistic difference, leading us to highlight that recognition ability for this category of auditory stimuli does not change across ages. We speculate that better performance for auditory stimuli with a negative valence can be explained in the frame of evolutionary theories suggesting a predisposition toward negative emotional content, playing a key role in enhancing the survival expectations of the species [75]. In this view, not only the rapid detection but, critically, the learning and memory of negative and potentially aversive stimuli might have conferred an evolutionary advantage to individuals living under threatening environmental conditions [76], possibly through a cognitive mechanism of facilitation in the encoding of sensory details [77,78]. However, neither participants' age nor the presentation side of the stimuli affected their ability to recognize auditory inputs, suggesting that this ability is independent of both age and hemispheric asymmetries and revealing that emotional valence is the key feature that can impact participants' performance. Future research should further explore this domain by exploiting electrophysiological measures to investigate the neural basis of complex interactions between aging, memory, and emotional valence in the auditory domain. Furthermore, standardized audiometric measures should also be collected for all participants to ensure that the auditory threshold is not different between the two ears. The lack of asymmetries found in the present study suggest that the self-assessment of a lack of auditory (and psychiatric/neurological) impairments was enough as an inclusion criterion; however, a limitation of the present study is that we cannot exclude that more sensitive measures could have revealed a different condition. Future studies in this domain should exclude this possibility by objectively assessing hearing thresholds before the auditory tasks. This is even more important when older adults are compared with younger participants. In this regard, the absence of cognitive and neuropsychological assessments of the sample is a further limitation of the present study because it is well-known that aging can lead to an overall cognitive decline, which could have impaired the comparison between age groups [79].

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data will be available on request.

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Conflicts of Interest: The authors declare no conflicts of interest.

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