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Research Article

Music Valence Can Affect Dichotic Listening Performance

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Highlights

- Music valence possibly affects emotional dichotic processing
- There is a lateralized interhemispheric effect on the acceptable noise level in music

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ABSTRACT

Background and Aim: Music can regulate the activity of brain structures that play a significant role in emotions. The perceived emotion techniques such as dichotic listening clarify the relationships between auditory emotional stimuli and hemispheric asymmetries in the auditory modality. We examined the impact of pleasantness/unpleasantness of music by Acceptable Noise Level (ANL) as a subjective measure of listeners' willingness to accept background noise.

Methods: In this study, 32 participants rated their pleasantness with about ten songs; then, we considered the effect of preferred pleasant and unpleasant music on dichotic music listening and acceptable background noise. There were six forced attention conditions to calculate ANL, followed by measuring the most comfortable level and background noise level for each condition.

Results: The pairwise comparison analyses revealed significantly higher ANL in forced attention to pleasant music than to speech ($p<0.004$) and unpleasant music to the left ear ($p\leq 0.05$). The mean ANLs difference in 2 groups of right ear advantage and left ear advantage showed significant intra-hemispheric differences in the forced pleasant music attention than the forced unpleasant music attention conditions ($p<0.007$), and forced speech conditions ($p=0.001$), only in the left ear advantage group. In addition, the interaction between conditions and groups showed interhemispheric asymmetry.

Conclusion: Music valence and intra- and interhemispheric differences can affect the ANL dichotic processing and, consequently, lower noise tolerance (higher ANL) in forced pleasant music attention conditions.

Keywords: Acceptable noise level; dichotic listening test; music valence; functional laterality

Introduction

Listening to music as a language of emotions covers a range of phenomena that might change over time in terms of arousal (stands for low to high activation) and valence (i.e., being unpleasant to pleasant) [1]. Various structures such as the primary auditory cortex (processing the basic musical features like pitch and loudness), the secondary auditory cortex includes superior temporal gyrus and planum polar (focus on harmonic, melodic, and rhythmic patterns) [2], and the tertiary auditory cortex (integrating these patterns into an overall perception of music) [3], in addition to emotion evoked regions, such as the amygdala, the hippocampal formation, right ventral striatum (including the nucleus accumbens) extending into the ventral pallidum, caudate nucleus, insula, the cingulate cortex, and the orbitofrontal cortex are activated with listening to music [4]. Research directions to clarify the relationships between emotions and hemispheric asymmetries studied the right and left hemispheres (usually known as the valence hypothesis) to comprehend and express the emotions [5]. Mounting evidence from clinical and experimental investigations illustrated stronger associations of the negative affect with the right amygdala activation [6], in addition to the right hemisphere that might specialize in the emotion processing [7] via the right faster subcortical routes. Although, there is a risk to claim certain areas as music-specific or emotion-specific [8].

To assess hemispheric asymmetry in the auditory modality for musical processing, we used the Dichotic Listening (DL) task [5, 9, 10]. DL means that two (di-) different auditory (-otic) stimuli are simultaneously presented to each ear. It is speculated that the DL method is associated with several other neurocognitive functions besides the classic laterality function and that these other functions are related to arousal, vigilance, attention, memory processing, and higher cognitive processes. Based on experimental findings, DL is controlled by both bottom-up (stimulus-driven or automatic) and top-down (instruction-driven or controlled) processing [8]. The Acceptable Noise Level (ANL) as a subjective DL measure of listeners' willingness to accept background noise was developed by Nabelek et al. [11]. In contrast to the other Speech-to-Noise Ratio (SNR) quantified metrics, the listener can manipulate the target level and control background noise [12]. Despite inherent psychological factors and the impact of higher auditory centers [13], some other variables, such as age [14], gender [15], music tempo (fast/slow) [16], preferences [17], and familiarity [18] have illustrated no effect on ANL.

Little research examined semantic sound sources as target sound and the music as the background noise for the ANL measurement in listeners with normal hearing [12, 16-18], and no studies considered music valence on ANL as target and noise signal in a dichotic listening paradigm. Thus, the present study aimed to determine whether music valence preferences would affect dichotic music listening via the ANL measure. For the second purpose, this study was intended to investigate ANL interaction with hemispheric asymmetry. Accordingly, it was allowed to analyze the effect of music valence on Right Ear Advantage (REA) and Left Ear Advantage (LEA).

Methods

Participants

A total of 32 (15 (47%) males and 17 (53%) females) native Persian subjects with a mean(SD) age of 30.88(5.74) years (range, 20-40 years) participated in this study. All the participants volunteered for the study and gave informed consent before inclusion. They had no history of neurological disorders and professional music experience. To be included in this study, all subjects had normal otoscopic, immittance, speech and pure tone audiometric findings. The Edinburgh Handedness Inventory was utilized for handedness dominance in everyday activities [19], and the Persian Randomized Dichotic Digit Test (RDDT) [20, 21] was used to assess the hemispheric laterality in auditory and verbal processing.

Acceptable noise level stimuli

At first, ten songs were selected out of the 25 most popular Persian songs with the highest number of downloads (based on Keihan Newspaper, Tehran, Iran). All songs were played for ten people and asked to subjectively rate the pleasantness of each song on a visual scale from 1 (low) to 10 (high) to index feelings of pleasure. Ratings were addressed on subjective feelings according to the singer's voice and rhythm. Based on these ratings, ten songs were finally selected from the five songs with the highest numerical score (most preferred) and the five with the lowest numerical score (least preferred).

Second, all participants were asked to listen to the ten selected songs and rate them on a visual scale from 1 (the least preferred) to 10 (the most preferred). The rating scores were stored separately for each song in the form of personal information (Table 1 for average ratings of each song).

In the third phase, song pairs (the most pleasant and unpleasant songs) were stored as audio files in the "WAV" format for each subject. After digitization, each pair was edited for onset synchronization with the help of Adobe Audition software (Adobe Co, 2017, USA).

The procedure for acceptable noise level testing

The ANL tests were evaluated in the following methods: first, in the typical monotic ANL test, a female speaker was running a story with a constant intonation and intensity (as the target signal) along with a 12-talkers babble noise (as the noise signal) [11], ipsilaterally to the attended ear (Persian version of the ANL test [22]). The monotic conditions contained forced speech attention along with babble noise to the right ear and forced speech attention along with babble noise to the left ear. Second, the modified dichotic ANL test, which includes various conditions such as the least and most preferred music (as the target in the attended ear and the distracting musical noise contralaterally to the non-attended ear). The modified dichotic conditions included forced pleasant music attention to the right ear along with unpleasant music to the left ear, forced pleasant music attention to the left ear along with unpleasant music to the right ear, forced unpleasant music attention to the right ear along with pleasant music to the left ear, and forced unpleasant music attention to the left ear along with pleasant music to the right ear was used. The root mean square of all songs was calibrated for the modified ANL conditions in terms of female speaker's speech with Adobe Audition software.

All the stimuli were delivered via a diagnostic Audiometer (Harp plus under PC-based control, Inventis, Italy), a headphone (TDH-39), and using a 3.5 mm audio jack to connect to a laptop (Microsoft Surface Pro 3). The volume of the laptop and auxiliary input of the audiometer were calibrated with a tone of 1000 Hz and set at 0 dB HL. For the monotic conditions, the target (speech story) and the background noise signal (12-talkers babble) were presented monoaurally (both to the right or the left). While, For the dichotic conditions, the running pleasant/ unpleasant music as target/distracting noise songs (depending on the side of forced attention) were presented spatially separated from each other, at the opposite side (ear).

Before the test, practice items with verbal instruction in Persian was given to ensure whether the participant comprehended the task correctly:

"This test is used to find out how well you tolerate background noise within an auditory target (story or music). First, you will listen to an auditory target through one side of the headphone, and I will turn the volume up and down until you point with thumbs-up and thumbs-down gestures that the signal is at the loudness, most comfortable level for you. Second, you will listen to the same auditory target with background noise simultaneously. I will turn the noise level up and down until you can understand the auditory target very clearly and willing to accept the background noise for a long period without getting tense or tired."

Acceptable noise level testings had three stages

For the Most Comfort Level (MCL) measurement, the target signal is presented by a calibrated audiometer at 30 dB HL through a headphone and adjusted in 5, then 2 dB steps until the listener reported the target signal was at their MCL. After three repetitions, the average was recorded as the MCL measurement. The Background Noise Level (BNL) measurement: on the next occasion, while the target signal was presented at the measured MCL, the distracting noise was introduced at a starting level of 30 dB HL. The noise level was increased in steps of 5 dB until the participant indicated that the target signal was incomprehensible. Finally, the noise was adjusted in 2 dB steps until the listener reported his/her highest preferred background noise loudness to follow the target signal, which is called BNL. This sequence of measures was repeated three times to reduce the different impacts of music with or without lyrics. The averaged measure is then recorded as the BNL. Finally, the ANL measure corresponds to the listener's MCL minus the BNL (ANL=MCL-BNL).

Three music samples of vocal parts with lyrics and instrumental parts without lyrics were selected randomly for MCL and BNL measure repeats, and measures were recorded after 5–10 seconds of music presentation at the final step. The total test duration for each participant was approximately 90 min. The presentation order of monotic and dichotic listening conditions was counterbalanced across subjects, and resting periods were provided every 20 minutes on average.

Data analysis

The statistical analyses were performed using SPSS version 17.0. The Shapiro-Wilk test was tested to examine the normal distribution of data. The first series of analyses focused on the ANL measures under six conditions were tested with repeated-measures analysis of

Table 1. Music tracks used as pleasant and unpleasant music in terms of the means of subjective scores provided by participants

Song and Singer	Genre	Mean score
30 Salegi (by Ehsan Khajeh Amiri)	Pop	7.52
Roya-ye Bi Tekrar (by Ali Zand Vakili)	Persian Traditional	6.34
Harmless Ruler (by Mohsen Chavoshi)	Pop	7.70
The Road's Dancing (by Charttaar band)	Rock	5.34
Full-Length Mirror (by Mehdi Yarrahi)	Pop	4.98
Dele Majnoon (by Mohammad Reza Shajarian)	Persian Traditional	7.11
Khoda Hamin Havalie (by Hamed Homayoun)	Pop	5.36
Ta Nafas Hast (by Shahram Shokoohi)	Pop	4.14
Absolute Nothingness (by Hafez Nazeri)	Persian Traditional	3.59
Manshour (by Kave Yaghmaei)	Rock	2.91

variance (ANOVA). Second, to compare paired conditions in two groups (REA and LEA), paired t-test was applied to evaluate the changes for the ANL. A mixed-within-subjects ANOVA was also conducted to analyze the impact of hemispheric laterality on conditions and answer the second research question. The test examined whether there were main effects for hemispheric laterality and conditions and also for their interaction. The critical level of significance was always $p< 0.05$ in this study.

Results

Participants' demographic details illustrated 26 (81%) right-handed and 6 (19%) left-handed subjects. Seventeen subjects (53% of subjects) had REA, and 15 subjects (47%) had LEA. The Shapiro-Wilk test of normality was not significant for any condition, which indicated the normality of the data.

Descriptive statistical parameters of the MCL, BNL and ANL for all background stimuli types are shown in Table 2, separated for monotic and dichotic listening conditions and LEA and REA groups. The range of ANL scores was 4.85 to 10.45 and 4.81 to 20.74 for monotic and dichotic conditions, respectively. It indicated a wide range of ANLs for all dichotic conditions compared to monotic conditions. Furthermore, it is apparent that a higher mean of ANLs for dichotic forced attention to pleasant music conditions, followed by unpleasant music conditions, and monotic forced speech attention in the total and LEA group.

To test the effect of forced attention conditions and background noise types in total cases, a within-subject one-factor repeated-measures ANOVA was used to compare the difference between forced attention conditions. Mauchly's test of sphericity was significant for ANL (Mauchly's $W=0.032$, $p=0.000$), indicating a need for Greenhouse-Geisser adjustment. Results of this ANOVA revealed a significant main effect ($F_{(2.598,\ 80.529)}=5.81$, $p<0.003$). The pairwise comparison analyses to compare ANL measures on six conditions revealed that forced pleasant music attention was significantly higher than the forced unpleasant music attention condition to the left ear ($p\leq0.05$) and monotic forced speech conditions ($p<0.004$). These findings suggest that forced attention to the pleasant music to either right or left ear affected ANL measure differently than forced attention to the unpleasant to the left ear. Moreover, a significant difference between forced attention to pleasant music and speech is possibly related to different processing of ANL for music and speech.

The means and pairwise comparisons between the forced attention conditions are found in Table 2 and Figure 1.

The paired t-tests were used to compare the mean difference between pair conditions for ANL measurements in 2 groups of REA and LEA. Significant intra-hemispheric differences for ANL measures were obtained only in the LEA group. A significant difference was maintained for comparing mean ANL changes in the forced pleasant music attention and forced unpleasant music attention conditions ($p<0.007$). In addition, dich-

Table 2. Mean, standard error, lower and upper bound with 95% confidence interval reports under six various conditions in total and the right ear advantage and left ear advantage groups

		95% confidence interval (Mean±SE)					
		SBr	**SBl**	**PAr-UNl**	**PAl-UNr**	**UAr-PNl**	**UAl-PNr**
REA group	MCL	59.15 to 67.79 (63.47±2.11)	52.45 to 59.89 (56.17±1.82)	59.17 to 68.00 (63.58±2.16)	58.31 to 67.80 (63.05±2.32)	55.55 to 65.27 (60.41±2.38)	54.78 to 65.68 (60.23±2.66)
	BNL	50.59 to 60.22 (55.41±2.35)	43.83 to 53.69 (48.76±2.41)	44.43 to 60.98 (52.70±4.05)	43.91 to 59.85 (51.88±3.90)	41.86 to 55.07 (48.47±3.23)	39.00 to 57.81 (48.41±4.60)
	ANL	4.25 to 11.86 (8.05±1.86)	3.24 to 11.57 (7.41±2.04)	3.47 to 18.28 (10.88±3.62)	4.00 to 18.34 (11.17±3.51)	5.97 to 17.90 (11.94±2.92)	4.51 to 19.13 (11.82±3.58)
LEA group	MCL	60.13 to 69.33 (64.73±2.25)	54.37 to 62.29 (58.33±1.93)	59.83 to 69.23 (64.53±2.30)	60.88 to 70.98 (65.93±2.47)	53.62 to 63.97 (58.80±2.53)	51.73 to 63.33 (57.53±2.83)
	BNL	52.27 to 62.52 (57.40±2.50)	44.75 to 55.24 (50.00±2.56)	35.65 to 53.27 (44.46±4.31)	37.51 to 54.48 (46.00±4.15)	37.10 to 51.16 (44.13±3.44)	39.38 to 59.41 (49.40±4.90)
	ANL	3.27 to 1.38 (7.33±1.98)	3.89 to 12.77 (8.33±2.17)	12.18 to 27.95 (20.06±3.68)	12.30 to 27.56 (19.93±3.73)	4.31 to 17.01 (10.66±3.11)	0.34 to 15.91 (8.13±3.81)
Total group	MCL	60.96 to 67.16 (64.06±1.52)	54.49 to 59.88 (57.18±1.32)	60.86 to 67.19 (64.03±1.55)	60.96 to 67.84 (64.40±1.68)	56.16 to 63.14 (59.65±1.71)	55.03 to 62.90 (58.96±1.92)
	BNL	52.87 to 59.80 (56.34±1.69)	45.80 to 52.87 (49.34±1.73)	42.73 to 54.95 (48.84±2.99)	43.31 to 54.93 (49.125±2.848)	41.64 to 51.23 (46.43±2.35)	42.13 to 55.61 (48.87±3.30)
	ANL	4.98 to 10.45 (7.71±1.33)	4.85 to 10.83 (7.84±1.46)	9.62 to 20.74 (15.18±2.72)	9.90 to 20.65 (15.28±2.63)	7.06 to 15.62 (11.34±2.09)	4.81 to 15.37 (10.09±2.58)

SE; standard error, SBr; speech with babble noise-right, SBl; speech with babble noise-left, PAr-UNl; pleasant attended right with unpleasant noise left, PAl-UNr; pleasant attended left with unpleasant noise right, UAr-PNl; unpleasant attended right with pleasant noise left, UAl-PNr; unpleasant attended left with pleasant noise right, REA; right ear advantage, MCL; most comfortable level, BNL; background noise level, ANL; acceptable noise level, LEA; left ear advantage

otic forced pleasant music attention showed significantly higher ANL than monotic forced speech conditions. In contrast, the remaining pairs showed no difference. As is evident from Figure 1, there are no significant differences in the REA group.

We tested ear advantage laterality×condition with a mixed one-way ANOVA. The main effect for conditions was significant [$F_{(2.805,\ 84.148)}$=6.922, p<0.001], but no significant effect was obtained for ear advantage laterality [$F_{(1,30)}$=0.360, p=0.553]. However, the interaction

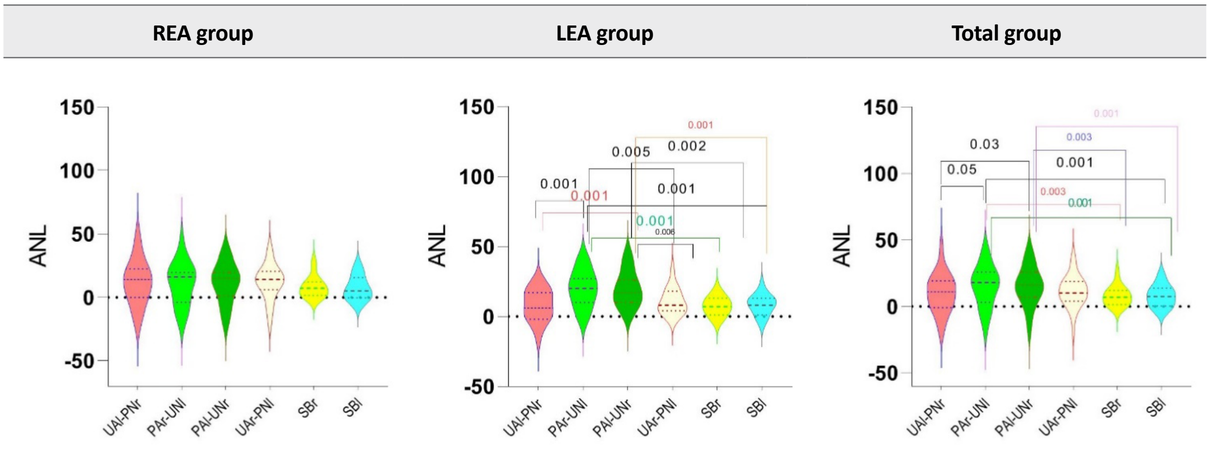

Figure 1. Pairwise comparisons between 6 forced attention conditions in total, right ear advantage and right ear advantage groups of acceptable noise level measures. REA; right ear advantage, LEA; left ear advantage, ANL; acceptable noise level, UAl-PNr; unpleasant attended left with pleasant noise right, PAr-UNl; pleasant attended right with unpleasant noise left, PAl-UNr; pleasant attended left with unpleasant noise right, UAr-PNl; unpleasant attended right with pleasant noiseleft, SBr; speech with babble noise-right, SBl; speech with babble noise-left

[$F_{(2.805,\ 84.148)}=4.151$, $p=0.01$, $\eta^2=0.158$] was significant; this means that the changes found in one hemisphere are significantly different from those observed in the other.

Discussion

The current experiment was conducted on normal subjects and aimed to determine the effect of music valence preferences on ANL for music. In this study, first, we found that the ANL results were more widespread for dichotic music listening than monotic speech listening and were highest for forced attention to pleasant music, followed by unpleasant music and speech. In addition, mean ANL in forced pleasant music attention was significantly higher than forced speech attention, associated with more noise tolerance in monotic conditions than in dichotic conditions. Similarly, BNLs were significantly higher in forced speech attention than in forced pleasant music conditions. This result seems consistent with Nabelek et al., which reported that young adults with normal hearing tolerated significantly lower levels of background music (with the mean ANL of 20.80 dB) than other environmental noise (babble of voices, speech-spectrum noise, traffic noise, and the noise of a pneumatic drill) [11]. In contrast, Gordon-Hickey and Moore found that the mean ANL for music was lower than that of twelve-talker babble noise, so the music as background noise was accepted at a higher level than twelve-talker babble while listening to speech [18]. The different findings may be due, in part, to the different target stimuli and selecting only one rock genre as music samples in Gordon-Hickey and Moore's study.

ANL measures showed no significant difference between forced speech attention to the right and left ear; however, higher MCL and BNL values in forced speech attention to the right ear are probably in agreement with the linguistic specialization of the left hemisphere [23].

ANL measure under forced unpleasant music attention to the left ear was significantly lower than forced pleasant music attention to the left and right ear in our study; thus, subjects could tolerate higher levels of pleasant music as distracting noise. In other words, pleasantness reduces the perceived noisiness of distracting music to the unattended ear and renders it a relatively tolerable noise. On the other hand, findings of this study indicated that subjects tolerated much less distracting background noise in the forced pleasant music attention conditions, whether presented to the right or left ear. They preferred to listen to pleasant music as vividly as possible. More specifically, higher MCL in forced pleasant music attention conditions compared to forced unpleasant music to the left ear probably justifies this higher ANL. A possible explanation is that tolerance to the background noise depends on the target [12] and its meaningful content [24]. Attentional bias exerts at a late stage of processing in which stimuli are either selected or rejected after being labeled according to the ear of entry. It is concluded that the attentional bias contributes significantly to the ear asymmetry in dichotic performance [8]. Previous studies have shown that despite ANL for music was not associated with music preference [18], its act differently relied on the music genre and was unrelated to music genre preference [17]. Gordon-Hickey and Bryan suggest that the intense and rebellious dimension of music preference may relate to this finding [17]. Results from Ahn et al.'s study showed a negative association between ANLs and familiarity and preference of music in the high-ANL group, with lesser acceptance of less familiar or preferred music as background noise [16].

Second, there were significant intra-hemispheric dichotic effects in the LEA group. Some studies revealed a similar direction that the right hemisphere dominates in the processing of pleasant or unpleasant music, which is relayed from the left ear contra pathways. The basic idea is likely that pathways of the attended channel are enhanced in the LEA during forced music listening attention. Emotional DL and familiarity feelings tasks, such as those involved in recognizing familiar people, are modulated mainly by the right hemisphere [5]. Furthermore, the valence of the unattended music (positive/negative) affected the neutral pleasantness ratings more robust with the left ear (right hemisphere) processing of the affective sound [25]. This study concluded by addressing asymmetries in intra- and interhemispheric effects, and the observed lateralized interhemispheric effect on the ANL, ear advantage laterality likely affects music dichotic listening.

We provided a novel and potentially very fruitful approach to suggest some degree of valence and hemispheric laterality on ANL with spatial precision. Since the literature search yields no previous work by any existing studies or research in using music valence on the ANL for music as target and background signals, asymmetrical activations in music-evoked emotion are still in their infancy and need to be resolved by future studies. It is suggested that future studies address ANL to music across various groups of the subject, for instance, in patients with brain lesions or degenerative diseases in the frontotemporal lobar, the amygdala, orbitofrontal cortex, cingulate cortex, and retro-insular cortex with the impairment in recognition of music [26-29], and professional musicians and bilingual subjects [30].

Conclusion

The study's primary purpose was to consider the effect of music valence on the acceptable noise level for music. The self-selected music valence possibly affects emotional dichotic processing and results in greater noise tolerance with the pleasant music background noise. Interestingly, there was also a highly significant intra- and interhemispheric difference only in the left ear advantage group that might provide insight into acceptable noise level to music underlying the ear advantage laterality.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Research Ethics Committee of Shahid Beheshti University of Medical Sciences (IR.SBMU.RETECH.REC.1396.571).

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Authors' contributions

FSG: Study design, acquisition of data, statistical analysis, interpretation of the results, drafting the manuscript; HJ: Study design and supervision, interpretation of the results, and critical revision of the manuscript; RN: Validation of data acquisition and statistical analysis; HA and BM: Interpretation of the results, and validation the final revision of the manuscript.

Conflict of interest

There are no competing financial interests.

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